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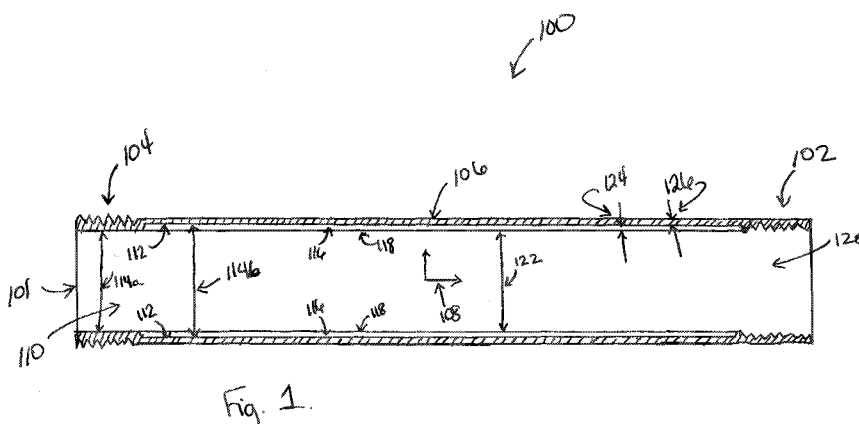
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(54) **Title:** ENGINEERED MATERIALS FOR DRILL ROD APPLICATIONS



(57) **Abstract:** Implementations described herein comprise drill rods comprising an integral tubular metallic body having a first ends, an opposing second end, and an elongate midbody extending along a central axis between the first and second ends and where the metallic body defines a central bore that extends along the central axis and has a body inner surface and at least one body bore diameter. In further aspects, the drill rods further comprise an underlying tubular composite lining that has a lining outer surface that is connected to at least the body inner surface of the midbody of the metallic body, the composite lining defining an operative bore that extends along the central axis and has at least one operative bore diameter.

ENGINEERED MATERIALS FOR DRILL ROD APPLICATIONS

BACKGROUND OF THE INVENTION

This application claims priority to U.S. Patent Application No. 13/731,499 filed on December 31, 2012 and U.S. Provisional Patent No. 61/794,308 filed on March 15, 2013.

The Field of the Invention

[0001] Implementations of the present invention relate generally to components and systems for drilling. In particular, implementations of the present invention relate to drill components comprising fiber-composite reinforced midbodies.

Background

[0002] Oilfield, exploration, and other drilling technologies make extensive use of drill string components such as drill rods in conventional percussive and coring drilling applications. Drill rods typically comprise a threaded box end and threaded a pin end joined by a midbody. Adjacent drill rods are joined together by coupling the threaded box end to the complementarily threaded pin end to form a tool joint. Conventionally, in drilling, a plurality of drill rod sections, which are each typically about twenty-five feet long more or less, are coupled together in series to form a drill string. As the depth of the bore increases, the drill string is correspondingly lengthened by the addition of drill rod sections at the drill rig. The drill string operatively couples a bottom hole assembly having a boring tool to a motor at the drill rig on the surface. The motor transmits axial impact and/or torque via the drill string to the bottom hole assembly and, thus, the boring tool. The forces transmitted by the motor combined with the weight of the drill string causes the boring tool to wear away the underlying material.

[0003] In accordance with convention, each drill rod section is made hollow so that the drill string can serve as a conduit for drilling fluid, such as compressed air, which is discharged through the drill bit at the bottom of the well. This drilling fluid picks up cuttings from the drill bit and carries them upwardly to the well top on the outside of the drill string. Compressed air, when used as the drilling fluid, can also be used to operate the drill bit, as in percussion drilling; or the drill bit can be operated directly by drill string rotation.

[0004] Conventional drill rods are hollow pipes that are subjected to high levels of at least one of axial and torsional loads during a drilling operation. Each drill rod in an assembly must support its own weight as well as the lengths of drill rod positioned above it in a drill string. Also, the drill rods can be subjected to high levels of impact, torsional and bending stresses, as well as dynamic loads, during the drilling operation. In percussive drilling, drill rods and other drill components are subject to high levels of impact, local working and bending stresses associated with the drilling process. Drill rods typically fail at the joints when failure occurs.

[0005] One limitation on the drilling of relatively deep wells is the drill string weight, which of course becomes greater and greater as the bore depth is increased. Historically, drill rod sections have been made of structural steel or alloys of structural steel; but with the deeper bores now being drilled, the heavier drill strings can impose fatiguing loads on the component drill rod sections and on the equipment used to rotate and raise and lower the drill string. Another limitation is the amount of tension that the drill string joints can withstand. Some drill string components such as, for example and without limitation, drill bits have a maximum load. In order to avoid overloading the drill bit, the drill rig must pull back on the drill string which creates tension that can eventually cause the drill string joints to fail. Drill rigs typically are limited in the amount of force they can exert to pull back.

[0006] In order to lessen the loads placed on the drill rod joints it is desirable to minimize the overall weight of the individual drill rods while retaining the desired range of load, torsional and impact capacity. It is currently known to reduce the weight of individual drill rod sections by forming drill rod sections in which the wall thickness of a middle portion of the midbody has a reduced cross-sectional thickness relative to the wall thickness proximate the respective box and pin ends. However, the thinner cross-sectional widths of the walls of the midbody of the drill rod section results in a direct loss of load, torsional and impact capacity of the drill rod.

[0007] Accordingly, a need exists for improved drill string components that preserve load, torsional and impact capacity but minimize the weight of the drill string component.

SUMMARY

[0008] It is to be understood that this summary is not an extensive overview of the disclosure. This summary is exemplary and not restrictive, and it is intended to neither identify key or critical elements of the disclosure nor delineate the scope thereof. The sole purpose of this summary is to explain and exemplify certain concepts of the disclosure as an introduction to the following complete and extensive detailed description.

[0009] In certain aspects, the present disclosure provides for drill rods comprising an integral tubular metallic body having a first ends, an opposing second end, and an elongate midbody extending along a central axis between the first and second ends and where the metallic body defines a central bore that extends along the central axis and has a body inner surface and at least one body bore diameter. In further aspects, the drill rods comprise an underlying tubular composite lining that has a lining outer surface that is connected to at least the body inner surface of the midbody of the metallic body, the composite lining defining an operative bore that extends along the central axis and has at least one operative bore diameter.

[0010] Additional features and advantages of exemplary implementations of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of such exemplary implementations. The features and advantages of such implementations may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description and appended claims, or may be learned by the practice of such exemplary implementations as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate aspects and together with the description, serve to explain the principles of the methods and systems.

[0012] Figure 1 illustrates a longitudinal cross-sectional view of one aspect of a drill string component having a fiber-composite reinforced midbody.

[0013] Figure 2 illustrates a longitudinal cross-sectional view of another aspect of a drill string component having a fiber-composite reinforced midbody and an increasing body bore diameter.

[0014] Figure 3 illustrates a longitudinal cross-sectional view of another aspect of a drill string component having a fiber-composite reinforced midbody and a V-shaped body bore diameter.

[0015] Figure 4 is a table comparing the response of a 2-3/4" conventional drill rod to the composite drill rod of the present invention.

DETAILED DESCRIPTION

[0016] The present invention can be understood more readily by reference to the following detailed description, examples, drawing, and claims, and their previous and following

description. However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this invention is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, as such can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

[0017] The following description of the invention is provided as an enabling teaching of the invention in its best, currently known aspect. To this end, those skilled in the relevant art will recognize and appreciate that many changes can be made to the various aspects of the invention described herein, while still obtaining the beneficial results described herein. It will also be apparent that some of the desired benefits described herein can be obtained by selecting some of the features described herein without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present invention are possible and can even be desirable in certain circumstances and are a part described herein. Thus, the following description is provided as illustrative of the principles described herein and not in limitation thereof.

[0018] Reference will be made to the drawings to describe various aspects of one or more implementations of the invention. It is to be understood that the drawings are diagrammatic and schematic representations of one or more implementations, and are not limiting of the present disclosure. Moreover, while various drawings are provided at a scale that is considered functional for one or more implementations, the drawings are not necessarily drawn to scale for all contemplated implementations. The drawings thus represent an exemplary scale, but no inference should be drawn from the drawings as to any required scale.

[0019] In the following description, numerous specific details are set forth in order to provide a thorough understanding described herein. It will be obvious, however, to one skilled in the art that the present disclosure may be practiced without these specific details. In other instances, well-known aspects of drill string technology have not been described in particular detail in order to avoid unnecessarily obscuring aspects of the disclosed implementations.

[0020] As used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another

aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0021] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0022] Throughout the description and claims of this specification, the word “comprise” and variations of the word, such as “comprising” and “comprises,” means “including but not limited to,” and is not intended to exclude, for example, other additives, components, integers or steps. “Exemplary” means “an example of” and is not intended to convey an indication of a preferred or ideal aspect. “Such as” is not used in a restrictive sense, but for explanatory purposes.

[0023] Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutation of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be perdefined it is understood that each of these additional steps can be perdefined with any specific aspect or combination of aspects of the disclosed methods.

[0024] Implementations described herein are directed toward drill string components that preserve load, torsional and impact capacity but minimize the weight of the drill string component as well as methods of using and manufacturing the same. In certain aspects, the present disclosure provides for drill rods comprising an integral tubular metallic body having a first end, an opposing second end, and an elongate midbody extending along a central axis between the first and second ends and where the metallic body defines a central bore that extends along the central axis and has a body inner surface and at least one body bore diameter. In further aspects, the drill rods further comprise an underlying tubular composite lining that has a lining outer surface that is connected to at least the body inner surface of the midbody of the metallic body, the composite lining defining an operative bore that extends along the central axis and has at least one operative bore diameter.

[0025] In certain aspects, implementations of the present disclosure provide for improved drill string components that preserve load, torsional and impact capacity while minimizing the weight of the drill string component. In other aspects, implementations of the

present disclosure maintain a continuous metal exterior surface and, thus, avoid any abrasive wear of the composite lining against the drilled hole or cuttings resulting therefrom.

[0026] In other aspects of the present disclosure, maintaining a continuous metal rod for threading drill string components together and limiting the use of composite material to an interior lining avoids the alternative of assembling drill string components from dissimilar materials. For example and without limitation, creating a drill string component by non-mechanical bonding of steel or steel alloy to, for example, a composite or even an aluminum midbody can create a weak and/or brittle interface or joint that can be insufficient to withstand the impact, vibration and fatigue loading associated with typical drill string loading conditions. Additionally, there can also be insufficient annular space available to allow a combination of mechanical and chemical bonding in certain drilling applications such as, for example and without limitation, wireline core drilling and the like. However, one skilled in the art will appreciate that there is enough annular space to enable feasibility of such an approach in other applications, such as, for example and without limitation, energy, oil and like drilling applications.

[0027] In yet other aspects, implementations of the present invention provide for corrosion protection in, for example and without limitation, percussive drilling applications. One skilled in the art will appreciate that corrosive and/or acidic drilling fluids can be pumped through drill rod interiors and this can lead to stress corrosion fatigue failures involving crack initiation on the inner diameter of the drill rod interior. One skilled in the art will appreciate that the present disclosure comprises drill string components having a composite lining that provides increased protection against corrosion and can reduce or eliminate stress corrosion fatigue failures.

[0028] In even other aspects, implementations of the present disclosure provide for more accurate drilling results by increasing the stiffness of the drill string components and, thus, the drill string. In light of the present disclosure, one skilled in the art will appreciate that the increased stiffness associated with the composite lining can result in an increased stiffness of the drill string component. This increased stiffness can reduce the deflection of the drill string and, correspondingly, the drilled hole, thereby providing more accurate drilling results such as, for example and without limitation, improved blasting efficiency when drilling blast holes, improved targeting in mineral exploration, and the like.

[0029] Reference will now be made to the drawings to describe various aspects of one or more implementations of the invention. It is to be understood that the drawings are

diagrammatic and schematic representations of one or more implementations, and are not limiting of the present disclosure. Moreover, while various drawings are provided at a scale that is considered functional for one or more implementations, the drawings are not necessarily drawn to scale for all contemplated implementations. The drawings thus represent an exemplary scale, but no inference should be drawn from the drawings as to any required scale.

[0030] In the following description, numerous specific details are set forth in order to provide a thorough understanding described herein. It will be obvious, however, to one skilled in the art that the present disclosure may be practiced without these specific details. In other instances, well-known aspects of drill string technology have not been described in particular detail in order to avoid unnecessarily obscuring aspects of the disclosed implementations.

[0031] Turning now to Figures 1-3, various exemplary implementations of a drill string components that preserve load, torsional and impact capacity while minimizing the weight of the drill string component are illustrated.

[0032] As illustrated in Figure 1, a drill rod 100 comprises an integral tubular metallic body 101 further comprising a first end 102, an opposing second end 104, and an elongate midbody 106 extending along a central axis 108 between the first end 102 and second end 104. The first end 102 of the tubular metallic body 101 can comprise a box end and a second end 104 can comprise a pin end. Alternatively, both the first end 102 and the second end 104 can form a box end or both form a pin end. The metallic body 101 can further define a central bore 110 that extends along the central axis 108 and has a body inner surface 112 and at least one body bore diameter 114. In further aspects, an underlying tubular composite lining 116 having a lining outer surface 118 can be connected to at least a portion of the body inner surface 112 of the midbody 106 of the metallic body. The composite lining 116 can define an operative bore 120 that can extend along the central axis and can have at least one operative bore diameter 122. In an additional aspect, the composite lining can extend to a terminal end of the second end 104 or pin end of the tubular metallic body 101.

[0033] In one aspect illustrated in Figure 1, the drill rod 100 can have midbody 106 having a substantially constant body bore diameter 114 and a substantially constant operative bore diameter 120. Here, the cross-sectional thickness of at least the composite lining 116 is substantially constant across at least the body inner surface 112 of the midbody 106.

[0034] In other aspects illustrated in Figure 1, the body bore diameter 114 of the metallic body 101 can comprise a first bore diameter 114a and a second bore diameter 114b, wherein the first bore diameter can be less than the second bore diameter. In one aspect, the second bore

diameter 114b extends at least the length of the midbody 106. In an alternative aspect, the second bore diameter can extend the combined length of the midbody 106 and the second end 104. In a further aspect, the composite lining 116 can have a substantially constant cross-sectional thickness and can be configured to extend the longitudinal length corresponding to the second bore diameter 114b. Here, the liner cross-sectional thickness plus the tubular metallic body wall thickness is substantially constant across at least longitudinal length corresponding to the midbody 106. In light of the present disclosure, one skilled in the art will appreciate that extending the composite lining through the pin end can increase the strength of the pin end and, thus, the joint.

[0035] In other aspects, the thickness of the composite lining 116 can comprise about 50% of the total wall thickness of at least the midbody 106. In yet other aspects, the cross-sectional area of the composite lining 116 can comprise between about 10% to about 50% of the total cross-sectional area of at least the midbody 106 and, more preferably, between about 10% and about 30% of the total cross-sectional area of at least the midbody 106. In yet other aspects, the composite lining 116 can be configured to provide between about 10% to 50% , more preferably between about 30% to 45%, and, preferred, about 44% of the moment of inertia or stiffness of at least the midbody 106.

[0036] In a further aspect, it is contemplated that the ratio of the thickness of the composite lining 116 of the total wall thickness of at least the midbody 106 can be about a 1:1 thickness ratio of composite to metal, for example and without limitation steel. In yet other aspects the ratio of the thickness of the composite lining 116 of the total wall thickness of at least the midbody 106 can be between about a 1:9 to about a 1:1 thickness ratio of composite to metal and, more preferably, between about a 1:9 to about a 3:7 thickness ratio of composite to metal. In yet other aspects, the composite lining 116 can be configured to provide 44% of the moment of inertia or stiffness of at least the midbody 106 (or a moment of inertia ratio of 1:1.3 composite to steel).

[0037] In another aspect, when at least a portion of the pin end of the drill rod 100 has a composite lining 116, it is contemplated that the ratio of the thickness of the composite lining 116 of the total wall thickness of the pin end of the drill can less than about a 1:1 thickness ratio of composite to metal, for example and without limitation steel. In yet other aspects the ratio of the thickness of the composite lining 116 of the total wall thickness of the pin end can be less than a range between about a 1:9 to about a 1:1 thickness ratio of composite to metal. It is contemplated that the ratio of the thickness of the composite lining 116 of the total wall

thickness of the pin end will be less than used in the midbody 106 due to the inherent stiffness of the pin end.

[0038] In other aspects, both the elastic modulus and the tensile strength of the composite lining 116 can be between about 1.5 and 2.5 and, more preferably about 2, times that of steel. As an illustrative example, the elastic modulus of steel can be about 30×10^6 psi. The tensile strength of conventional cold drawn steel tubing can be about 110,000 psi and the elastic limit or yield strength can be about 80 ksi. At least a portion of the drill rod joint ends are typically induction hardened to increase the elastic limit up to about 180,000 psi, but the elastic modulus remains constant. It is contemplated that the elastic modulus of the composite lining 116 can be up to about 60×10^6 psi, representing about twice the elastic modulus of conventional steel. It is contemplated that the elastic modulus of the composite lining 116 can be between about 40 to 90 MSI and, more preferably, between about 50 to 70 MSI. Similarly, the composite lining 116 tensile strength can be up to 240,000 psi, representing more than twice the tensile strength of steel tubing and about 1/3 greater than that of induction hardened rod joints. It is contemplated that the tensile strength of the composite lining 116 can be between about 200 to 300 KSI and, more preferably, between about 220 to 280 KSI.

[0039] For example, and not meant to be limiting, a composite drill rod 100 having a cross-sectional of up to 50% composite lining 116 area at the midbody 106 can have a modulus of up to 1.50 times that of a conventional steel midbody and, in other aspects, up to 1.17 times the strength of a conventional steel midbody. In another example and not meant to be limiting, a drill rod 100 having a cross-sectional area of up to 33% composite lining 116 at the midbody 106 can have a modulus of up to 1.32 times that of a conventional steel midbody and, in other aspects, up to 1.10 times the strength of a conventional steel midbody.

[0040] In other aspects, the drill rod 100 can have improved response under dynamic loading conditions over conventional drill rods. Computer simulations of the dynamic response of steel drill strings under compression and high r.p.m. indicate that the torque impulse loads from the drill bit create torsion and bending load waves that can rapidly travel up and reflect back down the drill string. This dynamic response can magnify the impulse load by a factor of about 2 to about 3, and such magnification can exceed the elastic limit of the conventional drill rod. One skilled in the art will appreciate that exceeding the elastic limit of the conventional drill rod under these loading conditions can lead to permanent twisting and bending of the drill string which, in turn, prevents productive drilling or even seizing of the drill string in the hole. However, these impulse loads are typically insufficient to overload the drill rod joints. Here,

using the drill rod 100 having a midbody wall thickness comprising about 50% composite liner 116 (or about an exemplary 1:1 thickness ratio of composite to metal) under identical loading conditions, the composite liner takes the majority of the bending and torque load. In an illustrative example, when simulating a 2-3/4" size drill rod under an extreme impulse and comparing the drill rod 100 to a conventional drill rod, the stress in the steel can be reduced by about 20%, down to 80 ksi, to avoid yielding. Refer to Table 1 for a summary of results comparing the response of a 2-3/4" conventional drill rod to the drill rod 100.

Table 6.2.1: Results Summary of the Sudden Bottom Resistance Simulation for Composite DR in Vertical Casing

Sudden Resistance on Bit - "N-Size" System - 3-in Casing ID													
System	Coeff. of Friction	RPM	Bit Load (kips)	Depth (ft)	Resistant Torque on Bit (ft-kip)	Material	OD (in)	ID (in)	Max. Bending Moment (ft-lbf)	Max. Bending Stress (ksi)	Max. Torque (ft-kips)	Max. Mises Stress (ksi)	Max. Torsion Stress (ksi)
"N" Size	0.2	1350	-6	2000	4	Composite	2.563	2.375	34.5	0.96	5.35	145.0	83.7
						ASTM A130	2.75	2.563	26.8	0.64	4.15	83.9	47.9
"N" Size	0.2	1350	-6	2000	4	ASTM A130	2.75	2.375	56.5	0.75	10.14	109.2	62.9

[0041] In other aspects illustrated in Figure 2, the body bore diameter 114 of at least the midbody 106 can increase from a first bore diameter 114a to a second bore diameter 114b. In a further aspect, the body bore diameter 114 can increase from a first bore diameter to a second bore diameter across the combined lengths of the midbody 106 and the second end 104. In a further aspect, the composite lining 116 can have a constant cross-sectional thickness and can be configured to extend the longitudinal length corresponding to at least the midbody 106 and, optionally, the second end 104. In an alternative aspect, cross-sectional thickness 124 of the composite liner 116 can vary such that the sum of the composite lining cross-sectional thickness 124 and the midbody cross-sectional thickness 126.

[0042] In yet other aspects illustrated in Figure 3, the tubular metallic body can further comprise a tubular wall and the body bore diameter 114 of the metallic body 101 can comprise a first bore diameter 114a and a second bore diameter 114b, wherein the first bore diameter can be less than the second bore diameter. Here, the body inner surface 112 of the midbody 106 can be configured to taper from both the respective first end 102 and second end 104 both having a first bore diameter 114a to a middle portion 128 of the midbody having a second bore diameter 114b. In a further aspect, the composite lining 116 can have a constant cross-sectional thickness and can be configured to extend the longitudinal length corresponding to the midbody 106. In an alternative aspect, cross-sectional thickness of the composite liner 116 can vary such that the sum of the cross-sectional thickness of the composite lining 106 and the cross-sectional thickness of at least the midbody 106 at any point can be substantially constant.

[0043] The underlying composite linings of the present disclosure can comprise a fiber-impregnated composite material. In one aspect, the fiber-impregnated composite material can comprise carbon fiber. In further aspects, the fiber-impregnated composite material can comprise a known quantity of pitch-based carbon fiber. In other aspects, the composite material can comprise a carbon-fiber containing polymer or resin material.

[0044] It is further contemplated that the composite material can at least partially comprise substantially unidirectionally-oriented carbon fiber. One skilled in the art will appreciate, in light of the present disclosure, that substantially unidirectional fibers can be selectively configured to provide increased stiffness or increased torsional strength. In one illustrative example, a composite material containing carbon fiber substantially aligned with the central axis 108 can be used to provide increased stiffness of the drill rod. In another illustrative example, a composite material containing carbon fiber oriented at an angle relative to the central axis 108 can be used to provide increased torsional strength of the drill rod.

[0045] In light of the present disclosure, one skilled in the art will appreciate that by converting about 50% of the wall thickness (or about an exemplary 1:1 thickness ratio of composite to metal), or about 48% of the cross-sectional area (or about an exemplary sectional area ratio of about 1:1.1 composite to metal), or about 44% of the moment of inertia (or a moment of inertia ratio of 1:1.3 composite to metal), to approximately double the elastic modulus, the load is distributed in about a 60%/40% split (or about a 3:2 ratio) favoring the composite layer. Further, it is contemplated to use composite liner thicknesses less than 50% of the total midbody thickness; however, calculations using 50% were used solely for clarity.

[0046] In another aspect, the total thickness of the midbody 106 can comprise a thickness of tubular metallic body sufficient to protect the composite liner 116 from abrasion against the hole wall. In a further aspect, the thickness of the tubular metallic body comprises at least about 50%, and, more preferably, at least about 70% of the total midbody thickness.

[0047] In other aspects, the fibers can be substantially bi-directionally-oriented with respect to the central axis 108. In an illustrative example, the fibers can be cross-laid to form spirals, imparting the drill rod with both increased stiffness and increased torsional strength. In other aspects, a predetermined percentage of the fibers can have a first direction. In a further aspect, the remaining fibers can have at least a second direction.

[0048] In other aspects, it is contemplated that a drill rod 100 can comprise a detached composite lining 116. One skilled in the art will appreciate that, in applications involving

substantially only bending loads, for example and without limitation, percussive drilling and the like, the composite lining 116 need not be bonded to the body inner surface 112.

[0049] In another aspect, a method of manufacturing drill string components that preserve load, torsional and impact, as well as dynamic load capacity but minimize the weight of a drill string component comprises the steps of (i) providing a drill rod 100 having an integral tubular metallic body 101 further comprising a first end 102, an opposing second end 104, and an elongate midbody 106 extending along a central axis 108 between the first end 102 and second end 104 and wherein the metallic body 101 further defines a central bore 110 that extends along the central axis 108 and has a body inner surface 112 and at least one body bore diameter 114; (ii) providing at least one rolled sheet of composite lining 116 containing a known quantity of pitch-based carbon fiber and impregnated with an adhesive material such as, for example and without limitation, a resin or the like; (iii) inserting the at least one rolled sheet of composite lining 116 into the metallic body 101 such that the composite lining does not overlap at least the first end 102 and such that the fibers take on a predetermined orientation; (iv) causing the rolled sheet of composite lining to deploy such that its outer surface 118 contacts at least a portion of the body inner surface 112 of the metallic body; and (v) curing the composite material to connect the composite lining outer surface 118 to the metallic body inner surface 112.

[0050] Accordingly, Figures 1-3, and the corresponding text, provide a number of different drill string components that preserve load, torsional and impact capacity but minimize the weight of a drill string component. In addition to the foregoing, implementations described herein can also be described in terms acts and steps in a method for accomplishing a particular result. For example, a method comprising manufacturing drill string components that preserve load, torsional and impact capacity but minimize the weight of a drill string component is described above with reference to the components and diagrams of Figures 1 through 3.

[0051] Thus, implementations of the foregoing provide various desirable features. For instance, the drill string components having composite liners provided herein can provide increased stiffness of the component and the resulting drill string, enabling more accurate drilling results. In another instance, the present disclosure limits composite elements to linings only and maintains a continuous metal rod on the exterior; thus avoiding the need to join dissimilar materials along the length of the drill string component as well as exposing the composite liner to abrasive wear against the drilling hole or the cuttings. In another instance, the interior composite lining protects against potential corrosion as corrosive and/or acidic drilling fluids are pumped through the interior of the drill string component.

[0052] The present invention can thus be embodied in other specific forms without departing from its spirit or essential characteristics. The described aspects are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

What is claimed is:

1. A drill string component, comprising:

an integral tubular metallic body comprising a first end, an opposing second end, a cross-sectional area, and an elongate midbody extending along a central axis therebetween the first and second ends, the metallic body defining a central bore that extends along the central axis and has a body inner surface and at least one body bore diameter;

an underlying tubular composite lining that has a cross-sectional area and a lining outer surface that is connected to at least the body inner surface of the midbody of the metallic body, the composite lining defining an operative bore that extends along the central axis and has at least one operative bore diameter;

wherein the metallic body cross-sectional area and the composite lining cross-sectional area comprise a total cross-sectional area.

2. The drill string component of claim 1, wherein the first end comprises a box end.
3. The drill string component of claim 1, wherein the second end comprises a pin end.
4. The drill string component of claim 3, wherein the underlying tubular composite lining extends to a terminal end of the pin end of the hollow body.
5. The drill string component of claim 1, wherein the metallic body cross-sectional area comprises at least 50% of the total cross-sectional area.
6. The drill string component of claim 5, wherein the metallic body cross-sectional area comprises at least 70% of the total cross-sectional area.
7. The drill string component of claim 5, wherein the composite lining cross-sectional area comprises from about 10% to about 50% of the total cross-sectional area.
8. The drill string component of claim 1, wherein the composite lining is configured to provide up to about 44% of the stiffness.
9. The drill string component of claim 1, wherein the tensile strength of the composite lining is between about 1.5 and about 2.5 that of steel.
10. The drill string component of claim 9, wherein the tensile strength of the composite lining is between about 2 times that of steel.

11. The drill string component of claim 1, wherein the drill string component further comprises a midbody.
12. The drill string component of claim 11, wherein the midbody has a modulus of about 1.50 times that of a conventional steel midbody.
13. The drill string component of claim 12, wherein the midbody has a strength of about 1.17 times that of a conventional steel midbody.
14. The drill string component of claim 11, wherein the midbody has a strength of about 1.10 times that of a conventional steel midbody.
15. The drill string component of claim 14, wherein the composite lining is configured to absorb the majority of a bending load.
16. The drill string component of claim 16, wherein the composite lining is configured to absorb the majority of a torque load.
17. The drill string component of claim 1, wherein the drill string component is configured to be a percussive drill rod.
18. The drill string component of claim 1, wherein the drill string component is configured to be a wireline coring drill rod.
19. The drill string component of claim 1, wherein both the first end and the second end comprise a box end.
20. The drill string component of claim 1, wherein both the first end and the second end comprise a pin end.

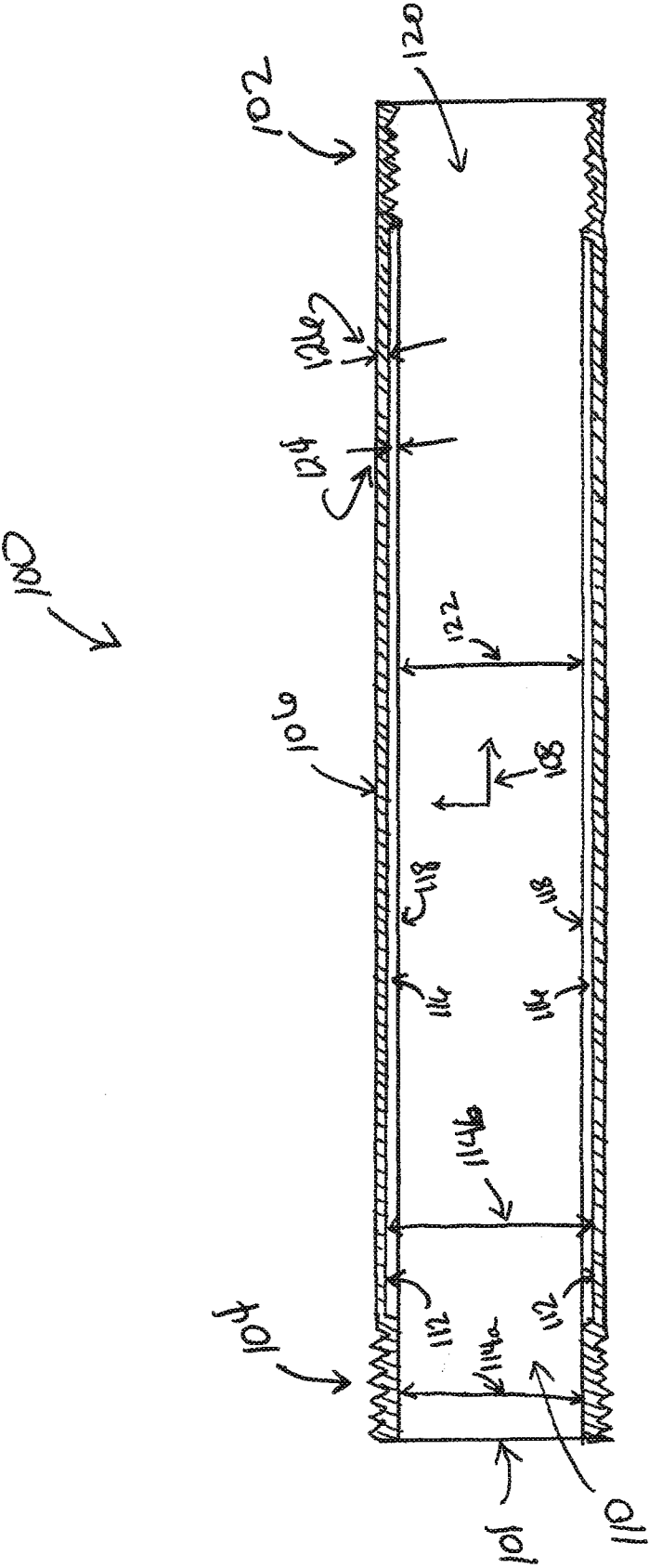


Fig. 1.

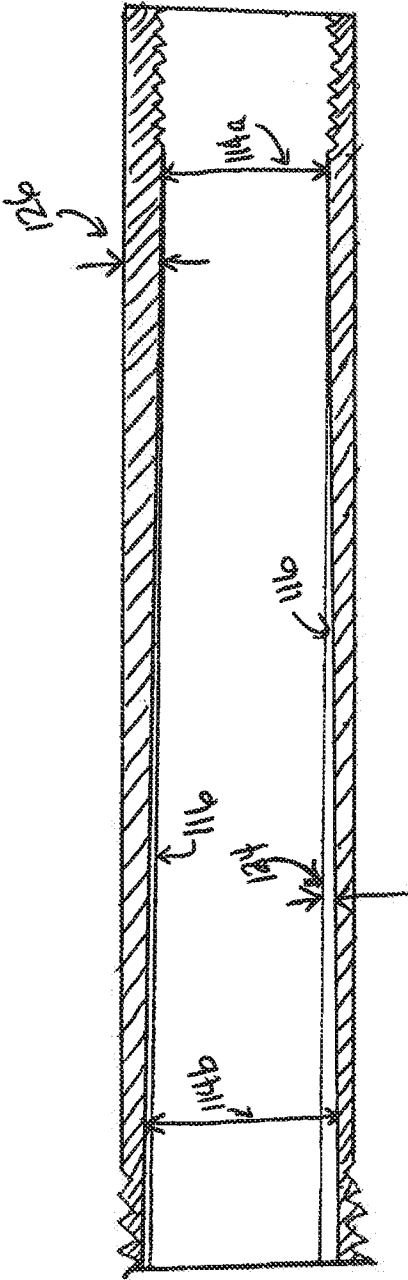


Fig. 2

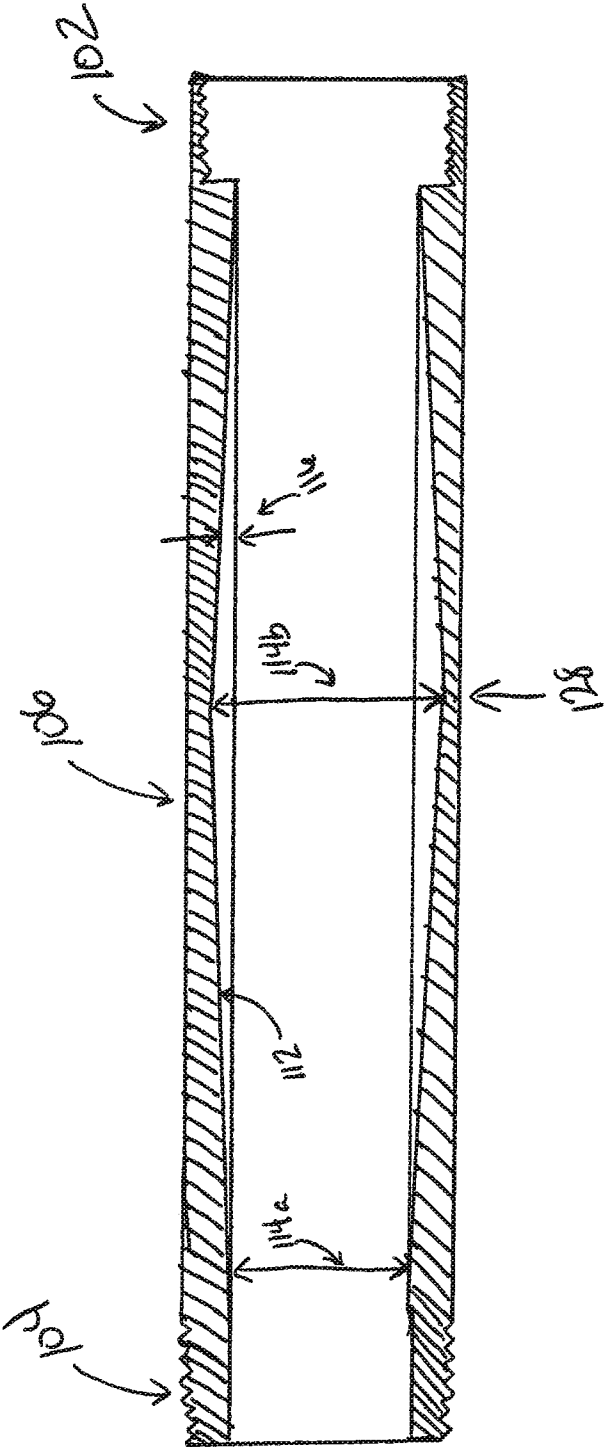


Fig. 3

Fig. 4

Sudden Resistance on Bit - "N-Size" System - 3-in Casing ID													
System	Coeff. of Friction	RPM	Bit Load (kips)	Depth (ft)	Resistant Torque on Bit (ft-kip)	Material	OD (in)	ID (in)	Max. Bending Moment (ft-lbf)	Max. Bending Stress (ksi)	Max. Torque (ft-kips)	Max. Mises Stress (ksi)	Max. Torsion Stress (ksi)
"N" Size	0.2	1350	-6	2000	4	Composite	2.563	2.375	34.5	0.96	5.35	145.0	83.7
						ASTM A130	2.75	2.563	26.8	0.64	4.15	83.9	47.9
"N" Size	0.2	1350	-6	2000	4	ASTM A130	2.75	2.375	56.5	0.75	10.14	109.2	62.9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/078322**A. CLASSIFICATION OF SUBJECT MATTER****E21B 17/00(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)

E21B 17/00; E21B 19/22; E21B 17/16; E21B 43/10; E21B 7/20; E21B 17/01

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: drill rod, lining, box end, pin end, and reduce load

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005-0039912 A1 (HALL et al.) 24 February 2005	1-3, 11, 17-20
Y	See paragraphs [0027]-[0030]; claims 1-2; and figures 2-4.	4-10, 12-16
Y	US 4872519 A (KOPECKI, DENIS S.) 10 October 1989	4-10, 12-16
	See column 2, lines 3 - column 4, line 49 and figures 1-3.	
A	US 6799632 B2 (HALL et al.) 05 October 2004	1-20
	See abstract and claims 1-2.	
A	US 2005-0103527 A1 (CHURCH et al.) 19 May 2005	1-20
	See claim 1 and figure 2.	
A	CN 2453110 Y (GEOPHYSICAL PROSPECTING BUREAUS OF CHINA PETROLEUM GROUP)	1-20
	10 October 2001	
	See abstract and claim 1.	



Further documents are listed in the continuation of Box C.



See patent family annex.

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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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/078322

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