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(54) METHODS FOR FORMING BORING SHOES FOR WELLBORE CASING, AND BORING SHOES AND INTERMEDIATE STRUCTURES FORMED BY SUCH METHODS

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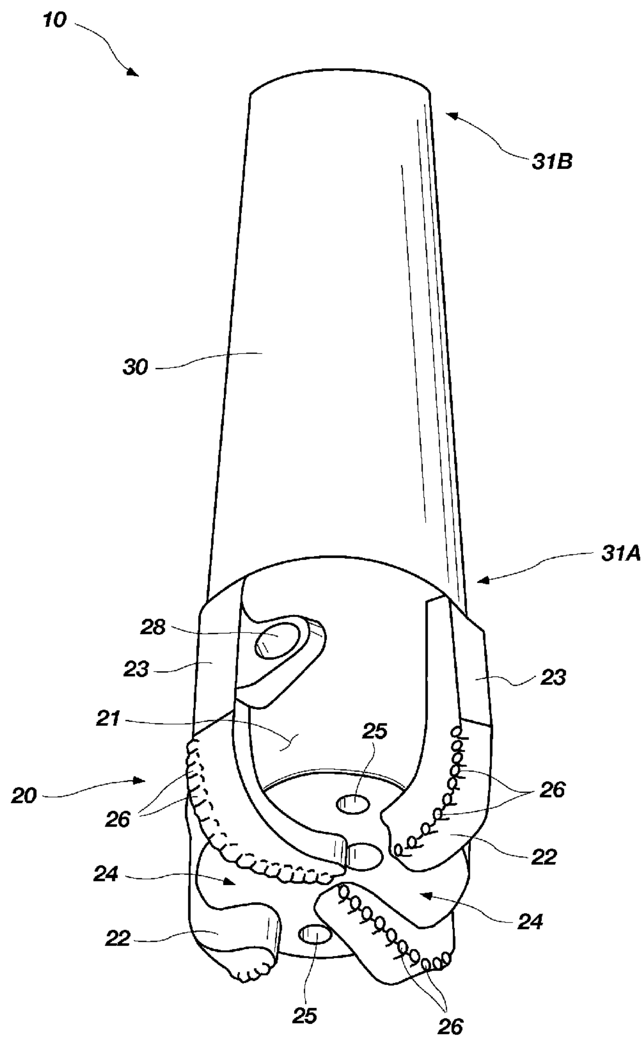
(57) **ABSTRACT**

Methods of attaching a crown of a boring shoe to a casing section include attaching an adaptable shank to a crown, and machining the adaptable shank to configure an end thereof for attachment to a casing section after attaching the adaptable shank to the crown. Additional methods include welding an end of an adaptable shank to a crown to form a boring shoe, selecting the adaptable shank to have an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown, and configuring an opposite end of the adaptable shank for attachment to a particular type of casing section after welding the shank to the crown. Boring shoes have an adaptable shank attached to a crown, wherein the shank comprises a generally cylindrical wall having an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown.



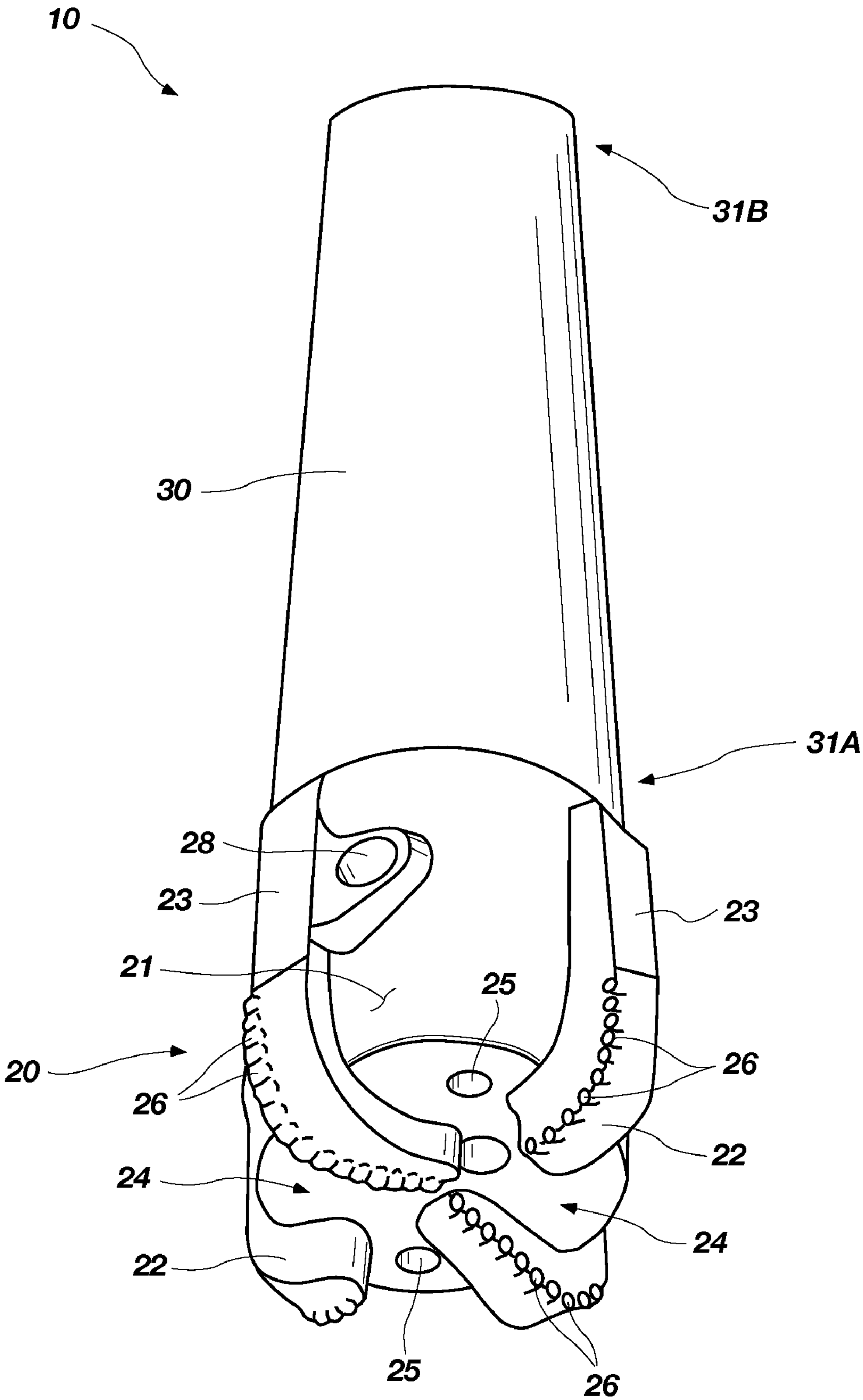


FIG. 1

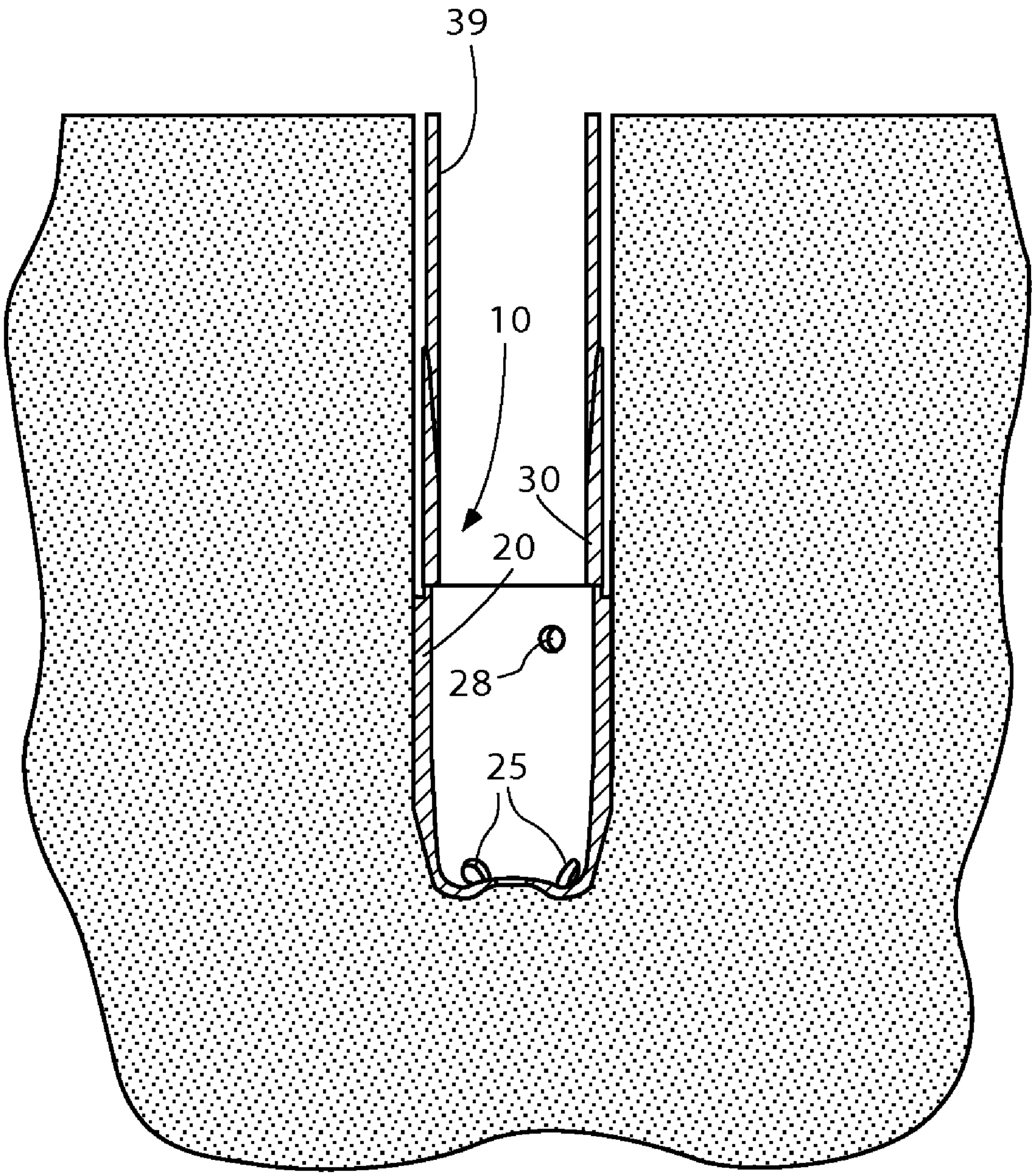


FIG. 2

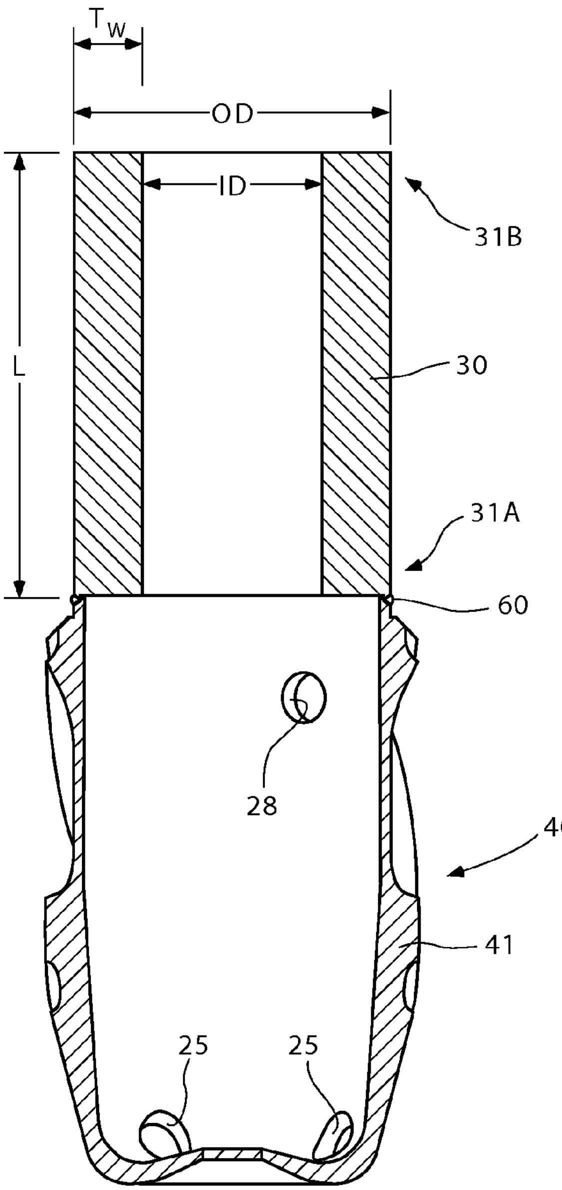


FIG. 3

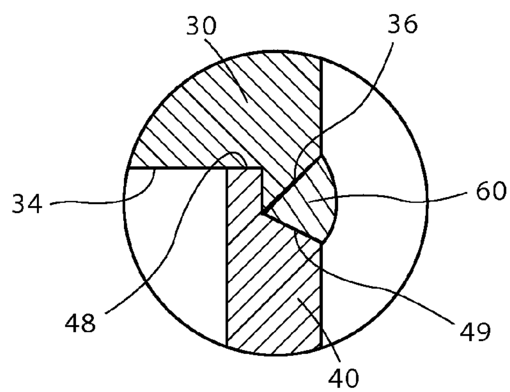


FIG. 4

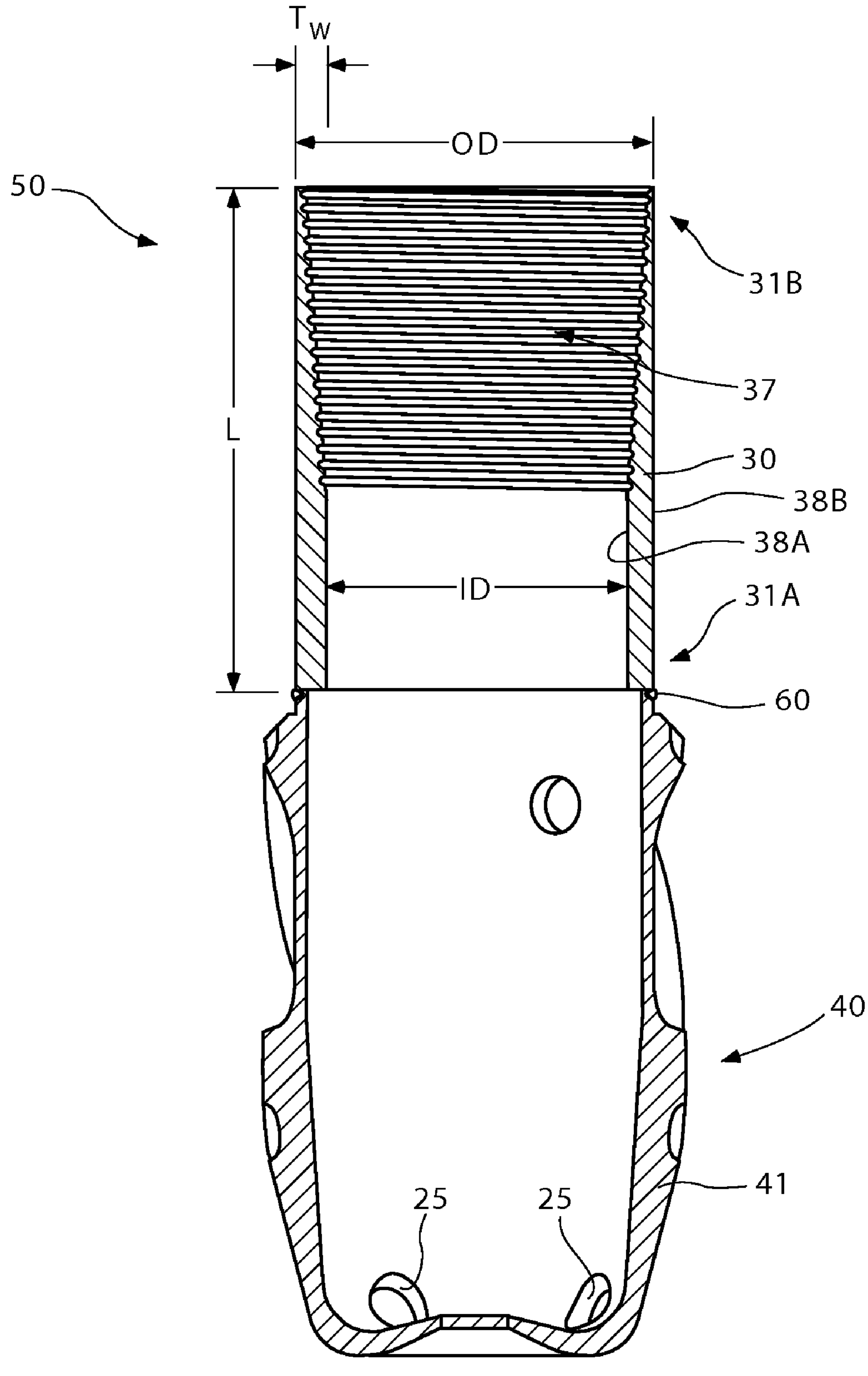


FIG. 5

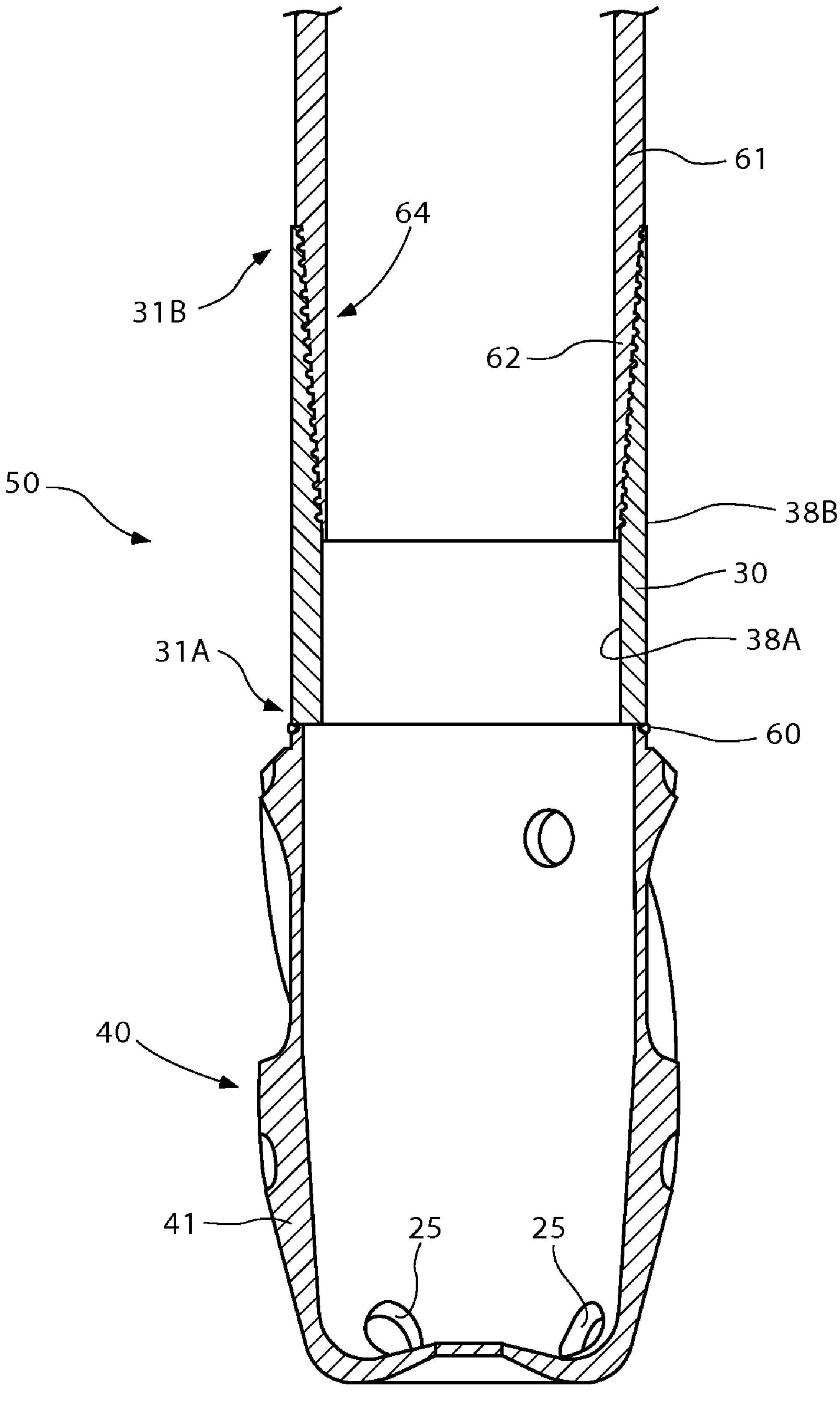


FIG. 6

METHODS FOR FORMING BORING SHOES FOR WELLBORE CASING, AND BORING SHOES AND INTERMEDIATE STRUCTURES FORMED BY SUCH METHODS

TECHNICAL FIELD

[0001] The present invention relates to earth-boring shoes configured for attachment to a section of wellbore casing, to methods of manufacturing such earth-boring shoes, and to methods of adapting such earth-boring shoes for attachment to a section of wellbore casing.

BACKGROUND

[0002] The drilling of wells for oil and gas production conventionally employs longitudinally extending sections or so-called "strings" of drill pipe to which, at one end, is secured a drill bit of a larger diameter. After a selected portion of the borehole has been drilled, the borehole is usually lined or cased with a string or section of casing. Such a casing or liner usually exhibits a larger diameter than the drill pipe and a smaller diameter than the drill bit. Therefore, drilling and casing according to the conventional process typically requires sequentially drilling the borehole using drill string with a drill bit attached thereto, removing the drill string and drill bit from the borehole, and disposing casing into the borehole. Further, often after a section of the borehole is lined with casing, which is usually cemented into place, additional drilling beyond the end of the casing may be desired.

[0003] Unfortunately, sequential drilling and casing may be time consuming because, as may be appreciated, at the considerable depths reached during oil and gas production, the time required to implement complex retrieval procedures to recover the drill string may be considerable. Thus, such operations may be costly as well, since, for example, the beginning of profitable production can be greatly delayed. Moreover, control of the well may be difficult during the period of time that the drill pipe is being removed and the casing is being disposed into the borehole.

[0004] Some approaches have been developed to address the difficulties associated with conventional drilling and casing operations. Of initial interest is an apparatus which is known as a reamer shoe that has been used in conventional drilling operations. Reamer shoes have become available relatively recently and are devices that are able to drill through modest obstructions within a borehole that has been previously drilled. In addition, the reamer shoe may include an inner section manufactured from a material which is drillable by rotary drill bits. Accordingly, when cemented into place, reamer shoes usually pose no difficulty to a subsequent drill bit. For instance, U.S. Pat. No. 6,062,326 to Strong et al. discloses a casing shoe or reamer shoe in which the central portion thereof may be configured to be drilled through. In addition, U.S. Pat. No. 6,062,326 to Strong et al. discloses a casing shoe that may include diamond cutters over the entire face thereof, if it is not desired to drill therethrough. Such reamers that are configured for attachment to a casing string are referred to hereinafter as "reamer shoes."

[0005] As a further extension of the reamer shoe concept, in order to address the problems with sequential drilling and casing, drilling with casing is gaining popularity as a method for initially drilling a borehole, wherein the casing is used as the drilling conduit and, after drilling, the casing is cemented into and remains within the wellbore to act as the wellbore casing. Drilling with casing employs a drill bit that is configured for attachment to the casing string instead of a drill string, so that the drill bit functions not only to drill the earth formation, but also to guide the casing into the wellbore. This may be advantageous as the casing is disposed into the borehole as it is formed by the drill bit, and therefore eliminates the necessity of retrieving the drill string and drill bit after reaching a target depth where cementing is desired. Such drill bits that are configured for attachment to a casing string are referred to hereinafter as "drill shoes."

[0006] As used herein, the terms "earth-boring shoes" and "boring shoes" mean and include any device that is configured for attachment to an end of a section of casing and used for at least one of drilling a wellbore, reaming a previously drilled wellbore, and guiding casing through a previously drilled wellbore, as the section of casing to which the device is attached is advanced into a subterranean formation. Earth-boring shoes and boring shoes include, for example, drill shoes, reamer shoes, casing shoes configured to merely guide casing through a wellbore and ensure that the wellbore diameter remains as drilled (i.e., has not decreased as sometimes occurs in reactive or sloughing formations), and shoes that both drill and ream as casing to which they are attached is advanced into a subterranean formation.

[0007] Commercially available casing sections are sold in a variety of different diameters and with a variety of different coupling configurations. As a result, when an earth-boring shoe is manufactured for a particular customer, a conventional boring shoe must be manufactured for the particular diameter of casing to which the boring shoe is to be attached. Furthermore, the boring shoe must be provided with a connection portion that is configured (e.g., with threads) to complimentarily engage the particular connection portion of the casing string to which the boring shoe is to be attached.

[0008] There is a need in the art for improved methods of coupling boring shoes to casing strings, and for improved methods of adapting boring shoes for attachment to casing strings having different connection configurations.

BRIEF SUMMARY

[0009] In some embodiments, the present invention includes methods of attaching a crown of a boring shoe to a section of casing. A first end of an adaptable shank may be attached to the crown of a boring shoe, and an opposite, second end of the adaptable shank may be machined to configure the second end of the adaptable shank for attachment to a section of casing after attaching the first end of the adaptable shank to the crown.

[0010] In additional embodiments, the present invention includes methods of attaching boring shoes to sections of casing. A first end of an adaptable shank is welded to a crown to form a boring shoe. The adaptable shank is selected to have an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown. An opposite, second end of the adaptable shank is configured for attachment to a particular type of casing section after welding the first end of the adaptable shank to the crown.

[0011] Yet further embodiments of the present invention include boring shoes having an adaptable shank attached to a crown, wherein the adaptable shank comprises a generally cylindrical wall having an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012] While the specification concludes with claims particularly pointing out and distinctly claiming that which is regarded as the present invention, the advantages of embodiments of this invention may be more readily ascertained from the following description of certain embodiments of the invention when read in conjunction with the accompanying drawings, in which:

[0013] FIG. **1** is a perspective view of an embodiment of a shoe tool of the present invention that includes a crown attached to an adaptable shank;

[0014] FIG. **2** is a schematic illustration showing the shoe tool of FIG. **1** attached to a section of casing and disposed within a subterranean formation;

[0015] FIG. **3** is a longitudinal cross-sectional view of an embodiment of a shoe tool like that of FIG. **1** including a crown attached to an adaptable shank;

[0016] FIG. **4** is an enlarged cross-sectional view of an interface between the crown and the adaptable shank shown in FIG. **3**;

[0017] FIG. **5** is a longitudinal cross-sectional view of the shoe tool shown in FIGS. **3** and **4** after adapting the shank for connection to casing in accordance with embodiments of methods of the present invention; and

[0018] FIG. **6** is a longitudinal cross-sectional view of the shoe tool shown in FIG. **5**, further illustrating a section of casing coupled to the shank of the shoe tool.

DETAILED DESCRIPTION

[0019] Illustrations presented herein are not meant to be actual views of any particular device or system, but are merely idealized representations which are employed to describe embodiments of the present invention. Additionally, elements common between figures may retain the same numerical designation.

[0020] An embodiment of a boring shoe **10** of the present invention is shown in FIG. **1**. The boring shoe **10** shown in FIG. **1** is an intermediate structure that has not yet been adapted for attachment to any particular section of casing. After formation of the intermediate boring shoe **10** shown in FIG. **1**, the boring shoe **10** may be adapted for attachment to a particular section of casing, as described in further detail herein below.

[0021] The boring shoe **10** shown in FIG. **1** may be a reamer shoe or a drill shoe configured for attachment to a section of casing for use in forming a wellbore in a subterranean formation. As shown in FIG. **1**, the boring shoe **10** includes a crown **20** and an adaptable shank **30** that is attached to the crown **20**.

[0022] In some embodiments, the crown **20** may be configured to drill a wellbore in a subterranean formation. In other embodiments, the crown **20** may be configured to ream (i.e., enlarge the diameter of) a previously drilled wellbore. In yet other embodiments, the crown **20** may be configured to merely guide casing through a wellbore and ensure that the wellbore diameter remains as previously drilled and has not decreased as sometimes occurs in reactive or sloughing formations. In other words, the crown **20** may only ream sections of the wellbore that have an undersized diameter due, for example, to encroachment of the formation material into the wellbore.

[0023] The crown **20** includes a body **21** that may be formed of and comprise, for example, a metal or metal alloy (e.g., steel, aluminum, brass, or bronze), or a composite material including particles of a relatively harder material (e.g., tungsten carbide) embedded within a relatively softer metal or metal alloy (e.g., steel, aluminum, brass, or bronze). The material of the body **21** may be selected to exhibit physical properties that allow the body **21** to be drilled through by another drill bit after the boring shoe **10** has been used to advance a section of casing attached thereto into a subterranean formation, as known in the art.

[0024] Drilling and/or reaming structures may be provided on exterior surfaces of the body **21** of the crown **20**. For example, the crown **20** may comprise a plurality of blades **22** that define fluid courses **24** therebetween. Apertures **25** may be formed through the crown **20** for allowing fluid (e.g., drilling fluid and/or cement) to be pumped through the interior of the boring shoe **10**, out through the apertures **25** in the crown **20**, and into the annular space between the walls of the formation in which the wellbore is formed and the exterior surfaces of the boring shoe **10** and the casing sections to which the boring shoe **10** may be attached. For example, the apertures **25** may comprise fluid passageways extending through the body **21** of the crown **20**. Optionally, nozzles (not shown) may be secured to the crown **20** within the fluid passageways to selectively tailor the hydraulic characteristics of the boring shoe **10**. Cutting element pockets may be formed in the blades **22**, and cutting elements **26**, such as, for example, polycrystalline diamond compact (PDC) cutting elements, may be secured within the cutting element pockets.

[0025] Also, each of blades **22** may include a gage region **23** that together define the largest diameter of the crown **20** and, thus, the diameter of any wellbore formed using the crown **20** and boring shoe **10**. The gage regions **23** may be longitudinal extensions of the blades **22**. Wear-resistant structures or materials may be provided on the gage regions **23**. For example, tungsten carbide inserts, cutting elements, diamonds (e.g., natural or synthetic diamonds), or hardfacing material may be provided on the gage regions **23** of the crown **20**.

[0026] In additional embodiments, the crown **20** may not include blades **22** and cutting elements **26**, like those shown in FIG. **1**. In such embodiments, the crown **20** may comprise other cutting and/or reaming structures such as, for example, deposits of hardfacing material (not shown) on the exterior surfaces of the crown **20**. Such a hardfacing material may comprise, for example, hard and abrasive particles (e.g., diamond, boron nitride, silicon carbide, carbides or borides of titanium, tungsten, or tantalum, etc.) embedded within a metal or metal alloy matrix material (e.g., an iron-based, cobalt-based, or nickel-based metal alloy). Such deposits of hardfacing material may be shaped into elongated, protruding structures on the exterior surfaces of the crown **20**.

[0027] FIG. **2** is a simplified schematic illustration showing the boring shoe **10** attached to a section of casing **39** and disposed within a wellbore that has been formed in a subterranean formation using the boring shoe **10**. As previously discussed, the casing **39**, with the boring shoe **10** attached thereto, may be rotated and advanced into the subterranean formation as drilling fluid is pumped down through the interior of the casing **39**, out through the apertures **25** in the crown

20, and up through the fluid courses 24 (FIG. 1) and up through the annular space between the walls of the formation within the wellbore and the exterior surfaces of the casing 39 to the surface of the formation.

[0028] Once the casing 39 has been advanced to a desirable location within the formation, drilling with the boring shoe 10 may be ceased, and the casing 39 may be cemented in place. To cement the casing 39 in place, cement (not shown) or another curable material may be forced through the interior of casing 39, through the apertures 25 in the crown 20, up through the fluid courses 24 (FIG. 1), and into the annulus between the wall of wellbore and the outer surface of the casing 39, where it may be allowed to harden. Of course, conventional float equipment may be used for controlling and delivering the cement through the boring shoe 10 and into the annulus between the wall of the wellbore and the casing 39. Cementing the casing 39 in place within the wellbore may stabilize the wellbore and seal the subterranean formations penetrated by the boring shoe 10 and the casing 39.

[0029] In some instances, the size and placement of the apertures 25 that are employed for drilling operations may not be particularly desired for cementing operations. Furthermore, the apertures 25 may become plugged or otherwise obstructed during a drilling operation. As shown in FIGS. 1 and 2, at least one of the crown 20 and the shank 30 of the boring shoe 10 may include one or more frangible regions 28 that can be breached (e.g. a metal disc that can be fractured, perforated, ruptured, removed, etc.) to form one or more additional apertures that may be used to provide fluid communication between the interior and the exterior of the boring shoe 10. Drilling fluid and/or cement optionally may be caused to flow through such frangible regions 28 after breaching the same.

[0030] Referring again to FIG. 1, the boring shoe 10 includes an adaptable shank 30 having a first end 31A attached to the crown 20 and a second end 31B that may be adapted and used to couple the boring shoe 10 to a section of casing (not shown in FIG. 1). The shank 30 may have a size and shape that allows it to be adapted, after attachment to the crown 20, for coupling to a wide variety of different casing configurations, as discussed in further detail herein below.

[0031] FIG. 3 is a longitudinal, cross-sectional view of another embodiment of an intermediate boring shoe 50 of the present invention. The intermediate boring shoe 50 is similar to the boring shoe 10 shown in FIG. 1, and includes a crown 40 having a body 41 that is attached to an adaptable shank 30, as previously described in relation to FIG. 1.

[0032] The adaptable shank 30 is a cylindrical structure having a length L. By way of example and not limitation, the length L of the adaptable shank 30 may be between about twenty-five (25) centimeters (about ten (10) inches) and about two hundred (200) centimeters (about seventy-nine (79) inches).

[0033] The adaptable shank 30 has a wall thickness T_W that is one-half of the difference between the outer diameter OD of the shank 30 and the inner diameter ID of the shank 30. The wall thickness T_W may vary, depending upon the size (e.g., the diameter) of the crown 40 to which the shank 30 is attached. The wall thickness T_W of the shank 30, however, may be sufficiently large to allow the shank 30 to be adapted for use with a number of different casing sections having a variety of weights and coupling configurations that might be used with the particular size of crown 40 to which the shank 30 is attached. Although the shank 30 of FIG. 3 is shown having an outer diameter that is less than an outer diameter of the crown 40 to which the shank 30 is attached, in additional embodiments, the shank 30 may have an outer diameter that is larger than a diameter of the crown 40 to which the shank 30 is attached.

[0034] Table 1 below lists a variety of different diameters of crowns that are often used in the industry, together with the outer diameter OD, the inner diameter ID, and the wall thickness T_W of examples of adaptable shanks 30 of the present invention that may be attached to such crowns. All dimensions in Table 1 are given in inches, and dimensions in centimeters are provided in parenthesis.

TABLE 1

Crown Diameter	Casing Diameter	Shank OD	Shank ID	Shank T_W	Shank T_W as Percentage of Crown Diameter
6.00 in (15.24 cm)	4.50 in (11.43 cm)	5.125 in (13.02 cm)	3.625 in (9.21 cm)	0.750 in (1.91 cm)	12.5%
8.50 in (21.59 cm)	7.625 in (19.37 cm)	8.625 in (21.91 cm)	6.00 in (15.24 cm)	1.313 in (3.34 cm)	15.4%
12.25 in (31.12 cm)	9.625 in (24.45 cm)	10.750 in (27.31 cm)	8.310 in (21.11 cm)	1.220 in (3.10 cm)	10.0%
17.50 in (44.45 cm)	13.375 in (33.97 cm)	14.500 in (36.83 cm)	12.250 in (31.12 cm)	1.125 in (2.86 cm)	6.4%
24.00 in (60.96 cm)	20.00 in (50.80 cm)	21.125 in (53.66 cm)	18.60 in (47.24 cm)	1.263 in (3.21 cm)	5.3%

[0035] As shown in Table 1, in some embodiments of the present invention, the crown 40 may have a diameter that is about 12.25 inches or less, and the adaptable shank 30 may have a wall thickness that is about 10% or more of the diameter of the crown 40, about 12% or more of the diameter of the crown 40, or even about 15% or more of the diameter of the crown 40. As one particular non-limiting example, the crown 40 may have a diameter of about 12.25 inches, the shank 30 may have an outer diameter OD of about 10.750 inches, an inner diameter ID of about 8.310 inches or less, and a wall thickness T_W of about 1.220 inches or more (i.e., about 10.0% or more of the diameter of the crown 40). As another particular non-limiting example, the crown 40 may have a diameter of about 8.50 inches, the shank 30 may have an outer diameter OD of about 8.625 inches, an inner diameter ID of about 6.00 inches or less, and a wall thickness T_W of about 1.313 inches or more (i.e., about 15.4% or more of the diameter of the crown 40). As yet another particular non-limiting example, the crown **40** may have a diameter of about 6.00 inches, the shank **30** may have an outer diameter OD of about 5.125 inches, an inner diameter ID of about 3.625 inches or less, and a wall thickness T_W of about 0.750 inches or more (i.e., about 12.5% or more of the diameter of the crown **40**). Other non-limiting examples of embodiments of the invention are also set forth in Table 1 above.

[0036] As shown in Table 1, in additional embodiments of the present invention, the crown **40** may have a diameter that is greater than about 12.25 inches, and the adaptable shank **30** may have a wall thickness that is about 5% or more of the diameter of the crown **40**, or even about 6% or more of the diameter of the crown **40**. As one particular non-limiting example, the crown **40** may have a diameter of about 17.50 inches, the shank **30** may have an outer diameter OD of about 14.500 inches, an inner diameter ID of about 12.250 inches or less, and a wall thickness T_W of about 1.125 inches or more (i.e., about 6.4% or more of the diameter of the crown **40**). As another particular non-limiting example, the crown **40** may have a diameter of about 24.00 inches, the shank **30** may have an outer diameter OD of about 21.125 inches, an inner diameter ID of about 18.60 inches or less, and a wall thickness T_W of about 1.263 inches or more (i.e., about 5.3% or more of the diameter of the crown **40**).

[0037] The adaptable shank **30** may be formed from and comprise a metal material such as, for example, an iron-based metal alloy (e.g., a steel alloy). In some embodiments, the adaptable shank **30** may be formed from and comprise a material that exhibits a tensile yield strength of at least about 60,000 pounds per square inch (PSI), at least about 90,000 pounds per square inch (PSI), or even at least about 120,000 PSI pounds per square inch (PSI). As previously mentioned, the adaptable shank **30** may be separately formed from the crown **40** and subsequently attached thereto.

[0038] FIG. **4** is an enlarged cross-sectional view of an interface between the crown **40** and the adaptable shank **30** shown in FIG. **3**. As shown in FIG. **4**, the shank **30** may be attached to the crown **40** by abutting an end surface **34** of the shank **30** against an end surface **48** of the crown **40** and welding an interface between the shank **30** and the crown **40**. In other words, a weld material **60** (e.g., one or more weld beads) may be provided around an exterior surface of the intermediate boring shoe **50** along the interface between the crown **40** and the shank **30**. In some embodiments, the shank **30** may have a beveled, frustoconical surface **36** at the first longitudinal end **31**A thereof, and the crown **40** may have a complementary beveled, frustoconical surface **49**. The frustoconical surface **36** of the shank **30** and the frustoconical surface **49** of the crown **40** may define a weld groove therebetween when the shank **30** is abutted against the crown **40**. A weld material **60** may be deposited in the form of one or more weld beads within the weld groove to weld the shank **30** and the crown **40** together. The shank **30** may be abutted against, and welded to, the crown **40** prior to adapting the shank **30** for attachment to a section of casing.

[0039] In additional embodiments, complementary threads (not shown) may be provided on the crown **40** and the shank **30** to allow the crown **40** and the shank **30** to be threaded together to attach the crown **40** and the shank **30** together. In such embodiments, a weld material **60** also may be provided along the interface between the crown **40** and the shank **30** to further secure the crown **40** and the shank **30** together.

[0040] Referring to FIG. **5**, after attaching the shank **30** and the crown **40** together, the shank **30** may be adapted for attachment to a particular section of casing. The shank **30** may be adapted for attachment to a particular section of casing by, for example, doing one or more of the following: reducing the length L of the shank **30**, reducing the wall thickness T_W of the shank **30**, and providing one or more features on the shank **30**, and/or shaping one or more surfaces of the shank **30**, for coupling to an end of a section of casing. The wall thickness T_W of the shank **30** may be reduced by reducing the outer diameter of the shank **30**, by increasing the inner diameter of the shank **30**, or by both reducing the outer diameter and increasing the inner diameter of the shank **30**.

[0041] The outer diameter of the shank **30** may be reduced, and the inner diameter of the shank **30** may be increased, as desirable, using, for example, conventional machining processes such as turning processes, milling processes, and combinations of turning and milling processes.

[0042] To configure the shank **30** for coupling to a section of casing, one or more features may be provided on the shank **30**, and/or one or more surfaces of the shank **30** may be provided with a certain shape, as previously mentioned. For example, an inner surface **38**A of the shank **30** may be formed to comprise what is referred to in the art as a "threaded box."

[0043] To form a threaded box in the inner surface **38**A of the shank **30**, a section of the inner surface **38**A of the shank **30** at the second end **31**B thereof may be formed to comprise a taper, such that the section of the inner surface **38**A has a frustoconical shape have a diameter that is greatest at the opening of the shank **30** at the second end **31**B thereof, the diameter becoming progressively smaller moving in the longitudinal direction toward the first end **31**A of the shank **30**. The angle of the taper of the inner surface **38**A of the shank **30** at the second end **31**B may be selected to correspond to the angle of a taper on the exterior surface of a section of casing to which the shank **30** is to be attached. Such a taper also may be formed in the inner surface **38**A using, for example, conventional machining processes such as turning processes, milling processes, and combinations of turning and milling processes.

[0044] Furthermore, threads **37** may be formed on a section of the inner surface **38**A of the shank **30** at the second end **31**B (e.g., on a tapered section of the inner surface **38**A). The size (e.g., dimensions), shape, and spacing (e.g., pitch) of the threads **37** also may be selected to correspond to the size (e.g., dimensions), shape, and spacing (e.g., pitch) of complementary threads on a section of casing to which the shank **30** is to be attached. The threads **37** also may be formed in the inner surface **38**A using, for example, conventional machining processes such as turning processes, milling processes, and combinations of turning and milling processes. Threads may also be formed by rolling the surface to be threaded against a threading die, as known in the art, and such roll threading processes also may be employed in embodiments of the present invention.

[0045] In some embodiments, threads **37** may be formed on the inner surface **38**A of the shank **30** at the second end **31**B thereof without providing any taper on the inner surface **38**A. In other words, the inner surface **38**A may remain at least substantially cylindrical, and a section of the cylindrical inner surface may be threaded.

[0046] In additional embodiments of the present invention, an outer surface **38**B of the shank **30** may be formed to comprise what is referred to in the art as a "threaded pin," which is a male pin member having threads on an exterior surface thereof that is configured to mate with, and engage, a female threaded box, as previously described herein.

[0047] Referring to FIG. **6**, after adapting the shank **30** for attachment to a particular section of casing **61**, the shank **30** and the section of casing **61** may be coupled together in preparation for drilling and/or reaming with the boring shoe **50** as the casing **61** and the boring shoe **50** are advanced into a subterranean formation.

[0048] In the embodiment shown in FIG. **6**, a threaded box is provided on the inner surface **38**A of the shank **30** at the second end **31**B thereof, and the section of casing **61** has a threaded pin **62** at an end **64** thereof that is complementary to, and configured to mate with and engage, the threaded box at the second end **31**B of the shank **30**.

[0049] In additional embodiments of the invention, however, the shank **30** may be formed to comprise a threaded pin, and the casing **61** may comprise a complementary threaded box configured to engage the threaded pin of the shank **30**. In yet further embodiments, each of the shank **30** and the casing **61** may comprise a threaded pin, and a collar having a threaded box on both ends thereof may be used to couple the threaded pin of the shank **30** to the threaded pin of the casing **61**. Such collars are commercially available and frequently used in the art.

[0050] Thus, in accordance with some embodiments of methods of the present invention, an adaptable shank may be attached to a crown of a boring shoe prior to identifying the type of casing to which the boring shoe will ultimately be attached. As a result, a manufacturer need not fabricate a variety of different types of shanks for each size of boring shoe, each type corresponding to the different types of casing to which the boring shoe might be attached. In contrast, a single, adaptable shank in accordance with embodiments of the present invention may be fabricated for each size of boring shoe, and the adaptable shank can be adapted, after attachment to a crown, for attachment to a particular type of casing.

[0051] Furthermore, in accordance with some embodiments of methods of the present invention, an adaptable shank may be attached to a crown of a boring shoe prior to identifying the type of casing to which the boring shoe will ultimately be attached. The crown, with the adaptable shank attached thereto, may be transported to another location other than where the crown and shank were attached together (e.g., the location of a distributor, the location of a drilling site, etc.) by way of a vehicle (e.g., a truck, plane, or boat). After transporting the crown, with the adaptable shank attached thereto, to another location, a particular type of casing to which the crown and adaptable shank are to be attached may be identified, and the adaptable shank may be adapted, as previously described herein, for attachment to that particular type of casing.

[0052] While the present invention has been described herein with respect to certain embodiments, those of ordinary skill in the art will recognize and appreciate that it is not so limited. Rather, many additions, deletions and modifications to the embodiments described herein may be made without departing from the scope of the invention as hereinafter claimed. In addition, features from one embodiment may be combined with features of another embodiment while still being encompassed within the scope of the invention as contemplated by the inventors.

What is claimed is:

1. A method of attaching a crown of a boring shoe to a section of casing, comprising:

attaching a first end of an adaptable shank to the crown of the boring shoe; and

machining an opposite second end of the adaptable shank to configure the second end of the adaptable shank for attachment to the section of casing after attaching the first end of the adaptable shank to the crown.

2. The method of claim **1**, further comprising forming the adaptable shank to comprise a generally cylindrical structure.

3. The method of claim **2**, further comprising forming the adaptable shank to comprise a metal alloy.

4. The method of claim **3**, further comprising forming the adaptable shank to comprise a steel alloy.

5. The method of claim **2**, further comprising selecting the metal alloy to exhibit a tensile yield strength of at least about 60,000 pounds per square inch.

6. The method of claim **2**, further comprising forming the adaptable shank to have a length between about twenty-five (25) centimeters (about ten (10) inches) and about two hundred (200) centimeters (about seventy-nine (79) inches).

7. The method of claim **1**, further comprising forming the adaptable shank to have an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown.

8. The method of claim **7**, further comprising forming the average wall thickness of the adaptable shank to be about 10% or more of the maximum diameter of the crown.

9. The method of claim **8**, further comprising:

forming the maximum diameter of the crown to be about 12.25 inches; and

forming the average wall thickness of the adaptable shank to be about 1.22 inches or more.

10. The method of claim **8**, further comprising forming the average wall thickness of the adaptable shank to be about 12.5% or more of the maximum diameter of the crown.

11. The method of claim **10**, further comprising:

forming the maximum diameter of the crown to be about 6.00 inches; and

forming the average wall thickness of the adaptable shank to be about 0.750 inches or more.

12. The method of claim **10**, further comprising forming the average wall thickness of the adaptable shank to be about 15% or more of the maximum diameter of the crown.

13. The method of claim **12**, further comprising:

forming the maximum diameter of the crown to be about 8.50 inches; and

forming the average wall thickness of the adaptable shank to be about 1.313 inches or more.

14. The method of claim **7**, further comprising:

forming the maximum diameter of the crown to be about 17.50 inches; and

forming the average wall thickness of the adaptable shank to be about 1.125 inches or more.

15. The method of claim **7**, further comprising:

forming the maximum diameter of the crown to be about 24.00 inches; and

forming the average wall thickness of the adaptable shank to be about 1.263 inches or more.

16. The method of claim **7**, wherein attaching a first end of an adaptable shank to the crown of the boring shoe comprises:

abutting a surface of the first end of the adaptable shank to a surface of the crown; and

welding an interface between the surface of the crown and the abutting surface of the first end of the adaptable shank.

17. The method of claim **16**, wherein welding the interface between the surface of the crown and the abutting surface of the first end of the adaptable shank comprises depositing a weld material in a weld groove.

18. The method of claim **1**, wherein machining the opposite second end of the adaptable shank comprises machining threads on at least one of an interior surface and an exterior surface of the adaptable shank.

19. A method of attaching a boring shoe to a section of casing, comprising:

selecting an adaptable shank to have an average wall thickness greater than about five percent (5%) of a maximum diameter of a crown to be welded thereto;

welding the first end of the adaptable shank to the crown to form the boring shoe; and

configuring an opposite second end of the adaptable shank for attachment to the section of casing after welding the first end of the adaptable shank to the crown.

20. The method of claim **18**, further comprising selecting the adaptable shank to have a length between about twenty-five (25) centimeters (about ten (10) inches) and about two hundred (200) centimeters (about seventy-nine (79) inches).

21. The method of claim **20**, further comprising selecting the average wall thickness of the adaptable shank to be about 10.0% or more of the maximum diameter of the crown.

22. The method of claim **21**, further comprising selecting the average wall thickness of the adaptable shank to be about 12% or more of the maximum diameter of the crown.

23. The method of claim **22**, further comprising selecting the average wall thickness of the adaptable shank to be about 15% or more of the maximum diameter of the crown.

24. The method of claim **19**, further comprising:

welding the first end of the adaptable shank to the crown at a first geographic location;

transporting the boring shoe from the first geographic location to a second geographic location using a vehicle; and

configuring the opposite second end of the adaptable shank for attachment to the section of casing at the second geographic location.

25. A boring shoe, comprising:

a crown configured for at least one of drilling and reaming a wellbore; and

an adaptable shank attached to the crown, the adaptable shank comprising a generally cylindrical wall having an average wall thickness greater than about five percent (5%) of a maximum diameter of the crown.

26. The boring shoe of claim **25**, wherein the crown is welded to the adaptable shank.

27. The boring shoe of claim **26**, wherein the average wall thickness of the generally cylindrical wall is greater than about 10% of the maximum diameter of the crown.

28. The boring shoe of claim **27**, wherein the average wall thickness of the generally cylindrical wall is greater than about 12% of the maximum diameter of the crown.

29. The boring shoe of claim **28**, wherein the average wall thickness of the generally cylindrical wall is greater than about 15% of the maximum diameter of the crown.

30. The boring shoe of claim **29**, wherein the adaptable shank comprises a metal alloy material exhibiting a tensile yield strength of at least about 60,000 pounds per square inch.

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