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(54) **DRILL BIT HAVING INCREASED RESISTANCE TO FATIGUE CRACKING AND METHOD OF PRODUCING SAME**

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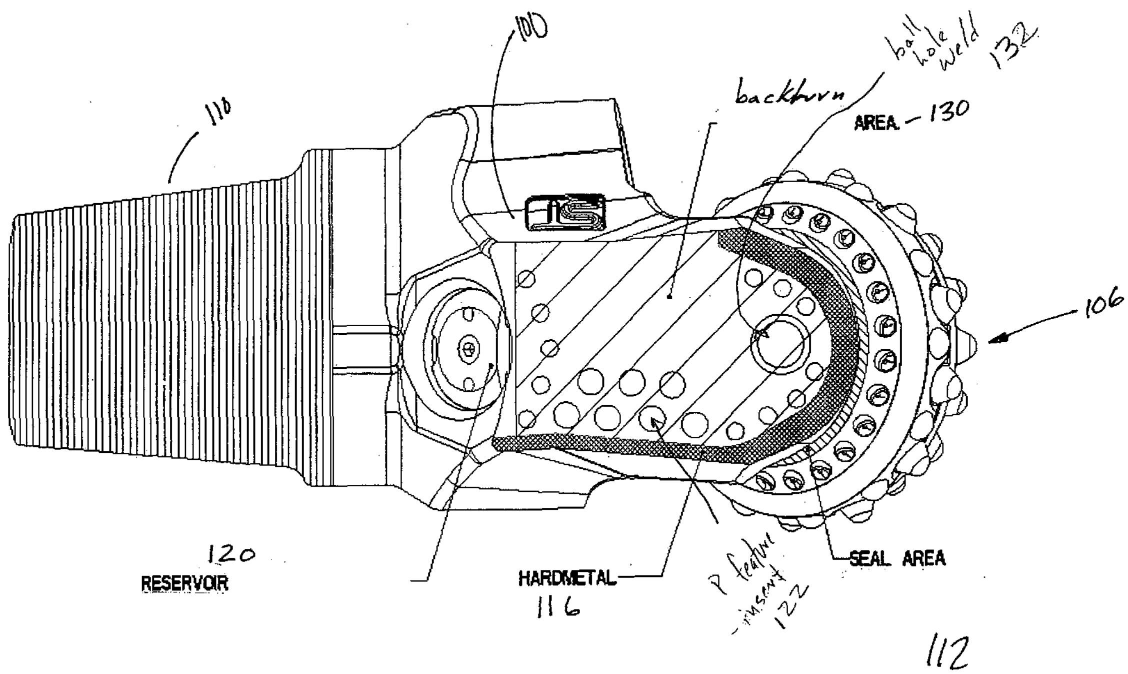
(57) **ABSTRACT**

The present invention relates to a roller cone drill bit that includes a bit body adapted to be rotated about a longitudinal axis, where the bit body has at least one leg depending therefrom, wherein the leg comprises a treated portion that provides a residual compressive stress, and a roller cone rotatably mounted on a journal. The treated portion treatment may comprise one selected from shot peening, laser-shock peening, and hammer peening. Further, the present invention relates to a method of manufacturing a roller cone drill bit that includes inducing a compressive stress, through plastic deformation, in at least a portion of at least one leg depending from a bit body. The inducing a compressive stress may comprise one selected from shot peening, laser-shock peening, and hammer peening.



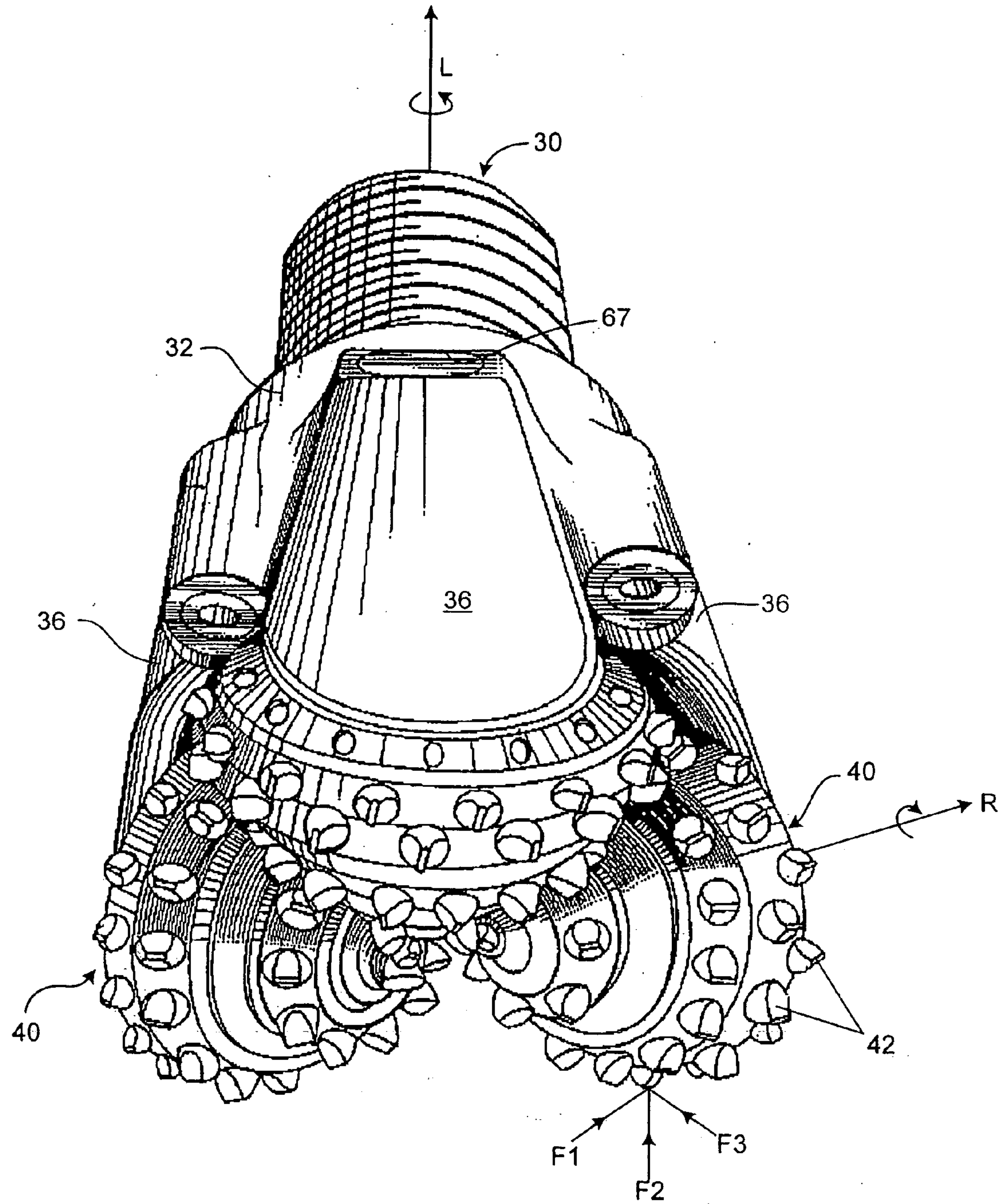


FIG. 1 (Prior Art)

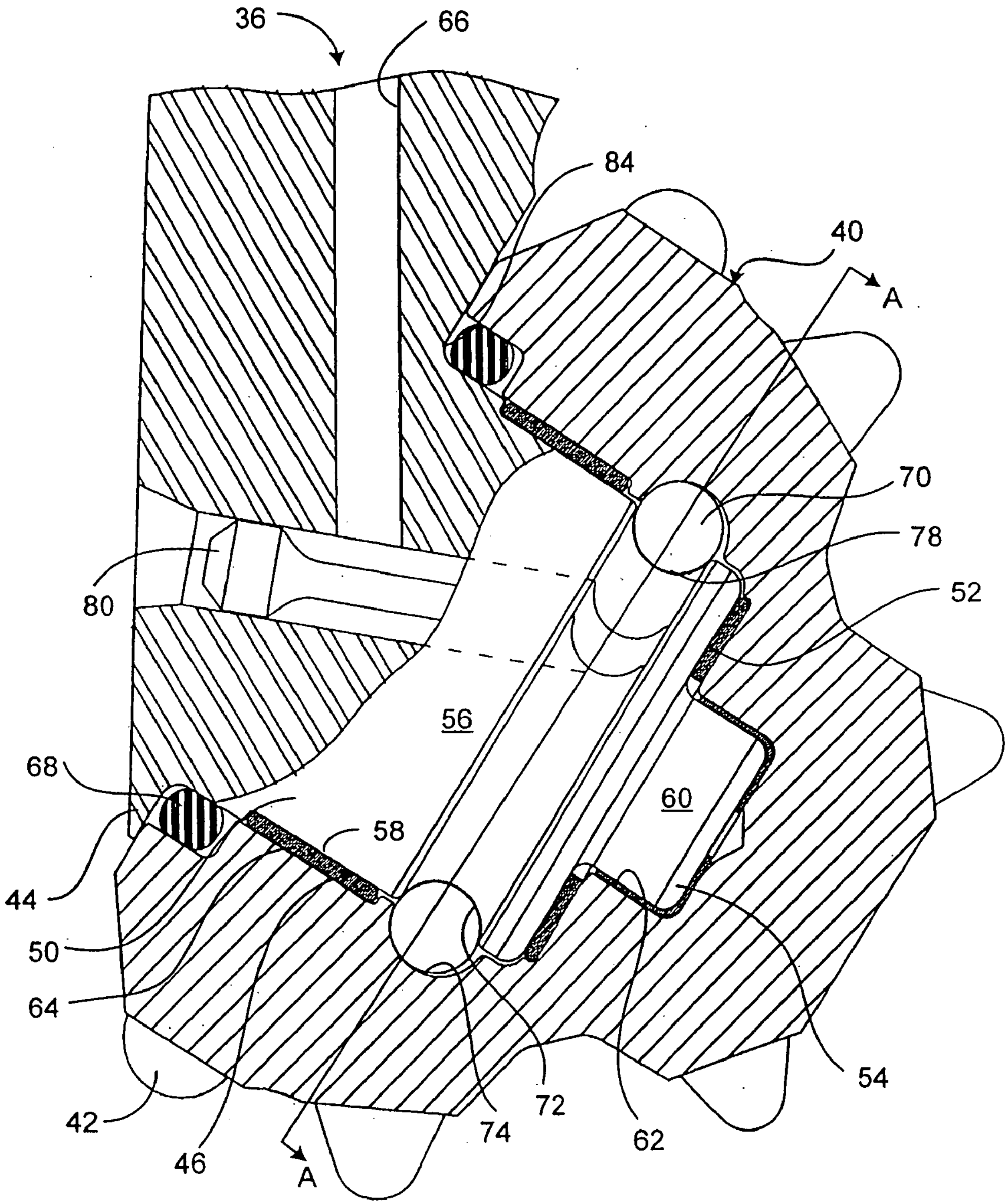


FIG. ~~1~~2 (Prior Art)

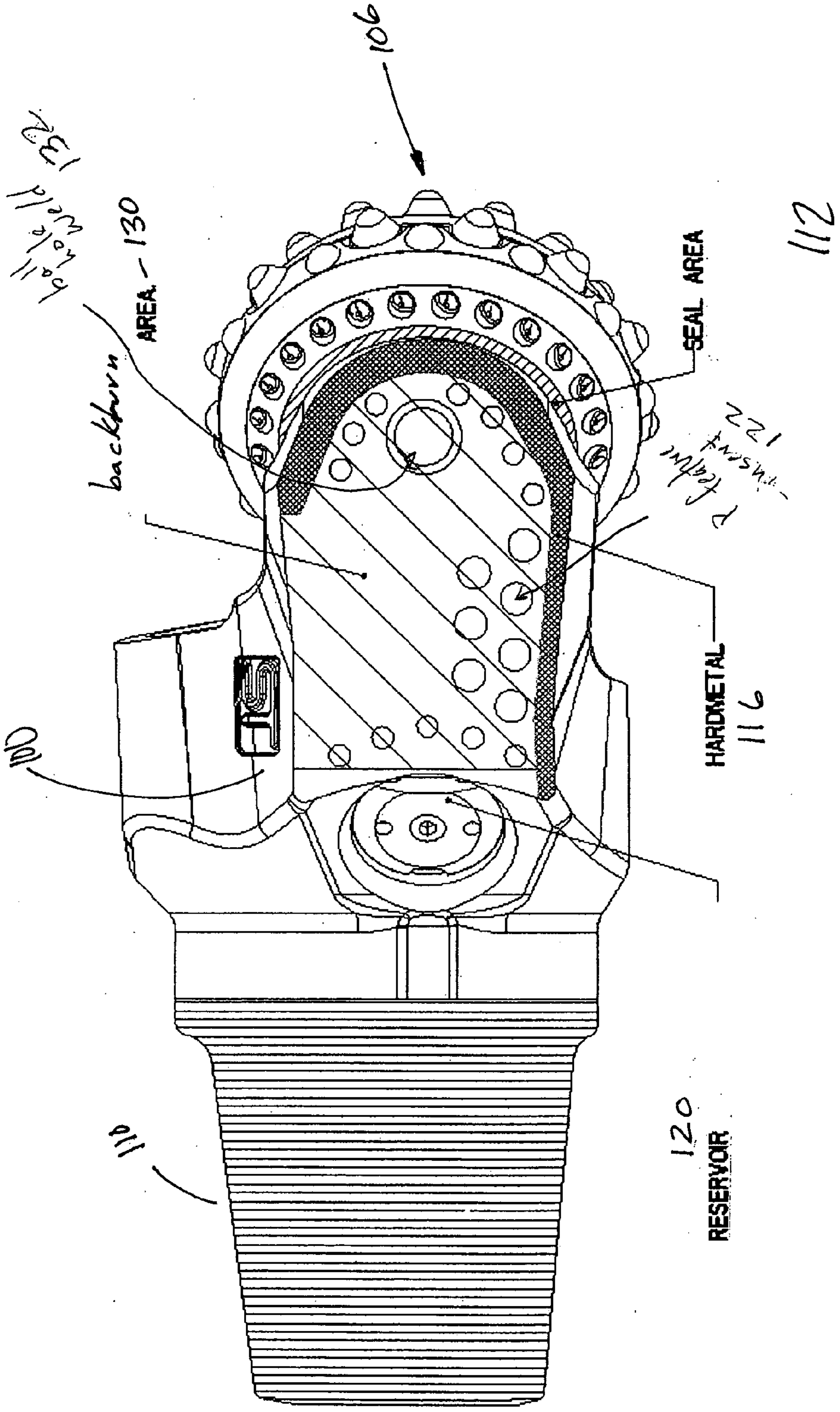

106
132
ball hole weld
AREA – 130
SEAL AREA
112
backturn
P feature insert
122
HARDMETAL
116
100
110
120
RESERVOIR

Figure 3A

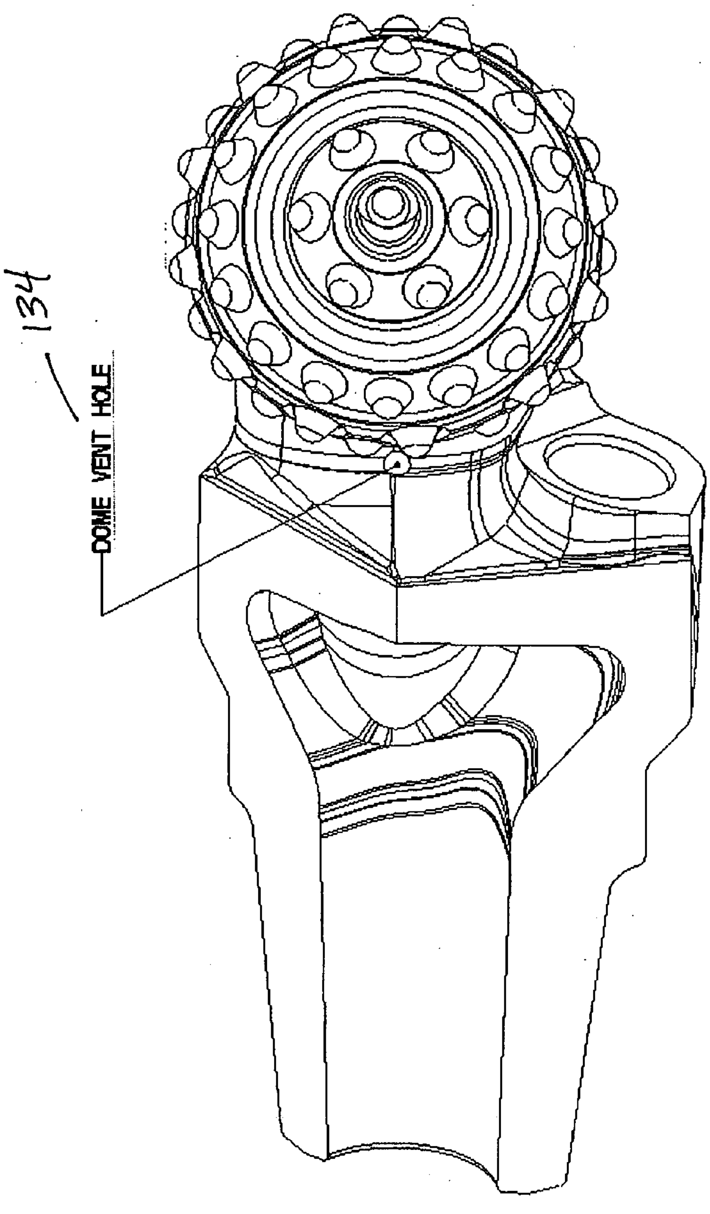


Figure 3B

DRILL BIT HAVING INCREASED RESISTANCE TO FATIGUE CRACKING AND METHOD OF PRODUCING SAME

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The invention is related generally to the field of roller cone drill bits. More particularly, the invention is related to methods for increasing the durability of a roller cone bit.

[0003] 2. Background Art

[0004] Drill bits used to drill wellbores through earth formations generally fall within one of two broad categories of bit structures. Shear cutter bits are configured with a multitude of cutting elements directly fixed to the bottom, also called the face, of the drill bit. The shear bit has no moving parts, and its cutters scrape or shear rock formation through the rotation of the drill bit by an attached drill string. Shear cutter bits have the advantage that the cutter is continuously in contact with the formation and see a relatively uniform loading when cutting the gage formation.

[0005] Furthermore, the shear cutter is generally loaded in only one direction. This significantly simplifies the design of the shear cutter and improves its robustness. However, although shear bits have been found to drill effectively in softer formations, as the hardness of the formation increases, it has been found that the cutting elements on the shear cutter bits tend to wear and fail, affecting the rate of penetration (ROP) for the shear cutter bit.

[0006] In contrast, roller cone rock bits are better suited to drill through harder formations. Roller cone rock bits are typically configured with three rotatable cones that are individually mounted to separate legs. The three legs are welded together to form the rock bit body. Each rotatable cone has multiple cutting elements such as hardened inserts or milled inserts (also called "teeth") on its periphery that penetrate and crush the formation from the hole bottom and side walls as the entire drill bit is rotated by an attached drill string, and as each rotatable cone rotates around an attached journal. Thus, because a roller cone rock bit combines rotational forces from the cones rotating on their journals, in addition to the drill bit rotating from an attached drill string, the drilling action downhole is from a crushing force, rather than a shearing force. As a result, the roller cone rock bit generally has a longer life and a higher rate of penetration through hard formations.

[0007] **FIG. 1** depicts a roller cone drill bit **30** which comprises a bit body **32** that is adapted to rotate about a longitudinal axis L. Three legs **36** extend downwardly from the bit body **32**. The legs **36** are spaced 120 degrees apart along the circumference of the bit body **32**. The upper end of the bit body **32** includes a threaded pin **38** which can be coupled to another tool, usually a drill string (not shown). A roller cone **40** is rotatably coupled to each leg **36**. The roller cones **40** have cutting elements **42** which deform earth formation as the drill bit **30** is rotated about the longitudinal axis L. Although the drill bit **30** is shown as having three legs **36**, those of ordinary skill will appreciate that other numbers of legs may also be used.

[0008] **FIG. 2** shows a partial cross section of one of the legs **36** shown in **FIG. 1**. The leg **36** terminates in a shirttail portion **44**. A bearing pin **46** extends from the shirttail portion **44**. The bearing pin **46** includes a journal **50**, an axial thrust face **52**, and a nose pin **54**. The journal **50** forms a main bearing surface **56** for the roller cone **40**. The roller cone **40** has a bearing surface **58** which provides a bearing for the main bearing surface **56**. The nose **54** forms a bearing surface **60** which is retained within a complementary surface **62** within the roller cone **40**.

[0009] Lubricant is fed between the bearing surfaces **56** and **58** through one or more lubrication ports (not shown) in the journal **50** to minimize friction between the bearing surfaces. Friction between the bearing surfaces **56** and **58** may also be minimized by placing a low-friction bearing material, such as a low-friction pad **64**, a roller bearing (not shown), a ball bearing (not shown), or other type of anti-friction bearing between the bearing surfaces. The lubrication ports (not shown) in the journal **50** communicate with a lubrication passage **66**, which is connected to receive lubricant from a grease reservoir **67** (shown in **FIG. 1**) in the upper part of the leg **36**. A seal **68** is provided to retain the lubricant between the bearing surfaces **56** and **58**.

[0010] A number of different forces can result in early failure of roller cone bits. In particular, much attention has been paid to the stresses that are applied to the inserts and the cones during typical drilling operations. These stresses tend to be very high and are cyclical. The cyclical nature of the stress results from the fact that each cutting element is only in contact with rock being drilled for a portion of the time when the drill bit is being rotated. As a result, it is common for the cone to crack within some of the sockets. Cracking in one or more of the sockets can result in loss of the inserts pressed into the sockets that undergo cracking, or can result in total cone failure.

[0011] Various methods have been developed to adjust the distribution of stresses in roller cones with the objective of reducing cracking and insert loss. For example, U.S. Pat. No. 4,181,187 issued to Lumen describes cutting stress relief grooves in the bottom of the sockets. U.S. Pat. No. 3,970,158 issued to Black describes placing a compressible (malleable) material at the bottom of the sockets to absorb some of the cyclic stress applied to the inserts. The malleable material extrudes against the sides of the socket to reduce the incidence of cracking.

[0012] In addition, U.S. Pat. No. 6,598,689 discloses treating the interior surface of a socket to provide a residual compressive stress near that portion of the socket. In one embodiment, that patent discloses providing residual compressive stress inside an interior surface of the socket by a shot peening process.

[0013] However, while various improvements have been made in reducing the failure rate on the cones, as described in the above patents, less attention has been paid to the other surfaces of the bit. In particular, the legs are subject to tensile stresses which lead to cracks in the surface, potentially resulting in breakage and failure of the bit. In particular, a portion of backturn surface of the leg has a low section modulus, which leads to a high failure rate.

[0014] What is still needed, therefore, are techniques and bits that have improved durability and fatigue resistance.

SUMMARY OF INVENTION

[0015] In one aspect, the present invention relates to a roller cone drill bit that includes a bit body adapted to be rotated about a longitudinal axis, where the bit body has at least one leg depending therefrom, wherein the leg comprises a treated portion that provides a residual compressive stress, and a roller cone rotatably mounted on a journal. The treated portion treatment may comprise one selected from shot peening, laser-shock peening, and hammer peening

[0016] In one aspect, the present invention relates to a method of manufacturing a roller cone drill bit that includes inducing a compressive stress, through plastic deformation, in at least a portion of at least one leg depending from a bit body. The inducing a compressive stress may comprise one selected from shot peening, laser-shock peening, and hammer peening.

[0017] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0018] **FIG. 1** shows a prior art roller cone drill bit;

[0019] **FIG. 2** shows a cross-section of one leg of the prior art drill bit of **FIG. 1**;

[0020] **FIG. 3*a*** shows an outside view of a leg illustrating a back turn area treated in accordance with one embodiment of the present invention; and

[0021] **FIG. 3*b*** shows an inside view of a leg illustrating a back turn area treated in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

[0022] In one aspect, the present invention relates to a method for improving the durability of a roller cone bit. In another aspect, the present invention relates to a drill bit having improved durability when compared to prior art bit. In particular, the methods and bits of the present invention comprise treating at least a portion of a roller cone bit leg surface.

[0023] In one embodiment, the treating comprises inducing a residual compressive stress in a backturned surface of at least one roller cone drill bit leg. In one specific embodiment, inducing the residual stress comprises applying a shot peening process to the selected area (i.e., at least a portion of the leg backturn area). As those having ordinary skill in the art are aware, shot peening is a cold working process in which the surface of a part is bombarded with small spherical media called shot. Shot-peening is a controlled cold work process in which the surface of a part is bombarded with controlled impingement of a stream of high velocity shot, causing plastic deformation on part surface and resulting in the surface being compressively stressed.

[0024] Each piece of shot striking the surface acts as a tiny peening hammer, which imparts a small indentation or dimple on the surface. Below the surface, the compressed grains try to restore to its original shape, which produces a hemisphere of cold-worked material, that is stressed in compression. By providing compressive stress, cracks are less likely to be initiated or to propagate. As a result, by inducing a compressive stress on at least a portion of at least one leg, the present invention reduces the likelihood that cracks will occur on the surface of a rock bit leg.

[0025] Turning to specific embodiments, the present inventors have discovered that the leg backtum area, as shown in the Figures below, is an area that is subject to high tensile stress during drilling operations and, therefore, is more prone to leg breakage, especially when stress risers in the area such as P-features, ballhole weld and hardfacing interfaces, etc. are present. In addition, the corrosive environment in which the drill bits operate, due to the presence of O_2, CO_2, and H_2S gases, for example, can cause corrosion of the legs, which also may lead to early failure. In addition, the drilling fluids (especially alkaline fluids) used in drilling operations can cause corrosion of the bit legs.

[0026] The present inventors have further discovered that inducing compressive stress is effective in retarding, and in many cases, preventing corrosion, e.g. pitting corrosion, stress corrosion cracking and corrosion fatigue. Moreover, the present inventors have discovered that inducing a compressive stress may improve other aspects of performance, for example improving resistance to thermal fatigue, axial fatigue, bending fatigue, and torsional fatigue. Also, an induced compressive stress may provide improved performance in the regions affected by welding, carburization, or other physical changes on the leg.

[0027] **FIG. 3*a*** illustrates a first embodiment of the present invention. In **FIG. 3*a***, an outside view of a single leg **100** of a roller cone bit (not separately numbered) is shown. A roller cone **106** is rotatably coupled to the leg **100**. A backturn area **130** is disposed between the roller cone **106** and a threaded end **110** of the roller cone bit. In addition, **FIG. 3*a*** shows that a portion of the leg **116** has been covered by hardfacing. The application of hardfacing **116** causes additional stress on the leg **100**. In addition, **FIG. 3*a*** shows p features **122** disposed on the leg **100**. The "p features" comprise inserts that are pressed in to give additional wear resistance to the leg backface. Also shown in **FIG. 3*a*** is ballhole weld **132** which is the point at which the cone is locked to the leg **100**. In this embodiment, at least a portion of the backtum area **130** has an induced compressive stress ("treated portion"). As the term is used herein, "treated portion" refers to an area that has been plastically deformed to create a surface compressive state.

[0028] In one embodiment, the compressive stress is induced by shot peening a select portion of the backtum area **130**. The select portion of the backturn area **130** may be the entire region, or may be significantly less than all of the backtum area **130**. However, in certain embodiments the region adjacent to the hardfacing **116** is treated in order to increase the resistance of the leg **100** to fatigue cracking.

[0029] Further, in certain embodiments, reservoir **120** and seal area **112** are protected, by means known in the art, such as by masking off with a selected area with industrial (heavy-duty) masking tape, from the shot peening process (or other treatment methods, as noted below). Another suitable means for protecting an area may be a plastic covering, or plug. Those having ordinary skill will appreciated that other types of protection may be used. The reservoir **120** and the seal area **112** can be damaged by the treatment process, if care is not taken to protect those regions. Similarly, as shown in **FIG. 3*b***, dome vent hole **134** should be protected from the treatment process, in order to avoid damaging the dome vent hole **134**.

[0030] In an embodiment of the invention using shot peening, a rain of metallic shot impinges at high speed, on the backturned surface of a rock bit leg. Those having ordinary skill will recognize that ceramic, glass, or other suitable types of shot may be used. The plastically deformed portion extends inwards from several thousandths of an inch to a few hundredths. The specific amount of cold working (i.e., the imparted compressive strength) depends principally on the plastic work done by the pellets, which in turn is dependent on the size and speed of the pellets and the total number of impacts. For different materials and locations, there are different combinations of shot size, speed, duration, which may be varied depending on the particular application.

[**0031**] Coverage is defined as the extent (in percept) of uniform and complete dimpling or obliteration of the original surface of the part or work piece. Inspection of percent coverage can be accomplished using a ten power (10×) magnifying glass. In one embodiment, the treated portion has 100 percent coverage. 100 percent coverage is reached when the original surface of the material is obliterated entirely by overlapping peening dimples.

[**0032**] Calibration of the impact energy or peening intensity of the shot stream is essential to controlled shot peening. The energy of shot stream is a function of the media size, material, hardness, velocity and impingement angle. In order to specify, measure and calibrate peening impact energy, J. O. Almen of General Motors Research Lab developed a method utilizing SAE 1070 spring steel specimens which he called Almen strips. In his method, an unpeened Almen strip is fastened to a steel block and exposed to a stream of peening shot for a given period of time. Upon removal from the block, the residual compressive stress and surface plastic deformation produced by the peening impacts will have caused the Almen strip to curve convexly on the peened surface. The height of this curvature when measured in a standard Almen gauge is called arc height. There are 3 standard Almen strips currently in use: "A" strip 0.051" thick, "C" strip 0.094" thick and "N" strip 0.031" thick. Intensity designations should include both arc height and the type of Almen strip used: e.g. 9C intensity=0.009" arc height on the "C" strip.

[**0033**] In a preferred embodiment, the shot peening operation is performed in accordance with AMS-S-13165 using a shot peening machine, such as specified by AMS S-13165. Further, in certain embodiments, a shot size that is used is specified as "cast steel shot **460**" which has hardness at 45-52 Rc and shot size between 10-18 (0.0787" and 0.0394") mesh per AMS S-13165. Additionally, in one embodiment, the treated region has 100 percent coverage. In one embodiment, the shot-peening intensity is between 0.007" and 0.009", or between 7 and 9 C. Those having ordinary skill will recognize that these standards for shot peening are publicly available, and that other methods of shot peening may be used. Moreover, those having ordinary skill in the art will appreciate that shot peening is only one method to induce a residual compressive strength and that other methods may be used that do not depart from the scope of the present invention.

[**0034**] Those having ordinary skill in the art will realize that the above considerations are merely examples, and that no limitation on the scope of the invention is intended thereby. Depending on the material to be treated, the thickness of the material, the coverage required, and other known considerations, a wide range of methods, shot sizes, and shot material may be used in order to induce the compressive stress.

[**0035**] Although various embodiments of this aspect of the invention are described in terms of shot peening the backturned surface of at least one roller cone leg, it should be understood that any treatment which provides a residual compressive stress on the backturned surface of at least one roller cone leg can also be used in accordance with this aspect of the invention. Two such treatment methods are hammer peening and laser peening. Laser peening and hammer peening are known in the art for providing residual compressive stress in materials. In some embodiments, the hammer peening and laser peening may be performed over the same portions of the backturned surface of at least one roller cone leg as described for shot peening.

[**0036**] Two bits that have been treated according to embodiments of the invention on two of the three legs were field tested. Both bits had severe cracks on the untreated legs, while the treated legs did not develop any significant cracks.

[**0037**] Advantageously, embodiments of the present invention induce compressive residual stresses in roller cone legs, which offset tensile stresses caused by drilling operations and, therefore, provide increases in bit life. In addition, embodiments of the present invention may be effective in retarding, and in many cases, preventing corrosion, e.g. pitting corrosion, stress corrosion cracking and corrosion fatigue.

[**0038**] 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 is:

1. A roller cone drill bit comprising:

a bit body adapted to be rotated about a longitudinal axis, the bit body having at least one leg depending therefrom, wherein the at least one leg comprises a treated portion that provides a residual compressive stress; and

a roller cone rotatably mounted on a journal.

2. The roller cone drill bit of claim 1, wherein a treated portion of the at least one leg comprises a leg backtum face.

3. The roller cone drill bit of claim 1, wherein the treated portion is a plastically deformed area.

4. The roller cone drill bit of claim 3, wherein the plastically deformed area extends inward about 0.035 inch.

5. The roller cone drill bit of claim 1, wherein the treated portion treatment comprises one selected from shot peening, laser-shock peening, and hammer peening.

6. The roller cone drill bit of claim 5, wherein the peening provides 100 percent coverage.

7. The roller cone drill bit of claim 1, further comprising a hardface coating disposed on a region adjacent the treated portion.

8. The roller cone drill bit of claim 2, wherein the treated portion of the leg backturn face of the at least one leg comprises p-features.

9. The roller cone drill bit of claim 8, wherein the p-features comprise inserts.

10. A method of manufacturing a roller cone drill bit comprising:

inducing a compressive stress, through plastic deformation, in at least a portion of at least one leg depending from a bit body.

11. The method of claim 10, wherein the portion comprises a leg backturn surface.

12. The method of claim 10, wherein inducing a compressive stress comprises one selected from shot peening, laser-shock peening, and hammer peening.

13. The method of claim 10, further comprising applying a hardface coating to a region adjacent the treated portion.

14. The method of claim 12, wherein the shot peening comprises shot having a hardness between 45 and 52 Rc.

15. The method of claim 12, wherein the shot peening comprises shot having a size between 10 and 18 mesh.

16. The method of claim 10, wherein the shot peening provides 100 percent coverage.

17. The method of claim 10, wherein the shot peening has a peening intensity between 7 and 9 C.

18. The method of claim 10, wherein the inducing a compressive stress is performed on at least one portion of at least one leg with p-features.

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