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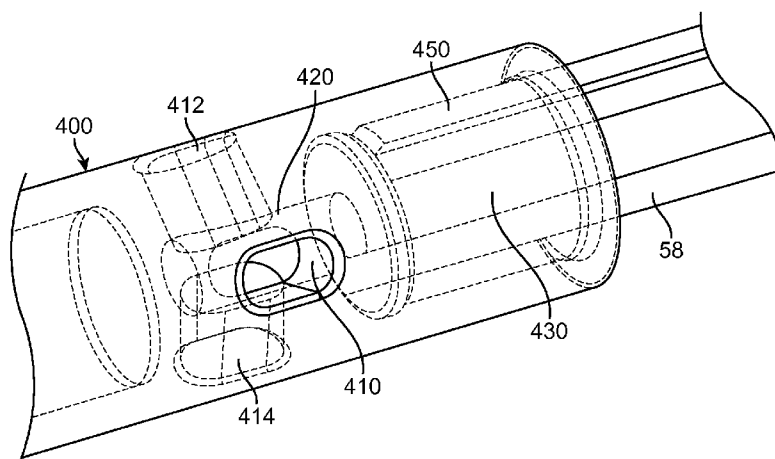


FIG. 4

(57) Abstract: A process of manufacturing a downhole tool having hardfacing erosion protection formed on the inner surface of a confined space having a cross-sectional width of at least 26 millimeters, such as an inlet port or an inner bore of a drilling tool component. A downhole tool manufactured according to the disclosed laser cladding process for use in a method of drilling a subterranean wellbore.

DRILLING TOOL HAVING FLOW PATH EROSION PROTECTION IN CONFINED SPACE

FIELD

[0001] The present disclosure relates to downhole tools used to drill subterranean wellbores. In particular, the present disclosure relates to drilling tools having flow path erosion protection in a confined space.

BACKGROUND

[0002] Wellbores are drilled into the earth for a variety of purposes including tapping into hydrocarbon bearing formations to extract the hydrocarbons for use as fuel, lubricants, chemical production, and other purposes. Drilling tools utilize drilling fluids to transfer hydraulic power through the drill string to the bottom of the wellbore where it is converted into rotational power to drive the drill bit. The drilling fluid also carries cuttings from the bottom of the wellbore to the surface where the cuttings are crudely separated from the drilling fluid before the drilling fluid is pumped back down inside the drill string. However, the drilling fluid may still contain various suspended abrasive solids as it is circulated at high speeds through downhole components that make up the drilling tool in the bottom hole assembly (BHA). For instance, the drilling motor must pass the drilling fluid, laden with solids and travelling at high speed, from the bottom of the motor power section to the bore of the driveshaft so that the drilling fluid can be passed to elements of the drill string beneath the motor, such as a drill bit. The high-speed circulation of drilling fluid containing abrasive solids tends to erode adjacent surfaces, particularly those surfaces characterized by high drilling fluid

impingement angles. Therefore, it is desirable to protect the inner bores and ports that define the flow path of a drilling tool from erosion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] In order to describe the manner in which the advantages and features of the disclosure can be obtained, reference is made to embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only exemplary embodiments of the disclosure and are not therefore to be considered to be limiting of its scope, the principles herein are described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0004] FIG. 1 is a schematic diagram of an embodiment of a wellbore operating environment in which a drilling tool having flow path erosion protection may be deployed;

[0005] FIG. 2 is a perspective-view illustration of a drill string that can include a drilling tool having flow path erosion protection, according to an exemplary embodiment;

[0006] FIG. 3 is a front-view cross-sectional illustration of a portion of the fluid-driven motor assembly of FIG. 2, according to an exemplary embodiment; and

[0007] FIG. 4 is a close-up perspective view of a tubular body having a plurality of inlet ports and an inner bore, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0008] Various embodiments of the disclosure are discussed in detail below. While specific implementations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without parting from the spirit and scope of the disclosure.

[0009] It should be understood at the outset that although illustrative implementations of one or more embodiments are illustrated below, the disclosed apparatus, methods, and systems may be implemented using any number of techniques. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques illustrated herein, but may be modified within the scope of the appended claims along with their full scope of equivalents.

[0010] Unless otherwise specified, any use of any form of the term "couple," or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and also may include indirect interaction between the elements described. 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 ...". Reference to up or down will be made for purposes of description with "upper," or "uphole" meaning toward the surface of the wellbore and with "lower," or "downhole" meaning toward the terminal end of the well, regardless of the wellbore orientation. The various characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description, and by referring to the accompanying drawings.

[0011] The present disclosure generally relates to a downhole drilling tool having at least one inlet port or at least one inner bore that is protected from erosion by a laser cladding process. More particularly, the process includes depositing a hardfacing on the inner surface of one or more confined spaces of a downhole drilling tool, such as an inlet port and/or an inner bore, having a cross-sectional width of at least 26 millimeters.

[0012] Drilling tools utilize drilling fluids to transfer hydraulic power through the drill string to the bottom of the wellbore where it is converted into rotational power to drive the drill bit. The drilling fluid also carries abrasive solids that were not able to be removed from the drilling fluid at the surface. The high-speed circulation of the drilling fluids laden with solids causes the erosion of surfaces of downhole tool components. The erosion of the surfaces increases with increasing impingement angles. Therefore inlet ports, inner bores and other adjacent surfaces that direct the flow path of the drilling fluid to make an abrupt turn, for example, anywhere from 30° to 90°, are especially susceptible to erosion, thereby reducing the service life of the tool component.

[0013] According to the present disclosure, the ports and inner bores of the downhole components that make up a drilling tool can be protected from erosion by a laser cladding process in the manufacturing of a downhole tool. The laser cladding process for a downhole tool includes depositing a hardfacing on the inner surface of the confined spaces of a downhole drilling tool, such as an inlet port or an inner bore, having a cross-sectional width of at least 26 millimeters. The erosion protection afforded by the disclosed process of manufacturing a downhole tool minimizes the destructive consequences of fluid entrant effects at the entrances of inlet ports and the inner bore of a tubular body that couples

the driveshaft to the mud motor assembly, as well as the inner bore of the driveshaft.

[0014] FIG. 1 illustrates a schematic view of an embodiment of a wellbore operating environment in which a drilling tool having flow path erosion protection deposited according to the laser cladding process disclosed herein, may be deployed. As depicted, the operating environment 50 includes a drill rig 51, a drill string 52, and a fluid-driven motor assembly 53 coupled to a drill bit 54. The fluid-driven motor assembly 53, sometimes referred to as a mud motor or downhole motor, converts the hydraulic energy of a drilling fluid, such as drilling mud, into mechanical energy in the form of rotational speed and torque output, which may be harnessed for a variety of applications such as downhole drilling. In some instances, the fluid-driven motor assembly may be a progressive displacement motor (PDM). The fluid-driven motor assembly 53 generally includes a hydraulic drive section 10, a bent housing 56, a bearing pack 57, and a driveshaft 58 coupled to a drill bit 54. The fluid-driven motor assembly 53 forms part of the bottomhole assembly (BHA) and is disposed between the lower end of the drill string 52 and the drill bit 54.

[0015] The hydraulic drive section 10, also known as a power section or rotor-stator assembly, can include a rotor disposed within a stator. The driveshaft 58 is coupled to the rotor and is supported by the bearing pack 57. Drilling fluid or mud is pumped under pressure between the rotor and stator, causing the rotor, as well as the drill bit 54 coupled to the rotor, to rotate relative to the stator. In general, the rotor has a rotational speed proportional to the volumetric flow rate of pressured fluid passing through the hydraulic drive section 10. Thus, the hydraulic drive

section 10 converts drilling fluid pressure pumped down the drill string 52 into rotational energy at the drill bit 54.

[0016] With force or weight applied to the drill bit 54 via the drill string 52 and/or the fluid-driven motor assembly 53, also referred to as weight-on-bit (WOB), the rotating drill bit 54 engages the earthen formation and proceeds to form a wellbore 60 along a predetermined path toward a target zone. As the drill bit 54 engages the formation, resistive torques generally opposing the rotation of the drill bit 54 and the rotor are applied to the drill bit 54 by the formation. The drilling fluid or mud pumped down the drill string 52 and through the fluid-driven motor assembly 53 passes out of the drill bit 54 through nozzles positioned in the bit face. The drilling fluid cools the drill bit 54 and flushes cuttings away from the face of bit 54. The drilling fluid and cuttings are forced from the bottom 61 of the wellbore 60 to the surface through an annulus 65 formed between the drill string 52 and the wellbore sidewall 62.

[0017] Even though FIG. 1 depicts a vertical wellbore 60, the present disclosure is equally well-suited for use in wellbores having other orientations including horizontal wellbores, slanted wellbores, multilateral wellbores or the like. Also, even though FIG. 1 depicts an onshore operation, the present disclosure is equally well-suited for use in offshore operations. Further, the present disclosure is equally well-suited for use in cased-hole or open-hole operating environments.

[0018] FIG. 2 illustrates a perspective-view of a portion of a drill string 52 that can include a drilling tool having flow path erosion protection deposited according the laser cladding process disclosed herein. As depicted in FIG. 2, the drill string 52 includes a bottom hole assembly (BHA) 110, which is shown partially broken away to more clearly depict

the hydraulic drive section 10, fluid-driven motor assembly 53 and bearing pack 57.

[0019] A rotatable drill bit 54 is located at a distal end of the drill string 52, projecting from an elongated housing 118. The housing 118 is operatively attached or otherwise coupled, e.g., via a top sub 122, to the distal end of a drill pipe or drill-pipe string 120 such that the drill-pipe string 120 transmits rotation drive forces and drilling fluid ("mud") to the housing 118. The bearing pack 57 protects the drill string 52 from off-bottom and on-bottom pressures. The bearing pack 57 may be oil lubricated and sealed. The bearing pack 57 may also be lubricated by drilling fluid. A bottom sub 124 couples a driveshaft 58 of the fluid-driven motor assembly 53 to the drill bit 54. In some instances, the fluid-driven motor assembly 53 may be a SperryDrill® or SperryDrill® XL/XS series positive displacement motor. However, any fluid-driven drilling motor or mud motor may be used without departing from the scope and spirit of the present disclosure. Additionally, the drill string 52, including the BHA 110 and powertrain, can include numerous additional, alternative, and other well-known peripheral components without departing from the scope and spirit of the present disclosure.

[0020] FIG. 3 illustrates a front-view cross-sectional portion of the hydraulic drive section 10 of FIG. 2. As depicted in FIG. 3, the hydraulic drive section 10 includes a helical-shaped multi-lobed stator 130 with an internal passage 134 within which is disposed a helical-shaped multi-lobed rotor 150. The rotor 150 is typically made of steel and may be chrome-plated or coated for wear and corrosion resistance. The stator 130 may be a heat-treated steel tube lined with a helical-shaped lobed elastomeric insert 140. The rotor 150 defines a set of rotor lobes 155 that intermesh with a set of stator lobes 135 defined by the elastomeric

insert 140. As depicted in FIG. 3, the rotor 150 typically has one fewer lobe 155 than the stator 130. When the rotor 150 and stator 130 are assembled, a series of helically shaped channels are formed between the outer surface 152 of the rotor 150 and the inner surface 132 of the stator 130.

[0021] The hydraulic drive section 10 of the fluid-driven motor assembly 53 operates according to the Moineau principle in which pressurized fluid (e.g., drilling fluid from the drill-pipe string 120) is forced into the hydraulic drive section 10 of the fluid-driven motor assembly 53 and through the series of helically shaped channels formed between the stator 130 and rotor 150. The pressurized fluid acts against the rotor 150 causing nutation and rotation of the rotor 150 within the stator 130. Rotation of the rotor 150 generates a rotation drive force for the drill bit 54, such forces being transmitted via the driveshaft 58. The distal end of the rotor 150 is coupled to the rotatable drill bit 54 via the driveshaft 58 such that the eccentric power from the rotor 150 is transmitted as concentric power to the bit 54. In this manner, the fluid-driven motor assembly 53 can provide a drive mechanism for the drill bit 54 which is at least partially and, in some instances, completely independent of any rotational motion of the drill string generated, for example, via rotation of a top drive in the derrick mast and/or the rotary table on the derrick floor. The drill bit 54 may take on any form without departing from the scope and spirit of the present disclosure, including diamond-impregnated bits and specialized polycrystalline-diamond-compact (PDC) bit designs, such as the FX and FS SeriesTM drill bits available from Halliburton, for example.

[0022] FIG. 4 illustrates a close-up perspective view of a tubular body 400 that couples the hydraulic drive section 10 to the driveshaft 58 of a

downhole drilling tool. The tubular body 400 is located between reference points A and A' of the fluid-driven motor assembly 53 depicted in FIG. 2. As depicted in FIG. 4, the tubular body 400 has a plurality of inlet ports 410, 412, 414 fluidly coupled to a first inner bore 420. The first inner bore 420 of the tubular body 400 is in turn fluidly coupled to a second inner bore 430 formed in the driveshaft 58. In some instances, the tubular body 400 may be coupled to the driveshaft 58 by driveshaft thread 450.

[0023] The tubular body 400 transfers drilling fluid that has exited the hydraulic drive section 10 to the second inner bore 430 of driveshaft 58 via inlet ports 410, 412, 414, in order to circulate drilling fluid to the drill bit 54. The drilling fluid serves to lubricate and cool the drill bit 54 as well as to carry cuttings from around the drill bit 54 to the surface. As the drilling fluid enters inlet ports 410, 412, 414, the high-velocity fluid is forced into a flow path that causes the drilling fluid to make an abrupt turn, which may be anywhere from 30° to 90°, for example, through inlet ports 410, 412, 414 and into the first inner bore 420 of the tubular body 400. Once the drilling fluid has entered the first inner bore 420 of tubular body 400 the drilling fluid is forced into a flow path that causes the drilling fluid to make another abrupt turn, and which may be anywhere from 30° to 90°, for example, as the drilling fluid flows downhole towards the second inner bore 430 of driveshaft 58. The drilling fluid continues to flow through the second inner bore 430 of the driveshaft 58 until it reaches the drill bit 54. Without protection, the entrances of inlet ports 410, 412, 414 as well as the inner surfaces of the first inner bore 420 of tubular body 400 and the second inner bore 430 of drillshaft 58 are susceptible to erosion due to the fluid entrant effects of high-velocity drilling fluid, laden with solids, as well as the high-impingement angles

characteristic of the flow path through the tubular body 400 and driveshaft 58.

[0024] According to the present disclosure, the inlet ports 410, 412, 414, first inner bore 420, and second inner bore 430, having a cross-sectional width of 26 millimeters or greater, can be protected from erosion by a laser cladding process that forms a hardfacing material on at least a portion of the inner surfaces of the inlet ports 410, 412, 414, first inner bore 420, and second inner bore 430. The laser cladding process includes depositing powdered cladding material onto at least a portion of an inner surface of the inlet port 410, 412, 414, first inner bore 420, and/or second inner bore 430, while simultaneously irradiating a laser beam onto the deposited powdered cladding material until the temperature of the cladding material is raised to or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the bore or port to form a hardfacing.

[0025] Laser cladding is a weld overlay process that uses a laser as the energy source in a manner similar to the way in which an arc is used in conventional welding. Laser cladding involves depositing powdered cladding material directly onto a substrate while simultaneously irradiating the substrate with a laser beam that heats the cladding material and the substrate sufficient to form a metallurgical bond between the deposited material and substrate. The hardfacing produced by the laser cladding process provides enhanced wear and/or corrosion resistance. Additionally, the metallurgical bond between the substrate and cladding material produces a hardfacing that is resistant to flaking away.

[0026] According to the present disclosure, the laser cladding process includes directly applying abrasion-resistant cladding material to the

internal surface of a port or bore using a laser cladding device having a facing head adapted to spray the cladding material into a confined space having a cross-sectional width of 26 millimeters or greater. In addition to the facing head, the laser cladding process is carried out by a laser cladding device that further includes a laser source adapted to direct a laser beam into the central passageway of the confined space simultaneous with the deposition of cladding material by the facing head. Accordingly, the laser cladding device, facing head and laser source have dimensions sufficient to allow the facing head to penetrate into the internal passageway of a port or bore having a cross-sectional width of 26 millimeters or greater, and deposit cladding material onto at least a portion of the internal surface of the port or bore at the same time that the laser source irradiates the same portion of the inner surface of the confined space. The laser cladding process disclosed herein can be carried out, for example, by Apollo Machine & Welding Ltd. of Leduc, Alberta, Canada.

[0027] According to one aspect of the present disclosure, a process of manufacturing a downhole tool is disclosed. The process includes obtaining a downhole tool comprising a tubular body having a first inner bore formed therein and at least one inlet port fluidly coupled to the first inner bore. The downhole tool further comprises a driveshaft, having a second inner bore formed therein, that couples a drill bit to the tubular body. The second inner bore of the driveshaft is fluidly coupled to the first inner bore of the tubular body. The process further includes depositing powdered cladding material onto at least a portion of an inner surface of the inlet port or a surface accessed through the inlet port. The process further includes irradiating a laser beam onto the deposited powdered cladding material in order to raise the temperatures of the

cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the inlet port, or a surface accessed through the inlet port, to form a hardfacing.

[0028] In one aspect of the present disclosure, the surface accessed through the inlet port is an inner surface of the first inner bore. In one aspect of the present disclosure, the process further includes depositing powdered cladding material onto at least a portion of an inner surface of the second inner bore and irradiating a laser beam onto the deposited powdered cladding material to raise the temperature of the cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the second inner bore to form a hardfacing.

[0029] In one aspect of the present disclosure, the process of manufacturing a downhole tool includes a downhole tool that further includes a housing that surrounds the tubular body and at least a portion of the driveshaft. The downhole tool can further include a stator disposed within the housing and defining an internal passage. The downhole tool can further include a rotor disposed within the internal passage of the stator and coupled to the tubular body.

[0030] The cladding material, described herein, can be tungsten carbide. Other suitable cladding materials include, but are not limited to, spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and combinations thereof.

[0031] The hardfacing can comprise tungsten carbide. The hardfacing can also comprise, but is not limited to, spherical or macro-crystalline

tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and combinations thereof.

[0032] According to the present disclosure, the cross-sectional width of the inlet port may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm. According to the present disclosure, the cross-sectional width of the first inner bore of the tubular body may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm. According to the present disclosure, the cross-sectional width of the second inner bore of the driveshaft may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0033] According to one aspect of the present disclosure, hardfacing may be applied to only a portion of the first inner bore of the tubular body and only a portion of the second inner bore of the driveshaft. For instance, the laser cladding process described herein can be used to apply a hardfacing to the first 27 inches of an inner bore having a cross-sectional width of 26 millimeters, as measured from the distal end.

[0034] According to one aspect of the present disclosure, after the hardfacing is formed by the laser cladding process disclosed herein and after the hardfacing has cooled, the hardfacing may be machined to produce a final cylindrical interior surface of a port or bore, having a desired cross-sectional width and dimensional thickness.

[0035] According to one aspect of the present disclosure, a downhole tool manufactured by the process of manufacturing, disclosed herein, is disclosed. According to another aspect of the present disclosure, a method of drilling a subterranean wellbore that includes a downhole tool manufactured by the process of manufacturing, disclosed herein, is disclosed. According to another aspect of the present disclosure, a subterranean wellbore drilling system that includes a downhole tool manufactured by the process of manufacturing, disclosed herein, is disclosed.

[0036] The process of manufacturing a downhole tool, disclosed herein, is desirable because the laser cladding process for forming a hardfacing in a port or bore does not require baking the tool at high temperatures, which can materially affect the metallurgical properties of the tool. Additionally, the laser cladding process, disclosed herein, can apply a hardfacing to a port or inner bore without tool assembly or preassembly complications. Further, hardfacing can be formed in a port or bore by the laser cladding process, disclosed herein, even after the machining of the port or bore has been completed.

[0037] In one aspect of the present disclosure, the hardfacing applied to a port or bore having a cross-sectional width of at least 26 millimeters can be repaired by repeating the laser cladding process, disclosed herein, thereby producing a new hardfacing on top of a previously deposited hardfacing. In another aspect of the present disclosure, the hardfacing applied to a port or bore having a cross-sectional width of at least 26 millimeters can be repaired by removing the previously deposited hardfacing layer, or a portion thereof, followed by repeating the laser cladding process disclosed herein.

[0038] According to another aspect of the present disclosure, a method of drilling a subterranean wellbore is disclosed. The method includes providing a drill string comprising a drill pipe and a drill bit. The method further includes applying an operative force to the drill bit, wherein applying the operative force includes flowing fluid through a downhole fluid-driven motor assembly. The fluid-driven motor assembly includes a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore. The fluid-driven motor assembly further includes a driveshaft that couples the drill bit to the tubular body. The driveshaft has a second inner bore formed therein that is fluidly coupled to the first inner bore. The inlet port of the fluid-driven motor assembly is configured to receive drilling fluid into the first inner bore and the first and second inner bores are configured to provide passage of the drilling fluid to drive the drill bit. At least a portion of an inner surface of at least one of the inlet port, first inner bore, and the second inner bore, is protected from erosion by a hardfacing, wherein the inlet port, first inner bore, or second inner bore protected from erosion by a hardfacing has a cross-sectional width between about 26 millimeters and about 100 millimeters.

[0039] In one aspect of the present disclosure, the fluid-driven motor assembly, included in the method of drilling a subterranean wellbore, further includes a housing surrounding the tubular body and at least a portion of the driveshaft. The fluid-driven motor assembly can further include a stator disposed within the housing and defining an internal passage. The fluid-driven motor assembly can further include a rotor, disposed within the internal passage of the stator, and coupled to the tubular body.

[0040] All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces.

Statements of the Disclosure Include:

[0041] Statement 1: A process of manufacturing a downhole tool comprising: obtaining a downhole tool comprising: a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore; a driveshaft coupling a drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore; depositing powdered cladding material onto at least a portion of an inner surface of the inlet port or a surface accessed through the inlet port; and irradiating a laser beam onto the deposited powdered cladding material to raise the temperature of the cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the inlet port, or the surface accessed through the inlet port, to form a hardfacing.

[0042] Statement 2: A process of manufacturing a downhole tool according to Statement 1, wherein the surface accessed through the inlet port is an inner surface of the first inner bore.

[0043] Statement 3: A process of manufacturing a downhole tool according to Statement 1 or Statement 2, wherein the cross-sectional width of the inlet port is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0044] Statement 4: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-3, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 100 millimeters.

[0045] Statement 5: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-4, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 50 millimeters.

[0046] Statement 6: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-5, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 35 millimeters.

[0047] Statement 7: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-6, wherein the cross-sectional width of the first inner bore of the tubular body may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0048] Statement 8: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-7, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 100 millimeters.

[0049] Statement 9: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-8, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 50 millimeters.

[0050] Statement 10: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-9, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 35 millimeters.

[0051] Statement 11: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-10, further comprising: depositing powdered cladding material onto at least a portion of an inner surface of the second inner bore and irradiating a laser beam onto the deposited powdered cladding material to raise the temperature of the cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the second inner bore to form a hardfacing.

[0052] Statement 12: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-11, wherein the cross-sectional width of the second inner bore of the driveshaft may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0053] Statement 13: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-12, wherein the

cross-sectional width of the second inner bore is between about 26 millimeters and about 100 millimeters.

[0054] Statement 14: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-13, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 50 millimeters.

[0055] Statement 15: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-14, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 35 millimeters.

[0056] Statement 16: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-15, wherein the cladding material is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0057] Statement 17: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-16, wherein the cladding material is tungsten carbide.

[0058] Statement 18: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-17, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0059] Statement 19: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-18, wherein the hardfacing comprises tungsten carbide.

[0060] Statement 20: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-19, wherein the downhole tool further comprises: a housing surrounding the tubular body and at least a portion of the driveshaft; a stator disposed within the housing and defining an internal passage; and a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

[0061] Statement 21: A process of manufacturing a downhole tool according to any one of the preceding Statements 1-20, wherein the depositing powdered cladding material and the irradiating a laser beam onto the deposited powdered cladding material occurs simultaneously.

[0062] Statement 22: A downhole tool manufactured according to the process of any one of the preceding Statements 1-21.

[0063] Statement 23: A method of drilling a subterranean wellbore comprising the downhole tool manufactured according to the process of any one of the preceding Statements 1-21.

[0064] Statement 24: A subterranean wellbore drilling system comprising the downhole tool manufactured according to the process of any one of the preceding Statements 1-21.

[0065] Statement 25: A method of drilling a subterranean wellbore comprising: providing a drill string comprising a drill pipe and a drill bit; applying an operative force to the drill bit, wherein applying the operative force comprises flowing fluid through a downhole fluid-driven motor assembly, the fluid-driven motor assembly comprising: a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore; a driveshaft coupling the drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore; wherein the inlet

port is configured to receive drilling fluid into the first inner bore, and wherein the first and second inner bores are configured to provide passage of the drilling fluid to drive the drill bit, wherein at least a portion of an inner surface of at least one of the inlet port, the first inner bore, and the second inner bore, is protected from erosion by a hardfacing, and wherein the inlet port, first inner bore, or second inner bore protected from erosion by a hardfacing has a cross-sectional width of at least 26 millimeters.

[0066] Statement 26: A method of drilling a subterranean wellbore according to Statement 25, wherein the cross-sectional width of the inlet port is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0067] Statement 27: A method of drilling a subterranean wellbore according to Statement 25 or Statement 26, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 100 millimeters.

[0068] Statement 28: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-27, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 50 millimeters.

[0069] Statement 29: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-28, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 35 millimeters.

[0070] Statement 30: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-29, wherein the

cross-sectional width of the first inner bore of the tubular body may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0071] Statement 31: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-30, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 100 millimeters.

[0072] Statement 32: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-31, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 50 millimeters.

[0073] Statement 33: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-32, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 35 millimeters.

[0074] Statement 34: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-33, wherein the cross-sectional width of the second inner bore of the driveshaft may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0075] Statement 35: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-34, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 100 millimeters.

[0076] Statement 36: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-35, wherein the

cross-sectional width of the second inner bore is between about 26 millimeters and about 50 millimeters.

[0077] Statement 37: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-36, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 35 millimeters.

[0078] Statement 38: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-37, wherein the cladding material is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0079] Statement 39: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-38, wherein the cladding material is tungsten carbide.

[0080] Statement 40: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-39, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0081] Statement 41: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-40, wherein the hardfacing comprises tungsten carbide.

[0082] Statement 42: A method of drilling a subterranean wellbore according to any one of the preceding Statements 25-41, wherein the fluid-driven motor assembly further comprises: a housing surrounding the tubular body and at least a portion of the driveshaft; a stator disposed

within the housing and defining an internal passage; and a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

[0083] Statement 43: A downhole drilling device comprising: a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore; a driveshaft coupling the drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore; wherein the inlet port is configured to receive drilling fluid into the first inner bore, and wherein the first and second inner bores are configured to provide passage of the drilling fluid to drive the drill bit, wherein at least a portion of the inlet port, the first inner bore, or the second inner bore, are protected from erosion by a hardfacing, and wherein the cross-sectional width of the inlet port, first inner bore, or second inner bore protected from erosion by hardfacing is at least 26 millimeters.

[0084] Statement 44: A downhole drilling device according to Statement 43, wherein the cross-sectional width of the inlet port is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0085] Statement 45: A downhole drilling device according to Statement 43 or Statement 44, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 100 millimeters.

[0086] Statement 46: A downhole drilling device according to any one of the preceding Statements 43-45, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 50 millimeters.

[0087] Statement 47: A downhole drilling device according to any one of the preceding Statements 43-46, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 35 millimeters.

[0088] Statement 48: A downhole drilling device according to any one of the preceding Statements 43-47, wherein the cross-sectional width of the first inner bore of the tubular body may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0089] Statement 49: A downhole drilling device according to any one of the preceding Statements 43-48, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 100 millimeters.

[0090] Statement 50: A downhole drilling device according to any one of the preceding Statements 43-49, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 50 millimeters.

[0091] Statement 51: A downhole drilling device according to any one of the preceding Statements 43-50, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 35 millimeters.

[0092] Statement 52: A downhole drilling device according to any one of the preceding Statements 43-51, wherein the cross-sectional width of the second inner bore of the driveshaft may be in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[0093] Statement 53: A downhole drilling device according to any one of the preceding Statements 43-52, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 100 millimeters.

[0094] Statement 54: A downhole drilling device according to any one of the preceding Statements 43-53, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 50 millimeters.

[0095] Statement 55: A downhole drilling device according to any one of the preceding Statements 43-54, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 35 millimeters.

[0096] Statement 56: A downhole drilling device according to any one of the preceding Statements 43-55, wherein the cladding material is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0097] Statement 57: A downhole drilling device according to any one of the preceding Statements 43-56, wherein the cladding material is tungsten carbide.

[0098] Statement 58: A downhole drilling device according to any one of the preceding Statements 43-57, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[0099] Statement 59: A downhole drilling device according to any one of the preceding Statements 43-58, wherein the hardfacing comprises tungsten carbide.

[00100] Statement 60: A downhole drilling device according to any one of the preceding Statements 43-59, further comprising: a housing surrounding the tubular body and at least a portion of the driveshaft; a stator disposed within the housing and defining an internal passage; and a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

[00101] Statement 61: A method of protecting an internal surface of a downhole tool from erosion, the method comprising: applying a hardfacing to the inner surface of a bore or port of a downhole tool using a laser cladding process; wherein the cross-sectional width of the bore or port is at least 26 millimeters.

[00102] Statement 62: A method of protecting an internal surface of a downhole tool from erosion according to Statement 61, wherein the cross-sectional width of the port or bore is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[00103] Statement 63: A method of protecting an internal surface of a downhole tool from erosion according to Statement 61 or Statement 62, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 100 millimeters.

[00104] Statement 64: A method of protecting an internal surface of a downhole tool from erosion according to any one of the preceding Statements 61-63, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 50 millimeters.

[00105] Statement 65: A method of protecting an internal surface of a downhole tool from erosion according to any one of the preceding

Statements 61-64, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 35 millimeters.

[00106] Statement 66: A method of protecting an internal surface of a downhole tool from erosion according to any one of the preceding Statements 61-65, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[00107] Statement 67: A method of protecting an internal surface of a downhole tool from erosion according to any one of the preceding Statements 61-66, wherein the hardfacing is tungsten carbide.

[00108] Statement 68: A method of repairing erosion protection on an internal surface of a downhole tool, the method comprising: applying a hardfacing to the inner surface of a bore or port of a downhole tool using a laser cladding process, wherein the cross-sectional width of the bore or port is at least 26 millimeters.

[00109] Statement 69: A method of repairing erosion protection on an internal surface of a downhole tool according to Statement 68, wherein the cross-sectional width of the port or bore is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[00110] Statement 70: A method of repairing erosion protection on an internal surface of a downhole tool according to Statement 68 or Statement 69, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 100 millimeters.

[00111] Statement 71: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding

Statements 68-70, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 50 millimeters.

[00112] Statement 72: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 68-71, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 35 millimeters.

[00113] Statement 73: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 68-72, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[00114] Statement 74: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 68-73, wherein the hardfacing is tungsten carbide.

[00115] Statement 75: A method of repairing the erosion protection on an internal surface of a downhole tool, the method comprising: removing at least a portion of a previously deposited hardfacing from the inner surface of a bore or port of a downhole tool, and applying a hardfacing to the inner surface of a bore or port of a downhole tool using a laser cladding process, wherein the cross-sectional width of the bore or port is at least 26 millimeters.

[00116] Statement 76: A method of repairing erosion protection on an internal surface of a downhole tool according to Statement 75, wherein the cross-sectional width of the port or bore is in the range of a lower limit of about 26mm, 27mm, 28mm, 29mm, 30mm, 31mm, 32mm, 33mm, and 34mm to an upper limit of about 102mm, 100mm, 90mm, 80mm, 70mm, 60mm, 50mm, 40mm, and 35mm.

[00117] Statement 77: A method of repairing erosion protection on an internal surface of a downhole tool according to Statement 75 or Statement 76, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 100 millimeters.

[00118] Statement 78: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 75-77, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 50 millimeters.

[00119] Statement 79: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 75-78, wherein the cross-sectional width of the port or bore is between about 26 millimeters and about 35 millimeters.

[00120] Statement 80: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 75-79, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

[00121] Statement 81: A method of repairing erosion protection on an internal surface of a downhole tool according to any one of the preceding Statements 75-80, wherein the hardfacing is tungsten carbide.

[00122] Although a variety of examples and other information was used to explain aspects within the scope of the appended claims, no limitation of the claims should be implied based on particular features or arrangements in such examples, as one of ordinary skill would be able to use these examples to derive a wide variety of implementations. Further and although some subject matter may have been described in language specific to examples of structural features and/or method steps, it is to be

understood that the subject matter defined in the appended claims is not necessarily limited to these described features or acts. For example, such functionality can be distributed differently or performed in components other than those identified herein. Rather, the described features and steps are disclosed as examples of components of systems and methods within the scope of the appended claims. Moreover, claim language reciting "at least one of" a set indicates that a system including either one member of the set, or multiple members of the set, or all members of the set, satisfies the claim.

CLAIMS

We claim:

1. A process of manufacturing a downhole tool comprising:
obtaining a downhole tool comprising:
a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore;
a driveshaft coupling a drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore;
depositing powdered cladding material onto at least a portion of an inner surface of the inlet port or a surface accessed through the inlet port; and
irradiating a laser beam onto the deposited powdered cladding material to raise the temperature of the cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the inlet port, or the surface accessed through the inlet port, to form a hardfacing.
2. The process of claim 1, wherein the surface accessed through the inlet port is an inner surface of the first inner bore.
3. The process of claim 1, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 100 millimeters.

4. The process of claim 2, wherein the cross-sectional width of the first inner bore is between about 26 millimeters and about 100 millimeters.

5. The process of claim 1, wherein the cladding material is selected from the group consisting of spherical or macro-crystalline tungsten carbide, titanium carbide, Ni-based alloys, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

6. The process of claim 1, further comprising:

depositing powdered cladding material onto at least a portion of an inner surface of the second inner bore and irradiating a laser beam onto the deposited powdered cladding material to raise the temperature of the cladding material to at or above the temperature needed to form a metallurgical bond between the deposited material and the inner surface of the second inner bore to form a hardfacing, wherein the cross-sectional width of the second inner bore is between about 26 millimeters and about 100 millimeters.

7. The process of claim 1, wherein the downhole tool further comprises:

a housing surrounding the tubular body and at least a portion of the driveshaft;

a stator disposed within the housing and defining an internal passage; and

a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

8. A downhole tool manufactured by the process of claim 1.

9. A method of drilling a subterranean wellbore comprising the downhole tool manufactured by the process of claim 1.

10. A subterranean wellbore drilling system comprising the downhole tool manufactured according to the process of claim 1.

11. A method of drilling a subterranean wellbore comprising:

providing a drill string comprising a drill pipe and a drill bit;

applying an operative force to the drill bit, wherein applying the operative force comprises flowing fluid through a downhole fluid-driven motor assembly, the fluid-driven motor assembly comprising:

a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore;

a driveshaft coupling the drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore;

wherein the inlet port is configured to receive drilling fluid into the first inner bore, and wherein the first and second inner bores are configured to provide passage of the drilling fluid to drive the drill bit,

wherein at least a portion of an inner surface of at least one of the inlet port, the first inner bore, and the second inner bore, is protected from erosion by a hardfacing, and

wherein the inlet port, first inner bore, or second inner bore protected from erosion by a hardfacing has a cross-sectional width between about 26 millimeters and about 100 millimeters.

12. The method of claim 11, wherein the cross-sectional width of the inlet port and first inner bore is between about 26 millimeters and about 100 millimeters.

13. The method of claim 11, wherein the cross-sectional width of the inlet port is between about 26 millimeters and about 35 millimeters.

14. The method of claim 11, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

15. The method of claim 11, wherein the hardfacing comprises tungsten carbide.

16. The method of claim 11, wherein the fluid-driven motor assembly further comprises:

- a housing surrounding the tubular body and at least a portion of the driveshaft;

- a stator disposed within the housing and defining an internal passage; and

- a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

17. A downhole drilling device comprising:

a tubular body having a first inner bore formed therein and an inlet port fluidly coupled to the first inner bore;

a driveshaft coupling the drill bit to the tubular body, wherein the driveshaft has a second inner bore formed therein, the second inner bore fluidly coupled to the first inner bore;

wherein the inlet port is configured to receive drilling fluid into the first inner bore, and wherein the first and second inner bores are configured to provide passage of the drilling fluid to drive the drill bit, wherein at least a portion of the inlet port, the first inner bore, or the second inner bore, are protected from erosion by a hardfacing, and

wherein the cross-sectional width of the inlet port, first inner bore, or second inner bore protected from erosion by hardfacing is between about 26 millimeters and about 100 millimeters.

18. The device of claim 17, wherein the hardfacing is selected from the group consisting of spherical or macro-crystalline tungsten carbide, Ni-based superalloys, Co-based alloys, Fe-based alloys, and any combination thereof.

19. The device of claim 17, wherein the hardfacing comprises tungsten carbide.

20. The device of claim 17, further comprising:

a housing surrounding the tubular body and at least a portion of the driveshaft;

a stator disposed within the housing and defining an internal passage; and

a rotor disposed within the internal passage of the stator, wherein the rotor is coupled to the tubular body.

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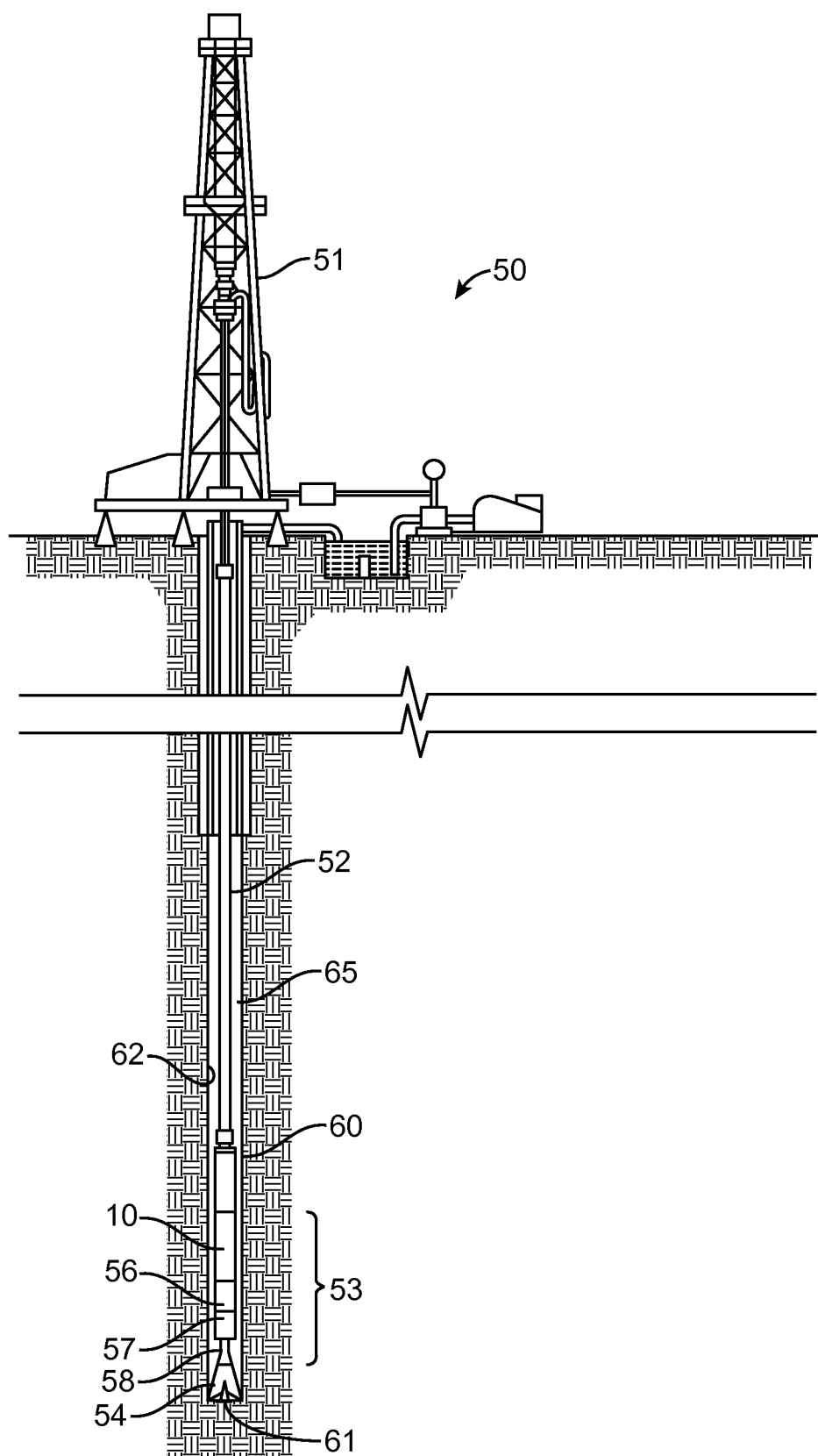


FIG. 1

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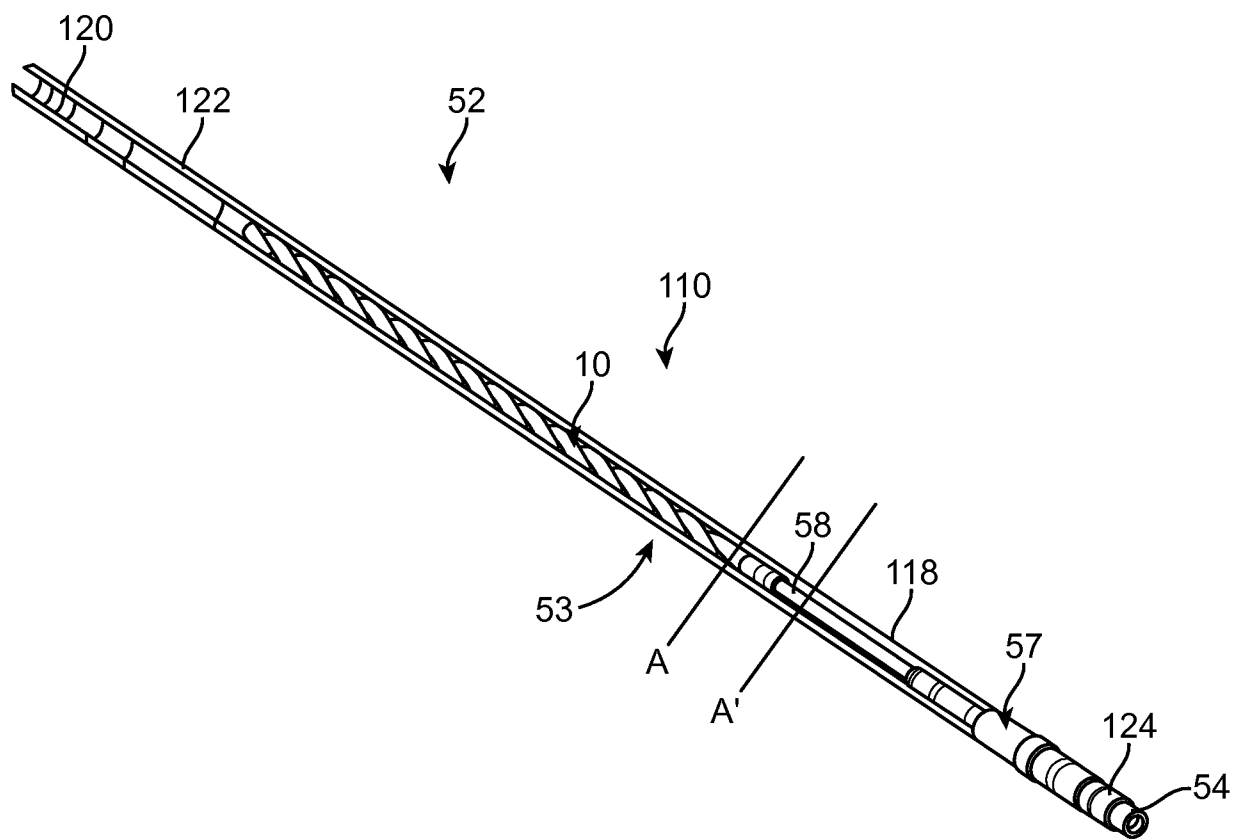


FIG. 2

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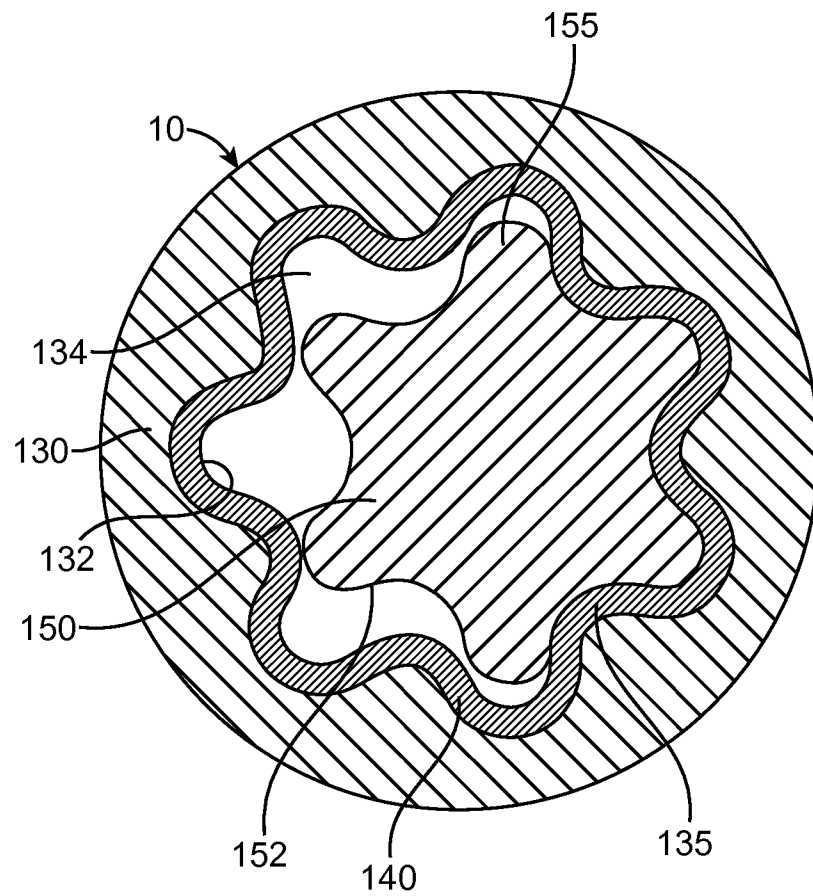


FIG. 3

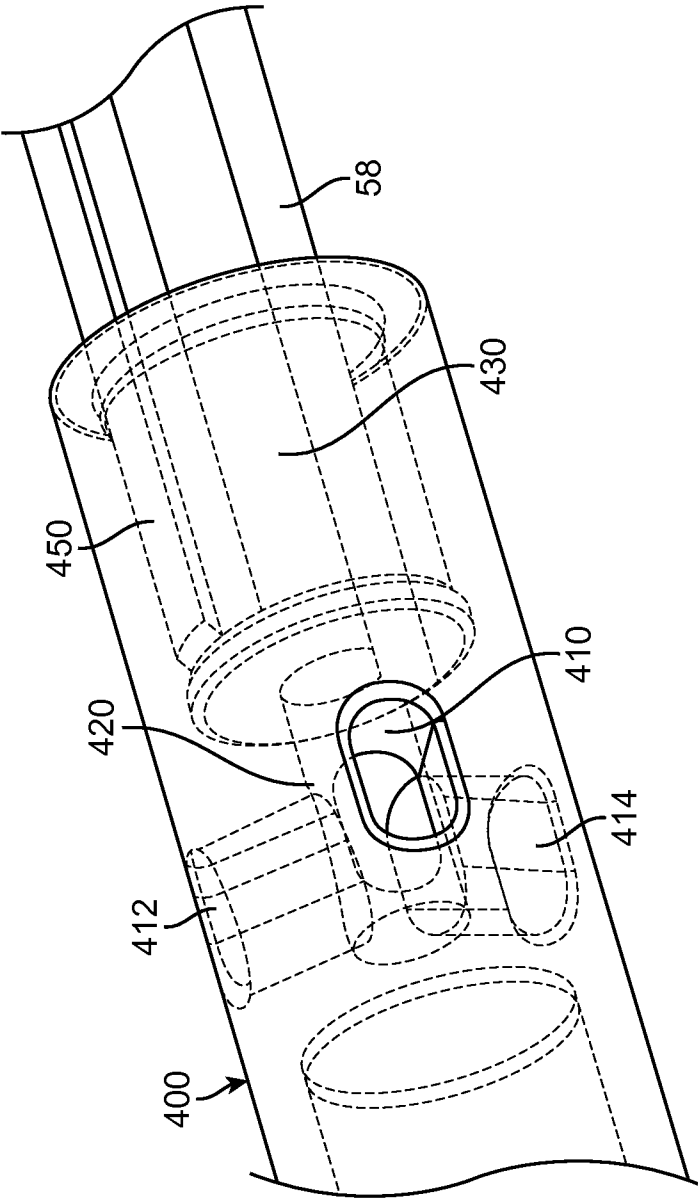


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/056990**A. CLASSIFICATION OF SUBJECT MATTER****E21B 4/02(2006.01)i, B23K 20/00(2006.01)i, B23K 26/342(2014.01)i, C23C 24/00(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 4/02; B32B 9/00; B21D 53/10; B05D 1/36; F16C 17/00; B24D 18/00; E21B 41/02; E21B 17/00; B23K 20/00; B23K 26/342; C23C 24/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: tool string, collar, borehole, mud, motor, inlet, fluid communication, drive shaft, drill bit, hardfacing and laser

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006-0283636 A1 (REAGAN, LOREN PETER) 21 December 2006 See paragraphs [0021]-[0025] and figures 1-3a.	1-20
Y	US 2012-0018227 A1 (PUZZ et al.) 26 January 2012 See paragraphs [0030], [0034], [0051] and figures 1A-4.	1-20
A	US 2004-0157066 A1 (ARZUMANIDIS, G. ALEXIS) 12 August 2004 See paragraphs [0016]-[0036] and figures 1-5.	1-20
A	US 2011-0203791 A1 (JIN et al.) 25 August 2011 See abstract and paragraph [0010].	1-20
A	US 2009-0044409 A1 (GYNZ-REKOWSKI et al.) 19 February 2009 See claims 1-11 and figures 1-2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

14 February 2016 (14.02.2016)

Date of mailing of the international search report

15 February 2016 (15.02.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/056990

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