BALL HOLE WELDING USING THE FRICTION STIRR WELDING (FSW) PROCESS

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Appl. No.: 12/629,201
Filed: Dec. 2, 2009

Related U.S. Application Data
Continuation-in-part of application No. 11/136,609, filed on May 23, 2005, which is a continuation of application No. 11/090,317, filed on Mar. 24, 2005, now abandoned, which is a continuation of application No. 11/090,909, filed on Mar. 24, 2005.

Provisional application No. 60/573,707, filed on May 21, 2004, provisional application No. 60/637,223, filed on Dec. 17, 2004, provisional application No. 60/652,808, filed on Feb. 14, 2005.

Publication Classification

Int. Cl.
E21B 10/22 (2006.01)
B23K 20/12 (2006.01)
E21B 10/06 (2006.01)

U.S. Cl. 175/369; 228/112.1

ABSTRACT
A roller cone drill bit includes a bit body, at least one leg extending downward from the bit body, a journal on each leg, and a roller cone mounted on each journal. A ball race is configured between each journal and roller cone, and a plurality of retention balls is disposed within each ball race. A ball hole extends from the back face of each leg to the ball race, and a ball hole plug fits within the ball hole. The ball hole plug is secured to the leg by a friction stir weld.
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CROSS-REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF INVENTION

[0002] 1. Field of the Invention

[0003] Embodiments disclosed herein relate generally to roller cone drill bits used in wellbore operations. In particular, embodiments disclosed herein relate generally to roller cone drill bits using friction stir welding.

[0004] 2. Background Art

[0005] Historically, there have been two main types of drill bits used drilling earth formations, drag bits and roller cone bits. The term “drag bits” refers to those rotary drill bits with no moving elements. Drag bits include those having cutters attached to the bit body, which predominantly cut the formation by a shearing action. Roller cone bits include one or more roller cones rotatably mounted to the bit body. These roller cones have a plurality of cutting elements attached thereto that crush, gouge, and scrape rock at the bottom of a hole being drilled.

[0006] Roller cone drill bits typically include a main body with a threaded pin formed on the upper end of the main body for connecting to a drill string, and one or more legs extending from the lower end of the main body. Referring to FIG. 1, a conventional roller cone drill bit, generally designated as 10, consists of bit body 11 forming an upper end 12 and a cutter end of roller cones 13 that are supported by legs 14 extending from body 11. Each leg 14 includes a journal 15 extending downwardly and radially inward towards a center line of the bit body 11, with cones 13 mounted thereon. Each of the legs 14 terminate in a shank portion 16. The threaded pin end 12 is adapted for assembly onto a drill string (not shown) for drilling oil wells or the like.

[0007] Conventional roller cone bits are typically constructed from at least three segments. The segments are often forged pieces having an upper body portion and a lower leg portion. The lower leg portion is machined to form the shank section and the journal section. Additionally, lubricant reservoir holes, jet nozzle holes, and ball races are machined into the forgings. Roller cones are rotatably mounted to a bearing system on the formed journals, and the leg segments are positioned together longitudinally with journals and cones directed radially inward to each other. The segments may then be welded together using conventional techniques to form the bit body. Upon welding the bit body, the internal geometry of each leg section forms a center fluid plenum. The center fluid plenum directs drilling fluid from the drill string, out nozzles to cool and clean the bit and wellbore, etc.

[0008] Roller cone bits may use a roller bearing system, a journal bearing system, or a combination of the two to allow rotation of the roller cones about the journal. Each type of bearing system is ordinarily comprised of a number of separate components, including primary bearings, secondary bearings, a seal system, features that resist thrust loading, and a lubrication system. Also typical to both bearing systems are cone retention balls, which are used to prevent roller cones from separating from each other.

[0009] Generally, roller bearing systems use rollers to separate the roller cones from the journal. A cone retention ball bearing is usually provided to carry axial load, and the rollers typically carry radial loads. Journal bearing systems, on the other hand, use a film of lubricant to separate the roller cones from the journal. The inner surfaces of roller cones are specially designed so the film of the lubricant prevents contact between the roller cone and journal. Roller bearings are common in roller cone drill bits, especially in roller cone drill bits with diameters larger than twelve inches, because they can reliably support large loads and generally perform well in the drilling environment. Bits having small diameters commonly use journal bearing systems because there is less space to install suitably sized rollers in a small cone.

[0010] Referring to FIG. 2, a typical ball bearing system is shown within a roller cone drill bit leg. Roller bearings 201 are placed around the journal 202 prior to sliding the journal 202 into the roller cone body 203. Alternate bearing systems may be used to separate the roller cone body 203 from the journal 202, such as floating bearings or a journal bearing system. The journal 202 has a journal race surface 204, and the roller cone body 203 has a roller cone race surface 205, which meets to form a ball race 206. A ball hole 207 extends from the back face 208 of the drill bit leg 209 to the journal race surface 204. A plurality of cone retention balls 210 are then inserted through the ball hole 207 into the ball race 206, to hold the roller cone 203 on the journal 202. Once the balls 210 are in place, a ball hole plug 211 is inserted into the ball hole 207 and welded into place, to prevent the roller cone 203 from slipping off the journal 202.

[0011] To prevent damage to the cone retention balls 210 and edges of the ball hole 207, cutter designs known in the art have the ball hole 207 placed at 180 degrees from the load bearing zone of the journal 202. This placement is selected to prevent forcing the balls 210 against the rough edges of the ball hole 207 as they pass over the hole 207. If the ball hole 207 were positioned in the load bearing zone, the balls 210 would forcibly impact the edges of the ball hole 207, probably resulting in metal chips and debris being removed from the journal 202 so as to contaminate the lubricant and eventually destroy the bearings and seals.

[0012] Contained within the bit body is a grease reservoir system (not shown). A lubricant passage 212 is provided from the reservoir to race surfaces 204, 205 formed between the journal 202 and roller cone body 203, to lubricate race surfaces 204, 205 by a lubricant or grease composition. Lubricant or grease also fills the portion of the ball hole 207. Lubricant or grease is retained in the bearing structure by a resilient seal 213 between the roller cone 203 and journal 202.

[0013] For many applications, roller cone drill bits are limited by the bearing capacity or bearing life of the bit. A contributing cause of bearing failure in roller cone systems is failure of the weld joint between the ball hole plug and the back face of the leg. In addition to providing a secure weld, protection of the weld joint from wear, erosion and corrosion...
is necessary to prevent failure of the plug and/or leg in the plug region, and ultimately, failure of the bit. [0014] Current methods of welding the ball hole plug to the back surface of the bit leg are difficult to implement and may cause flaws in the weld joint. For example, GMAW welding can cause porosity, inclusions, cracks and an area of un-fused material at the weld root, any of which can lead to premature failure by initiating fatigue stresses. Further, in gas or plasma arc welding, heat of the arc weld and molten weld deposit can potentially affect the seal integrity of the weld joint. Additionally, dissimilar chemistry in a deposit weld metal and the leg steel may cause galvanic corrosion in caustic or acidic drilling conditions.

[0015] Another cause of bearing failure in roller cone drill bit systems is spalling, which may occur, for example, when the ball hole plug is not exactly in line with the journal race surface and continuously passing retention balls flake off material from the plug. When the surface spalls, debris contaminates the lubricant which causes rapid wear and damage to the rest of the operable bearing and seal components which eventually results in bearing failure. Accordingly, there exists a continuing need for developments in securing a ball hole plug to a bit leg that may at least provide for increased bearing life.

SUMMARY OF INVENTION

[0016] In one aspect, embodiments disclosed herein relate to a roller cone drill bit including a bit body, at least one leg extending downward from the bit body. Each leg includes a leg back face and a journal and each journal has a journal race surface, a roller cone mounted on each journal, wherein each roller cone includes a roller cone race surface, a ball race configured between the journal race surface and the roller cone race surface, a plurality of retention balls disposed within the ball race, a ball hole extending from the leg back face to the journal race surface, and a ball hole plug. The ball hole plug is secured to the leg by a friction stir weld.

[0017] In another aspect, embodiments disclosed herein relate to a roller cone drill bit including a bit body and at least one leg extending downward from the bit body. Each leg includes a leg back face and a journal and each journal has a journal race surface. A roller cone is mounted on each journal, wherein each roller cone has a roller cone race surface. A ball race is configured between the journal race surface and the roller cone race surface, and a plurality of retention balls is disposed within the ball race. A ball hole extends from the leg back face to the journal race surface, wherein the ball hole is non-cylindrical near the leg back face. A ball hole plug is secured to the leg by a friction stir weld. The ball hole plug includes a plug head, wherein the plug head is non-cylindrical, a plug body, and a ball retainer end.

[0018] In another aspect, embodiments disclosed herein relate to a method for retaining a roller cone on a bit leg, including mounting a roller cone on a journal extending downward from the bit leg, inserting a plurality of retention balls into a ball hole extending through a leg back face to the journal, inserting a ball hole plug into the ball hole, and friction stir welding the ball hole plug to a back face of the bit leg.

[0019] In yet another aspect, embodiments disclosed herein relate to a method for retaining a roller cone on a bit leg, including inserting a plurality of retention balls into a ball hole, inserting a ball hole plug into the ball hole, friction stir welding the ball hole plug to a back face of the bit leg using a friction stirring tool, and removing the friction stirring tool.

[0020] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0021] FIG. 1 is a conventional roller cone drill bit.
[0022] FIG. 2 is a conventional ball bearing system of a roller cone drill bit.
[0023] FIGS. 3A and 3B show a ball hole plug friction stir welded to a bit leg.

DETAILED DESCRIPTION

[0024] Generally, embodiments disclosed herein relate to securing a ball hole plug to a roller cone drill bit leg. In particular, embodiments disclosed herein relate to securing the ball hole plug using friction stirring. Embodiments of the present disclosure related to securing the ball hole plug may also relate to improvements in assembly of the ball hole plug into the ball hole by fitting a shaped plug into a corresponding shaped ball hole prior to friction stirring.

[0025] Friction stirring is a process by which frictional heat plasticizes, mixes, and forges metal, metal alloys, and other materials. Friction stirring uses a combination of rotational and directional motion applied to the surface of an object to be treated. A rotating member is conventionally applied to the surface that is to be friction stirred and is moved in a particular direction until a plasticized state of the material is achieved. The rotating member is moved along the surface to treat the material by changing the material microstructure. Friction stirring includes friction stir processing, friction stir mixing, and friction stir welding (FSW). Friction stir processing is a treatment process, which generally involves engaging two or more previously adjoined materials (i.e., previous weld) to strengthen or improve the weld characteristics. Alternatively, friction stir processing may refer to treating a single material of a workpiece. FSW involves engaging two or more adjoining materials to form a weld.

[0026] In one embodiment of the present disclosure, as shown in FIGS. 3A and 3B, a ball hole plug 311 is friction stir welded to the leg back face 309. A tool used for friction stirring is characterized by a generally cylindrical tool 300 having a shoulder 301 and a pin 302 extending downward from the shoulder. The pin 302 is rotated as force is exerted to urge the pin 302 and a workpiece 330 together. The workpiece 330, in FIG. 3A, includes the ball hole plug 311, the back face of the leg 309, and an interface 360 between the ball hole plug 311 and the leg 309. Frictional heating caused by the interaction between the rotating pin 302 and the workpiece 330 causes the workpiece material to soften without reaching the melting point of the material, which results in plasticization of the workpiece material. Once sufficient heat is generated, the pin 302 is plunged into the workpiece 330 through the interface 360. The tool 300 is then moved along the workpiece 330, plasticizing the workpiece material as it flows around the pin 302. The friction stirring tool 300 is moved along the interface 360 in such a manner that the pin 302 presses into the interface 360 at an orientation that is co-planar with the interface 360 between the two materials. The result is a solid state bond 370 between the ball hole plug 311 and the leg 309. Friction stir welding does not require a solder or filler material to form a bond, but the use of an additional
material is not necessarily outside the scope of the present invention. Additional material may be used, for example, to add corrosion inhibitors, wear resistant material, and other material enhancing properties.

[0027] The resulting solid state bond of a friction stir weld is an inter-metallic atomic bond formed by mechanical deformation. A solid-state bond differs from bonds formed by conventional welding techniques (i.e., welds resulting in a fusion bond or solder or braze bond) in that conventional welding techniques include melting the welding material and then cooling the material to form a bond. The high rates of heating and cooling during conventional welding may result in non-uniformity throughout the microstructure of the welded material, which may create different strain rates and increased stress within the welded material. A solid state bond, on the other hand, does not require the workpiece material to melt. Thus, more uniformity of the microstructure, and better mechanical properties of the welded material may be achieved. For example, a solid state bond may have substantially no metallurgical discontinuities, including minimal or no porosity.

[0028] Referring back to FIGS. 3A and 3B, the ball hole plug 311 comprises a plug head 312, a plug body 313, and a ball retainer end 314. The plug head 312 comprises a top surface 316 and a side surface 317. The plug head top surface 316 is flush with the back face surface of the leg 309, and the plug head side surface 317 fits against the ball hole wall 307, at the opening portion 308 of the ball hole, to create the interface 360 between the ball hole plug 311 and the leg 309. However, the plug head 312 may initially protrude from the back face surface of the leg 309 in order to have a flush surface with the leg back face after friction stirring. The ball retainer end 314 has a concave surface 315 with a radius of curvature that mates with a corresponding radius of curvature of the cone retention balls 310.

[0029] Generally, ball hole plug heads 312 are cylindrical in shape. However, it is within the scope of the present disclosure that the plug head 312 may be cylindrical or non-cylindrical in shape. When the plug head 312 is cylindrical in shape, it may be difficult to orient the ball hole plug 311 in such a manner that the plug retainer end 314 configures exactly to the cone retention balls 310. However, in accordance with various embodiments of the present disclosure, the ball hole 307 is formed in a shape corresponding with a non-cylindrical plug head 312. The corresponding shapes are oriented in a position that secures the retainer end 314 in configuration with the cone retention balls 310 when the plug head 312 is inserted into the ball hole 307.

[0030] Any non-cylindrical shaped plug head and corresponding ball hole is within the scope of the present disclosure, including, for example, an oval-shaped plug head, a plug head with at least one flat side, a triangular-shaped plug head, a rectangular plug head, etc. Additionally, the plug head may be non-symmetrical in shape, such that the plug head has a notch, a protrusion, or other variation from the general shape of the plug head.

[0031] As shown in FIG. 3A, the pin 302 may be plunged to a depth in the workpiece 330 such that part of the interface 360 is friction stir welded. Alternatively, as shown in FIG. 3B, the pin 302 may have sufficient depth so as to friction stir weld the entire height of the ball hole plug head 312. Friction stir welding the workpiece such that the entire plug head 312 is completely consumed may yield a reduced subsurface notch affect at the weld root. A reduced subsurface notch affect may be desirable because the notch affect can promote failure by allowing fatigue crack initiation sites. However, depending on the geometry of the plug head, the entire head may not be consumed. For example, rather than friction stirring the entire plug head 312, only the joint interface 360 around the plug head may be friction stirred. Furthermore, it is within the scope of the present disclosure that the diameter of the pin 302 may be smaller, larger, or equal to the diameter of the plug head 312. Likewise, the shoulder 301 may be smaller, larger, or equal to the diameter of the plug head 312.

[0032] Large forces may be exerted between the pin and the workpiece in order to apply sufficient pressure to the workpiece to cause plasticization of the material. For example, for friction stir welding an aluminum alloy workpiece of 1/4-inch thickness, forces of up to 4000 pounds or more may have to be exerted between the pin and the workpiece. Where the workpieces have sufficient structural strength and rigidity, some of the force may be absorbed by the workpieces themselves.

[0033] Furthermore, FIGS. 3A and 3B show a friction stirring tool 300 positioned at an orientation that is co-planar with the interface 360 between the ball hole plug head 312 and the leg 309. However, in accordance with another embodiment of the present disclosure, the friction stirring tool may be moved along an interface in such a manner that the pin is oriented perpendicular to the interface plane. For example, a layer of wear resistant material may be applied to the outer surface of a drill bit, thereby creating an interface perpendicular to the pin. Depending on the component being friction stirred and its configuration, one skilled in the art would appreciate that either orientation of the tool may be used.

[0034] The ball hole plug and the bit leg may be formed from the same material, or alternatively, they may be formed from dissimilar material. Further, the ball hole plug may be formed from material with a higher yield strength and toughness than the leg material. The ball hole plug and leg may be formed from material selected from, for example, at least one of the following: austenitic steel, carbon steels, low alloy carburizing steel, high alloy carbon steel, and high alloy materials. (High alloy materials include, for example, iron-cobalt-, or nickel-based materials, which may be used for higher strength or improved corrosion resistance. Additionally, the ball hole plug material may be subjected to different processing conditions than the leg material. For example, the ball hole plug material may be annealed or heat treated to have the same hardness as the leg material.

[0035] Furthermore, additional material may be added to the friction stirring process, so as to control mechanical properties of the resulting workpiece material, including one or more of the following unique properties: improved corrosion resistance, higher toughness or equivalent toughness, higher hardness, fatigue resistance, crack resistance, minimal or no significant heat affected zone, and higher yield strength and wear resistance than the base material used in a drill bit. In one embodiment of the present disclosure, an additive material is friction stirred into the roller cone drill bit leg, including over the ball hole plug weld to increase wear resistance. For example, an additive material may be applied by conventional methods to hardface the outer surface of a drill bit. The hardfacing may then be treated using the friction stirring methods disclosed herein, depending on the desired material properties for the particular application, such as hardness, toughness, casing-friendly wear resistance, etc.

[0036] Additive material may include, for example, metal matrix composites, ferrous alloys such as steel and stainless steel, non-ferrous materials such as aluminum, aluminum alloys, and titanium, super alloys such as nickel, iron-nickel, and cobalt-based alloys generally suitable for use at temperatures above 1,000 degrees Fahrenheit, and nit hardend steels. These materials may be described as "high melting tempera-
ture compounds,” or compounds having a melting temperature greater than steel. Additional elements in the types of materials that may be friction stirred include, but are not limited to, diamond, tungsten carbide, chromium, molybdenum, manganese, silicon, carbon, boron, tungsten, aluminum, titanium, niobium, tantalum, vanadium, nickel, cobalt, zirconium, phosphorus, and rhenium.

[0037] Additive materials may be applied to the back face of a drill bit leg, including over the ball hole plug weld by any means known in the art, as described in U.S. patent application Ser. No. ______ (Attorney Docket Number 05516/446001), which is filed concurrently herewith and is incorporated by reference in its entirety. For example, additive material may be applied as hard particles, as a tape, or as a plate to the leg base material prior to friction stirring. Methods of application include: thermal spraying, plasma spraying, using adhesives to bind the friction stirring material to the base material, entrenching a packed powder into the surface of the base material, sandwiching a first friction stirring material between the base material and a second friction stirring material, etc.

[0038] Alternatively, the additive material may have been welded to a base material using a variety of conventional techniques, such as GMAW (gas metal arc welding), GTAW (gas tungsten arc welding), PTA (plasma transferred arc), FCAW (flux cored arc welding), etc. Due to the phase transformations (to liquid state, then cooled to a solid state) that occur during such conventional techniques, the microstructure can possess undesirable characteristics, such as precipitation of unwanted phases or structures, grain growth, and residual stresses. Thus, one or more thermal treatments may have been performed on the welded material (including pre-and/or post-hear treatments) to relieve some of those residual stresses and minimize cracking. In accordance with embodiments of the present disclosure, the additive material may subsequently be friction stir processed to achieve an improved fine-grained microstructure (with improved material properties).

[0039] In one embodiment of the present disclosure, a plate may be friction stir welded to the back surface of a drill bit leg and cover the ball hole. The plate may comprise nickel or stainless steel alloys, high strength steel alloys, or any air hardenable steel, including D2 and A2 steel, or alloy steels such as 4815, 9313, and 8720 steels. In such an embodiment, the ball hole plug may be welded (by conventional means or by friction stir welding) to the leg prior to friction stir welding the plate to the leg, or alternatively, the ball hole plug and the plate may be friction stir welded to the leg during a single friction stirring process. However, while the leg may be friction stirred prior to or after assembly of the drill bit, the ball hole plug must be welded before the drill bit, in particular the multiple leg forgings, is assembled. Thus, if a plate is to be friction stir welded after assembly of the drill bit, the ball hole plug must have been welded to the leg prior to welding the plate to the leg.

[0040] Friction stir welding typically leaves lower asperity heights and results in a smoother finish than conventional welding techniques. However, a friction stirrered surface may have a depressed surface height, i.e., a keyhole, at the location where the friction stirring tool was removed from the workpiece. Depending on the application of the workpiece being friction stirred, a keyhole may be left in the workpiece, the keyhole may be filled, or the keyhole may be diminished by certain tool removal processes. In one embodiment of the present disclosure, a keyhole is left in the ball hole plug material upon removal of the friction stirring tool. In another embodiment of the present disclosure, a gradual removal process is used to minimize the occurrence of a keyhole at the point of exit. The gradual removal process includes: beginning the removal of the friction stirring tool at an initial location in the workpiece; gradually pulling the friction stirring tool out of the workpiece as the tool is moved a distance away from the initial removal location; and finally, completely removing the friction stirring tool at a distance from the initial position. The removal process may also be aided by use of a secondary, sacrificial material onto which the friction stirring tool may be pulled, to minimize the effect of the tool removal on the leg.

[0041] Using the friction stir treatment methods of the present disclosure, the solid-state processing principles associated with friction stirring, may likely reduce the microstructure defects present in the original weld or deposit, reducing the incidence of cracking. By reducing the incidence of cracking, the need for additional heat processing treatments, such as pre- and/or post-heat treatments may be eliminated. Moreover, the processing technique may be less hazardous, which may also allow for friction stirring at any given location, including at the rig site, allowing for better rebuild service. Another byproduct of the friction stirring techniques of the present disclosure may be a reduction in the surface roughness, i.e., reduced asperity heights, as compared to a conventional weld. Lower asperity heights result in a smoother finish, which reduces an apparent need for surface finishing or grinding.

[0042] In addition to the above mentioned benefits of friction stirring over conventional welding techniques, a greater hardness of the friction stirrered material may be achieved without losing toughness. Specifically, friction stirring results in materials having a refined grain microstructure. Refined grain microstructures provide the friction stirred material with both increased toughness and increased strength, as well as increased corrosion resistance, and other favorable material characteristics. Conventional welding, on the other hand, generally results in materials having an inverse relationship between strength and toughness (toughness decreases as strength is increased).

[0043] Increased hardness depends on the material composition and type of material being friction stirred. The bit leg material is generally made of low alloy carburizing steels, such as 4815, 8720, 4718, and 9313. However, other materials, such as 4130, 4145, and other alloy steels, may be used as bit leg material. Friction stirring 4815 steel that has been heat treated to have a hardness of 36-40 HRC may yield a hardness increase of 5-10 HRC. However, friction stirring 4140 steel or 4130 steel, for example, may result in an increased hardness of 20 HRC or more. Such improved hardness may result from the change in the material microstructure (i.e., through grain refinement/recrystallization to produce fine precipitates such as carbides). Further, friction stir welding a ball hole plug to a bit leg may result in the weld strength being higher than the strength of the parent material (the original material being friction stirrered).

[0044] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

What is claimed:
1. A roller cone drill bit, comprising:
   a bit body;
   at least one leg extending downward from the bit body, wherein each leg comprises a leg back face and a journal and each journal has a journal race surface;
a roller cone mounted on each journal, wherein each roller cone has a roller cone race surface; a ball race configured between the journal race surface and the roller cone race surface; a plurality of retention balls disposed within the ball race; a ball hole extending from the leg back face to the journal race surface; and a ball hole plug, wherein the ball hole plug is secured to the leg by a friction stir weld.

2. The roller cone drill bit of claim 1, wherein the ball hole plug is welded directly to the leg back face without a filler material.

3. The roller cone drill bit of claim 1, wherein the ball hole plug material is the same as the leg material.

4. The roller cone drill bit of claim 1, wherein the ball hole plug comprises a material selected from at least one of austenitic stainless steel, high alloy carbon steel, and nickel and cobalt based alloys.

5. The roller cone drill bit of claim 3, wherein the high alloy materials are nickel based materials.

6. The roller cone drill bit of claim 1, wherein the ball hole plug comprises the same material as the leg.

7. The roller cone drill bit of claim 1, wherein the ball hole plug comprises a different material from the leg.

8. The roller cone drill bit of claim 7, wherein the ball hole plug comprises material with a higher yield strength and higher toughness than the leg.

9. The roller cone drill bit of claim 1, wherein the ball hole plug is heat treated.

10. The roller cone drill bit of claim 1, further comprising a keyhole in the friction stir weld.

11. The roller cone drill bit of claim 1, wherein no keyhole remains in the friction stir weld.

12. The roller cone drill bit of claim 1, wherein the ball hole plug comprises:

   a plug head, wherein the plug head comprises a top surface and a side surface;
   a plug body; and
   a ball retainer end.

13. The roller cone drill bit of claim 12, wherein the top surface of the plug head is flush with the leg back face.

14. The roller cone drill bit of claim 12, wherein the friction stir weld extends down the entire side surface of the plug head.

15. The roller cone drill bit of claim 12, wherein the friction stir weld extends down to a depth of the side surface.

16. The roller cone drill bit of claim 12, wherein the plug head is non-cylindrical.

17. The roller cone drill bit of claim 16, wherein the ball hole is non-cylindrical at the opening to the leg back face.

18. A roller cone drill bit, comprising:

   a bit body;
   at least one leg extending downward from the bit body, wherein each leg comprises a leg back face and a journal and each journal has a journal race surface;
   a roller cone mounted on each journal, wherein each roller cone has a roller cone race surface;
   a ball race configured between the journal race surface and the roller cone race surface;
   a plurality of retention balls disposed within the ball race;
   a ball hole extending from the leg back face to the journal race surface, wherein the ball hole is non-cylindrical near the leg back face; and
   a ball hole plug, wherein the ball hole plug is secured to the leg by a friction stir weld.

19. The roller cone drill bit of claim 19, wherein the ball retainer end has a mating curve with the same radius of curvature as the race.

20. A method for retaining a roller cone on a bit leg, comprising:

  mounting a roller cone on a journal extending downward from the bit leg;
   inserting a plurality of retention balls into a ball hole extending through a leg back face to the journal;
   inserting a ball hole plug into the ball hole; and
   friction stir welding the ball hole plug to the back face of the bit leg.

21. The method of claim 21, further comprising providing an additive material and friction stir mixing the additive material into the bit leg.

22. The method of claim 21, further comprising covering the ball hole plug with a plate prior to friction stir welding, wherein the friction stir welding welds the ball hole plug, the plate, and the bit leg together.

23. The method of claim 23, wherein the ball hole plug is friction stir welded to the bit leg prior to friction stir welding the plate.

24. The method of claim 21, wherein the ball hole plug comprises a non-cylindrical head and the ball hole is non-cylindrical near the back face of the bit leg.

25. The method of claim 21, further comprising welding a plurality of bit legs together.

26. A method for retaining a roller cone on a bit leg, comprising:

   inserting a plurality of retention balls into a ball hole;
   inserting a ball hole plug into the ball hole;
   friction stir welding the ball hole plug to a back face of the bit leg using a friction stirring tool; and
   removing the friction stirring tool.

27. The method of claim 27, further comprising removing the friction stirring tool at an initial removal location.

28. The method of claim 27, further comprising removing the friction stirring tool by a gradual removal process, wherein the gradual removal process comprises:

   beginning the removal of the friction stirring tool at an initial removal location;
   gradually removing the friction stirring tool as the friction stirring tool is moved a distance away from the initial removal location; and
   completely removing the friction stirring tool at a distance from the initial removal location.

29. The method of claim 27, wherein removing the friction stirring tool comprises pulling the friction stirring tool onto a sacrificial material.