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(54) **PERCUSSION DRILL BIT WITH V-SHAPED SPLINES**

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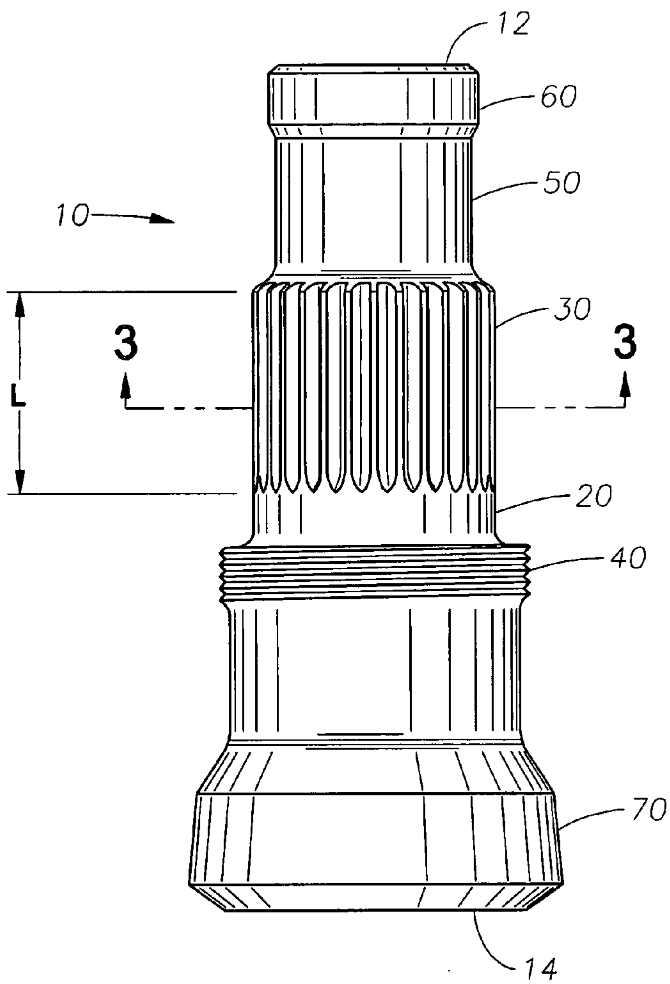
(57) **ABSTRACT**

A drill bit is disclosed for use in a percussion drilling apparatus of the type for boring into the earth. Embodiments of the drill bit comprise an elongate body with a first end, a second end, and a longitudinal surface extending between the first and second ends. Embodiments further comprise a plurality of splines on the longitudinal surface of the drill bit, with at least one of the plurality of splines comprising an apex, a root, and a planar surface between the apex and root. In preferred embodiments, the planar surface is oriented at an angle between 10 and 45 degrees to a plane extending from a center of the drill bit to a midpoint of the apex.



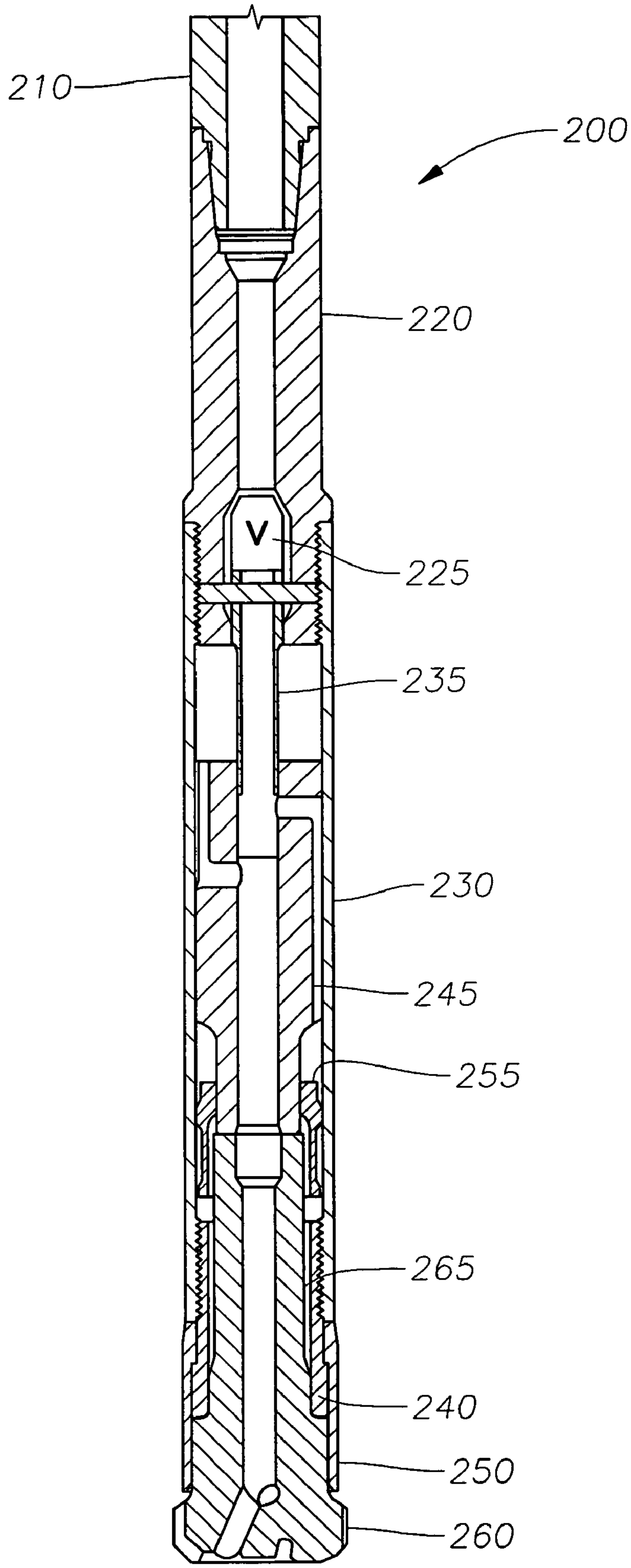


Fig. 1
(Prior Art)

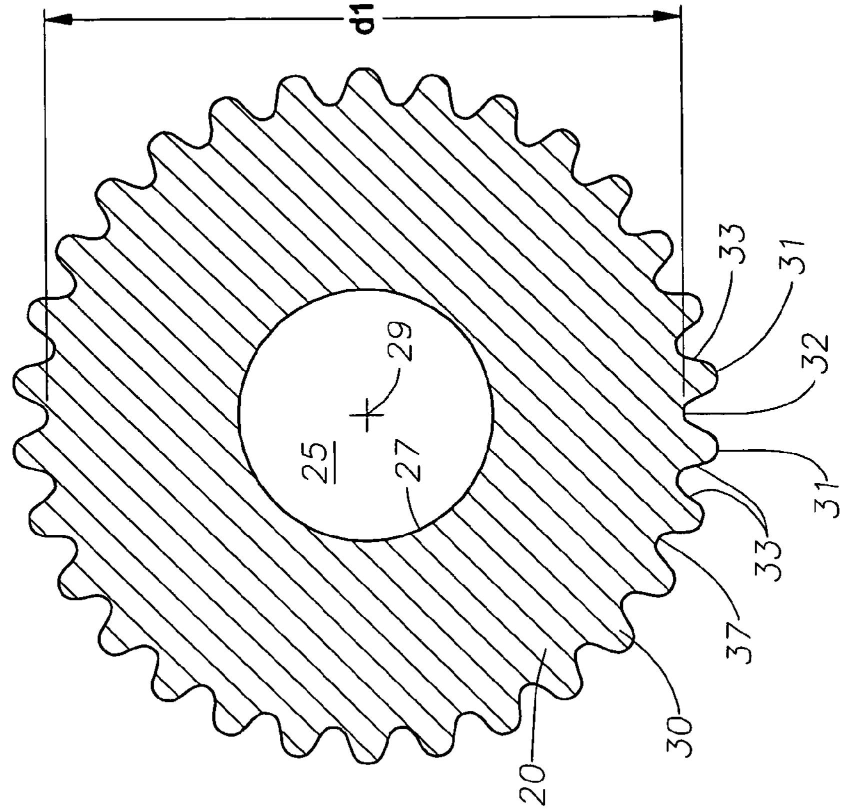


Fig. 3

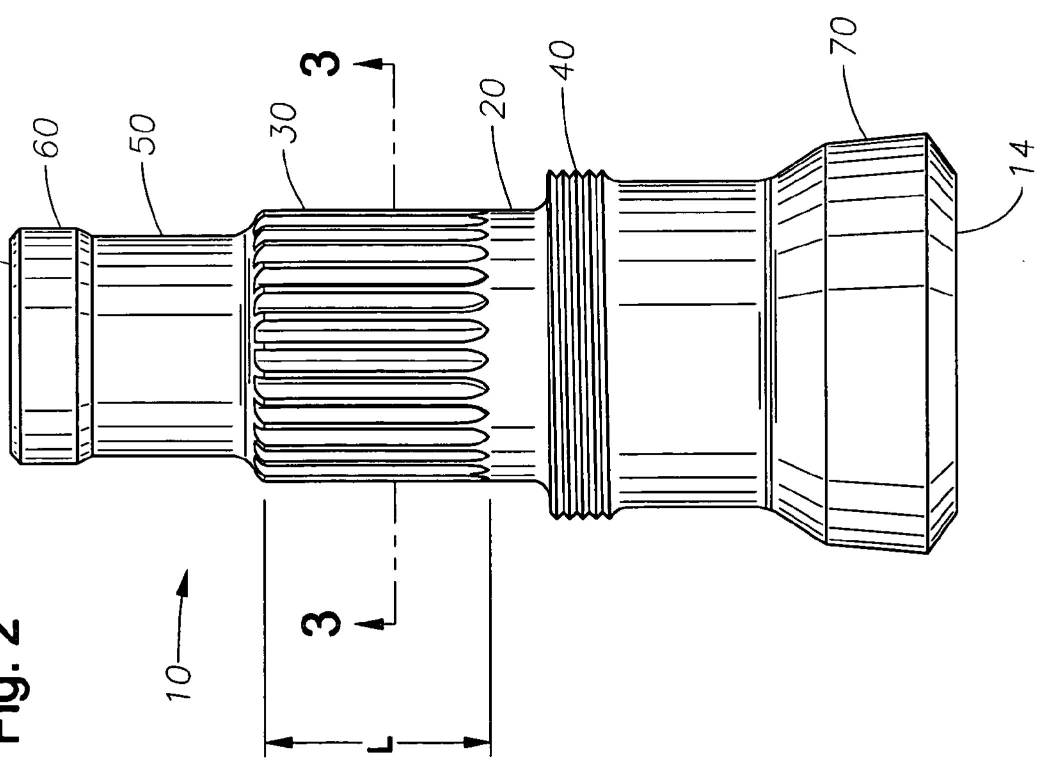


Fig. 2

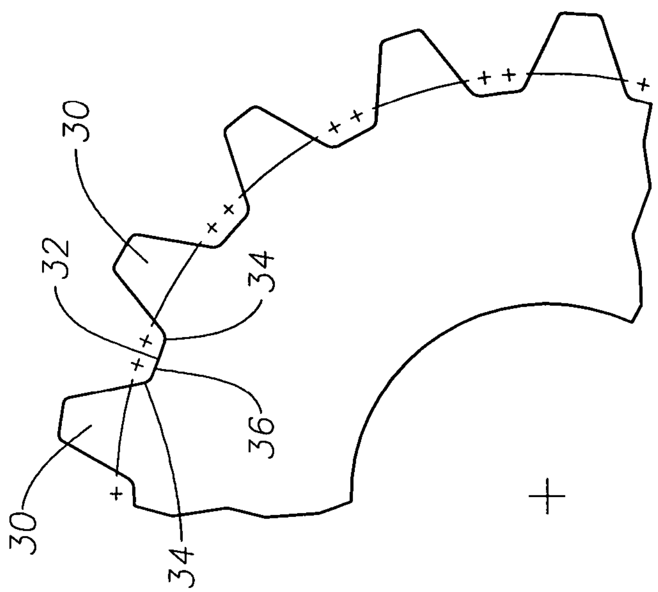


Fig. 4A

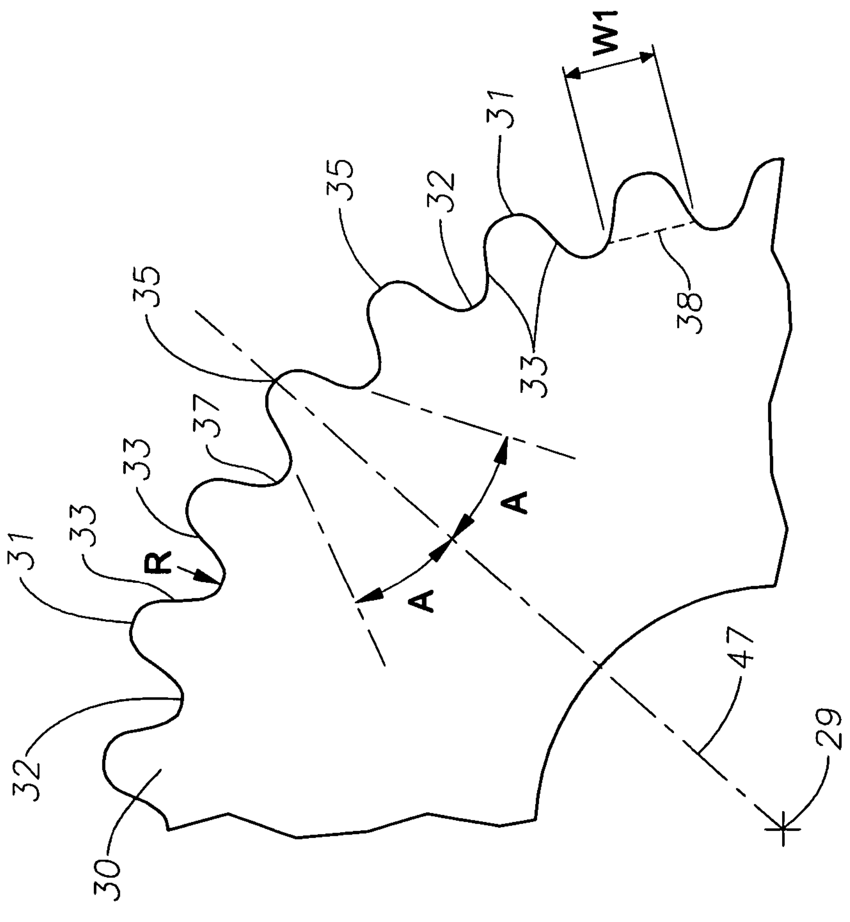


Fig. 4

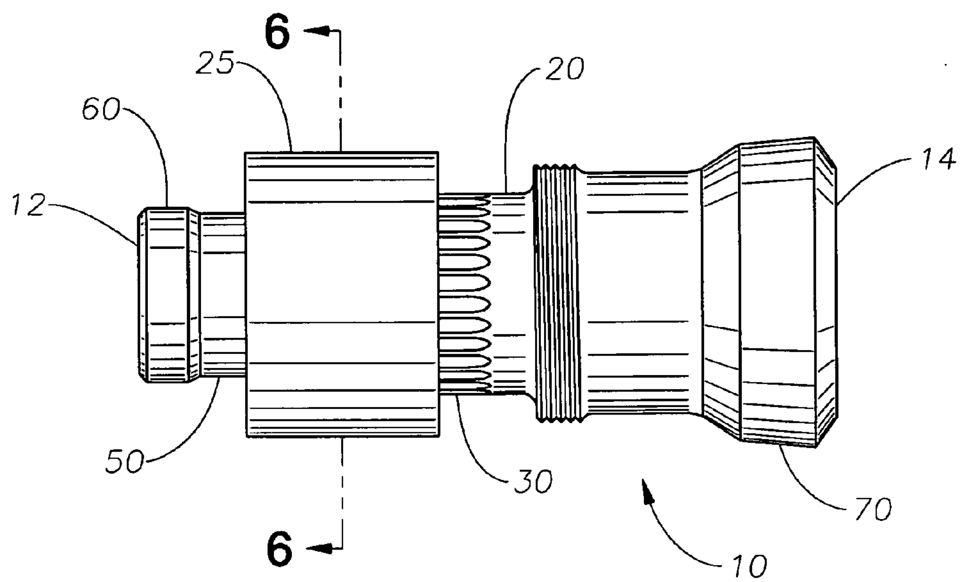
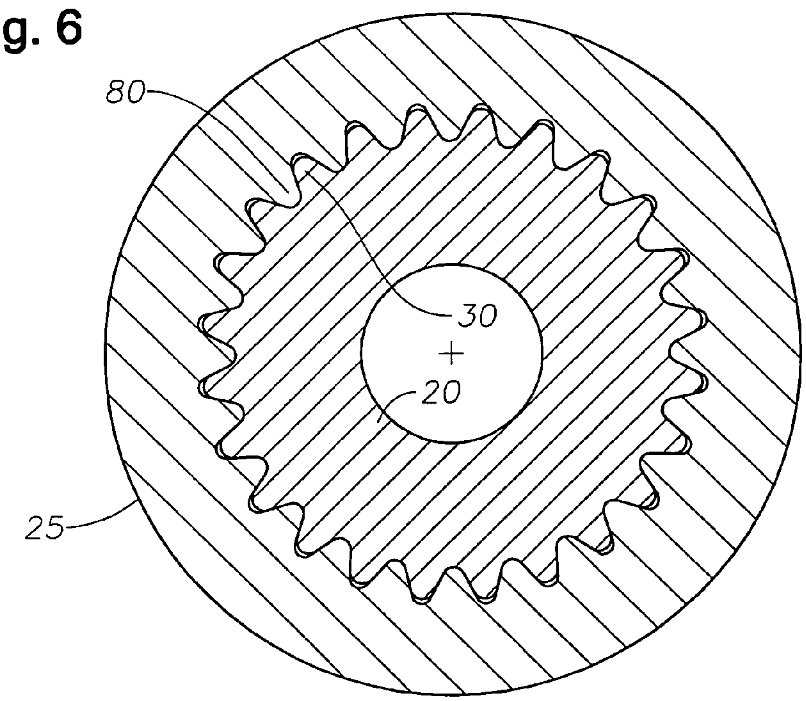


Fig. 5

Fig. 6



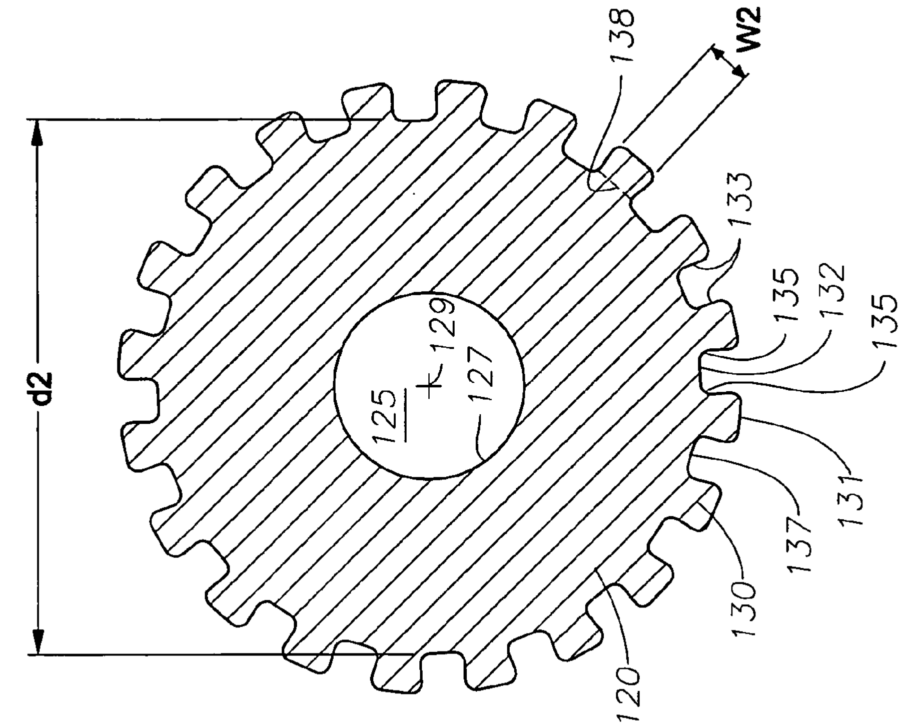


Fig. 8
(Prior Art)

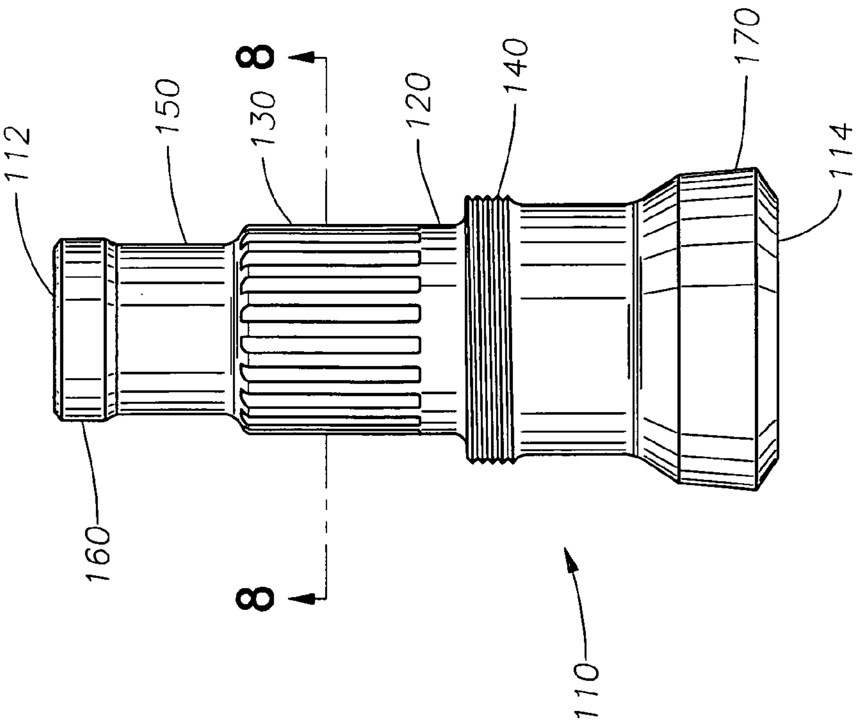


Fig. 7
(Prior Art)

PERCUSSION DRILL BIT WITH V-SHAPED SPLINES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable.

BACKGROUND

[0003] 1. Technical Field

[0004] The disclosure herein generally relates to earth boring bits used to drill a borehole for applications including the recovery of oil, gas or minerals, mining, blast holes, water wells and construction projects. More particularly, the disclosure relates to percussion hammer drill bits.

[0005] 2. Description of the Related Art

[0006] In percussion hammer drilling operations, the bit impacts the earth in a cyclic fashion while simultaneously rotating. In such operations, the mechanism for penetrating the earth is of an impacting nature rather than shearing. Therefore, in order to promote efficient penetration by the bit, the cutting elements of the bit need to be "indexed" to fresh earthen formations during each impact. This need is achieved by rotating the drill string a slight amount between each impact of the bit to the earth and incorporating longitudinal splines which key the bit body to a cylindrical sleeve (commonly known as the driver sub or chuck) at the bottom of the hammer assembly. As a result, the drill string rotation is thereby transferred to the hammer bit itself. Experience has demonstrated for an eight inch hammer bit that a rotational speed of approximately 20 rpm for an impact frequency of 1600 bpm (beats per minute) typically results in efficient drilling operations. This rotational speed translates to an angular displacement of approximately 4 to 5 degrees per impact of the bit against the rock formation.

[0007] An example of a typical hammer bit connected to a rotatable drill string is described in U.S. Pat. No. 4,932,483, incorporated herein by reference. The downhole hammer comprises a top sub and a drill bit separated by a tubular housing incorporating a piston chamber therebetween. A feed tube is mounted to the top sub and extends concentrically into the piston chamber. A piston is slideably received within the housing and over the feed tube. Fluid porting is provided in the feed tube and the piston to sequentially admit fluid in a first space between the piston and top sub to drive the piston towards the drill bit support and to a second space between the piston and the drill bit support to drive the piston towards the top sub.

[0008] Rotary motion is provided to the hammer assembly and drill bit by the attached drill string powered by a rotary table typically mounted on the rig platform or top drive head mounted on the derrick. The drill bit is rotated through engagement of a series of splines on the bit and driver sub that allow axial sliding between the components but do not allow significant rotational displacement between the hammer assembly and bit.

[0009] Due to the forces transmitted between the splines, as well as the cyclic nature of the stress created, mechanical failure of the splines can force an operator to remove the drill bit from operation for repair or replacement, thereby increasing maintenance and operation costs. Typically, the mechanical failure of the splines is initiated by galling between the splines of the drill bit and the driver sub or fatigue cracking in the splines of either component.

[0010] As a result of the significant costs associated with premature failure of the drill bit, it is desirable to increase the mechanical reliability of percussion hammer drilling systems. It is also desirable to optimize the design characteristics of the percussion bit (such as the bit length and weight) to maximize the transfer of energy between the piston and the bit, thereby increasing the rate of penetration for the bit.

[0011] The embodiments described herein provide opportunities for improvement in percussion bit service life and rate of penetration. These and various other characteristics and potential advantages will be readily apparent to those skilled in the art upon reading the following detailed description of the preferred embodiments, and by referring to the accompanying drawings.

SUMMARY OF THE PREFERRED EMBODIMENTS

[0012] Embodiments described herein comprise a drill bit for use in a percussion drilling apparatus of the type for boring into the earth. Preferred embodiments comprise an elongate body with a first end, a second end, and a longitudinal surface extending between the first and second ends. Preferred embodiments further comprise a plurality of splines on the longitudinal surface of the drill bit, with at least one of said plurality of splines comprising an apex, a root, and a planar surface between the apex and root. In certain preferred embodiments, the planar surface is oriented at an angle between 10 and 45 degrees to a plane extending from a center of the drill bit to a midpoint of the apex.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more detailed description of the preferred embodiments, reference will now be made to the accompanying drawings, wherein:

[0014] FIG. **1** is a cross-section of a percussion hammer drilling assembly;

[0015] FIG. **2** is an elevational view of a percussion bit made in accordance with principles of the present invention;

[0016] FIG. **3** is a section view of the embodiment of FIG. **2**;

[0017] FIG. **4** is a detailed view of the section view of FIG. **3**

[0018] FIG. **4**A is a detailed section view of an alternative embodiment of a percussion bit made in accordance with principles of the present invention;

[0019] FIG. **5** is an elevational view of a percussion bit and a drive collar made in accordance with principles of the present invention;

[0020] FIG. **6** is a section view of the embodiment of FIG. **5**;

[0021] FIG. 7 is an elevational view of a prior art percussion bit; and

[0022] FIG. 8 is a section view of the prior art bit of FIG. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Referring first to FIG. 1, a cross-section of a typical prior art percussion drilling assembly 200 is attached to a drillstring 210. Assembly 200 comprises a top sub 220 threadably connected to a case 230, which is threadably connected to a driver sub 240. A bit 260 is slideably engaged with driver sub 240, and a retainer sleeve 250 is disposed between case 230 and bit 260. Top sub 220 further comprises a check valve 225 and a feed tube 235 that extends from check valve 225 to a piston 245 that is slideably engaged with a guide sleeve 255.

[0024] During operation, drillsting 210 rotates, thereby rotating percussion drilling assembly 200. In addition, piston 245 travels back and forth in an axial direction so that it cyclically impacts bit 260. A series of engaged splines 265 on bit 260 and driver sub 240 allow bit 260 to slide axially relative to driver sub 240 while also allowing driver sub 240 to rotate bit 260. As described previously, this allows the cutting elements (not shown) of bit 260 to be "indexed" to fresh rock formations during each impact of bit 260, thereby improving the efficiency of the drilling operation.

[0025] Referring now to FIG. 2, a percussion bit 10 for earth-boring applications comprises an elongate body 20 with a drillstring end 12 (nearest a drillstring, not shown) and an insert end 14. A plurality of generally axially-aligned splines 30 are disposed circumferentially about the outer surface of elongate body 20 between a threaded portion 40 and a recessed portion 50. Elongate body 20 further comprises a collar 60 near drillstring end 12 and a flared portion 70 near insert end 14.

[0026] As shown in FIG. 3 (a section view taken along line 3-3 of FIG. 2) elongate body 20 comprises a cavity 25 disposed longitudinally through elongate body 20. In the embodiment of FIG. 3, cavity 25 has a generally circular cross section with an inner wall 27 circumscribing a central axis 29. As shown in FIG. 3, the cross-section of each spline 30 comprises an apex or peak 31, as well as a pair of angled surfaces 33 between peak 31 and a root 32, thereby creating a generally "V"-shaped spline 30. In certain embodiments, peak 31 may be relatively flat or formed with a radius, and does not comprise a sharply pointed surface. In the embodiment shown in FIG. 3, each root 32 comprises a single curved surface 37 between a pair of angled surfaces 33.

[0027] Referring now to FIG. 4, a detailed view of a portion of the view in FIG. 3 is shown. Although still depicting a section view, the section lines have been removed in FIG. 4 to more clearly illustrate the details of splines 30. In the embodiment shown in FIG. 4, angled surfaces 33 are generally planar and each is disposed at an angle A measured relative to a radius 47 drawn from central axis 29 to the midpoint 35 of peak 31. In the embodiment shown in FIG. 4, angle A is approximately 30 degrees, so that the angle between the pair of angled surfaces 33 defining a spline 30 is about 60 degrees. In other embodiments, angle A can range from 10 degrees to 45 degrees, so that the angle between angled surfaces 33 is 20 to 90 degrees. Also shown in the embodiment of FIG. 4, root 32 comprises a single curved portion 37 with a radius R that intersects a pair of adjacent angled surfaces 33. In the embodiment of FIG. 4, radius R is 0.080 inches, while other embodiments may comprise a root radius with different values. Referring now to an alternative embodiment shown in FIG. 4A, root 32 may comprise a pair of curved surfaces 39, joined by a substantially planar surface 36. In still other embodiments, the surface of root 32 designated in FIG. 4A as surface 36 may be radiused, rather than substantially planar, and would have a radius that is substantially greater than the radius of a curved surface 34.

[0028] Referring now to FIG. 5, a drive collar (or driver sub) 25 is shown engaging splines 30 of drill bit 10. During operation, drive collar 25 imparts a rotational force to drill bit 10 and causes drill bit 10 to rotate slightly during each cycle of operation. As shown in FIG. 6 (a section view taken along line 6-6 of FIG. 5), drive collar 25 comprises a plurality of splines 80 which intermesh and engage splines 30 of elongate body 20 of bit 10. During operation, splines 80 and 30 allow longitudinal or axial sliding between drive collar 25 and drill bit 10, but restrict rotational movement between drive collar 25 and drill bit 10. Therefore, as drive collar 25 rotates, it translates its rotational movement to drill bit 10, thereby causing drill bit 10 to rotate as well.

[0029] Referring now to FIG. 7, a typical prior art percussion bit 110 comprises an elongate body 120 with a drillstring end 112 and an insert end 114. A plurality of splines 130 are disposed on elongate body 120 between a threaded portion 140 and a recessed portion 150. Elongate body 120 further comprises a collar 160 near drillstring end 112 and a flared portion 170 near insert end 114.

[0030] As shown in FIG. 8, a section view taken along line 8-8 of FIG. 5, elongate body 120 comprises a cavity 125 disposed longitudinally through elongate body 120. In the embodiment of FIG. 8, cavity 125 has a generally circular cross section with an inner wall 127 circumscribing a central axis 129. As shown in FIG. 8, each spline 130 comprises a peak 131 and with a pair of side surfaces 133 adjacent to a root 132.

[0031] Unlike the embodiment of FIGS. 2-6, the prior art embodiment shown in FIGS. 7-8 comprises splines 130 that are generally rectangular or square in cross-sectional shape. More particularly, splines 130 comprise peaks 131 that have a pair of side surfaces 133 that are generally planar. In addition, adjacent to each spline 130 is a pair of roots 132 with a bottom surface 137 that may be straight or curved. A radiused portion 135 is formed between each bottom surface 137 and side surface 133.

[0032] Comparing the embodiments shown in FIGS. 3 and 8, the number of splines 30 that are disposed around elongate body 20 is greater than the number of splines 130 that are disposed around prior art elongate body 120. The number of splines 30 is increased in FIG. 3 even though the minor diameter d1 of elongate body 20 (as measured from a first root 32 to a second root 32 that is disposed 180 degrees from the first root) is equivalent to the minor diameter d2 of elongate body 120. In addition, the width (depicted as dimension W1 in FIG. 4) of a base portion 38 of spline 30 is equivalent to the width W2 of a base portion 138 of spline 130 shown in FIG. 8. Base portion 38 is the portion of spline **30** that is closest to central axis **29**. In the embodiment of FIG. **4**, the width W**1** is measured across the base of the spline **30** between the points where angled surface **33** meets root **32**. In the embodiments of FIGS. **3** and **8**, the minor diameter d**1** and d**2** is 3.618 inches. In other embodiments, the minor diameter of the drill bit may be a different value.

[**0033**] In the embodiment of FIG. **3**, the number of splines **30** is therefore greater than the number of splines **130** in the embodiment of FIG. **8**, even though each embodiment has an equivalent bit minor diameter and spline base width. The increased number of splines **30** in FIG. **3** is due to the fact that root **32** is not as wide as root **132**. Because splines **30** are subjected to (and sometimes fail as a result of) rotational or torsional stresses during operation, increasing the number of splines **30** can increase the torque capacity and fatigue strength of bit **10**. While it would be possible to increase the number of square or rectangular splines on a drill bit by decreasing the width of the root between the splines, this would also decrease the width of the spline on a driver sub that engages the drill bit. Decreasing the width of the splines on the driver sub would therefore reduce the torque capacity and fatigue strength of the driver sub splines and counteract the benefits gained from increasing the number of splines on the drill bit. By incorporating V-shaped splines on both the drill bit and driver sub, the number of splines on each component can be increased, and the base width of each spline can be maintained.

[**0034**] In addition, in the embodiment of FIGS. **24**, root **32** is configured of a single curved surface with a single radius R, as contrasted with the embodiment of FIG. **8** where two separate radii **135** are separated by the generally flat bottom surface **137** of root **132**. Incorporating a larger single radius, as in the embodiment of FIGS. **24**, as opposed to two smaller radii, reduces the stress concentration in root **32** and potentially increases the torque capacity and fatigue strength of bit **10** as well.

[**0035**] Furthermore, by increasing the number of splines **30**, the overall length L of splines **30** (as shown in FIG. **2**) may also be reduced. Increasing the number of splines **30** increases the area of bit **10** that is subjected to torsional forces during operation. Therefore, by increasing the number of splines **30**, the length L of splines **30** can be reduced while still maintaining a torque load area equivalent to that of designs with fewer (but longer) splines. The reduction in the length of splines **30** can result in a reduction of the overall length of drill bit **10**, thereby reducing the weight of drill bit **10**. A reduction in weight of drill bit **10** can lead to an increased transfer of energy from the hammer (not shown) to drill bit **10**, resulting in more efficient drilling operations.

[**0036**] While various preferred embodiments have been showed and described, modifications thereof can be made by one skilled in the art without departing from the spirit and teachings herein. The embodiments herein are exemplary only, and are not limiting. Many variations and modifications of the apparatus disclosed herein are possible and within the scope of the invention. For example, the angle of the planar surfaces on each side of the spline may vary from those depicted in the embodiments shown. Accordingly, the scope of protection is not limited by the description set out above, but is only limited by the claims which follow, that scope including all equivalents of the subject matter of the claims

What is claimed is:

1. A drill bit for use in a percussion drilling apparatus of the type for boring into the earth, said drill bit comprising:

an elongate body with a first end, a second end, a central axis, and a longitudinal surface disposed about said axis and extending between said first and said second ends; and

a plurality of splines on said longitudinal surface of said drill bit, wherein at least one of said plurality of splines comprises a base portion, an apex, a root, and a generally planar surface between said apex and said root, wherein a first plane parallel to said generally planar surface is oriented at an angle between 10 and 45 degrees to a second plane extending from said axis to a midpoint of said apex and wherein the base portion is wider than the apex.

2. The drill bit of claim 1 wherein said plurality of splines comprises a plurality of roots and each root comprises a radiused portion with a root radius that connects said planar surface from a first spline of said plurality of splines to a second planar surface from a second spline of said plurality of splines.

3. The drill bit of claim 2 further comprising a diameter inscribing said roots of said plurality of splines, wherein the ratio of said diameter to said root radius is less than 50.

4. The drill bit of claim 1 wherein said angle is between 20 and 35 degrees.

5. The drill bit of claim 1 wherein said root does not comprise a substantially flat surface.

6. The drill bit of claim 1 wherein the root comprises a curved surface that intersects a pair of planar surfaces adjacent to the root.

7. The drill bit of claim 1, wherein:

said plurality of splines extend a distance L along said longitudinal surface;

said elongate body has a minor diameter d; and

a ratio of L/d is less than 0.7.

8. The drill bit of claim 7 wherein the ratio of L/D is between 0.60 and 0.40.

9. The drill bit of claim 1 wherein the root comprises a curved surface that intersects a pair of planar surfaces adjacent to the root.

10. A drill bit for use in a percussion drilling apparatus of the type for boring into the earth, said drill bit comprising:

an elongate body with a central axis;

a plurality of splines disposed on said elongate body, said splines disposed parallel to said central axis, wherein at least one of said plurality of splines comprises a base portion and an apex, wherein the base portion is wider than the apex and the apex is disposed between a first planar surface and a second planar surface;

wherein a first plane parallel to said first planar surface is oriented at a first angle between 10 degrees and 45 degrees to a second plane extending from said central axis to a midpoint of said apex; and wherein a third plane parallel to said second planar surface is oriented at a second angle between 10 degrees and 45 degrees to said second plane.

11. The drill bit of claim 10, wherein the first angle is between 20 and 35 degrees.

12. The drill bit of claim 10, wherein the second angle is between 20 and 35 degrees.

13. The drill bit of claim 10, further comprising a root on either side of said apex, wherein said root comprises a root radius and does not comprise a flat surface.

14. The drill bit of claim 13 further comprising a diameter inscribing said roots of said plurality of splines, wherein the ratio of said diameter to said root radius is less than 50.

15. The drill bit of claim 13 wherein the root comprises a curved surface, wherein the curved surface intersects a first planar surface adjacent to the root and the curved surface intersects a second planar surface adjacent to the root.

16. A drill bit for use in a percussion drilling apparatus of the type for boring into the earth, said drill bit comprising:

an elongate body;

a plurality of splines disposed on said elongate body, wherein at least one of said plurality of splines comprises a first and second surface angled relative to one another and configured to form an angle therebetween of between 20 and 90 degrees.

17. The drill bit of claim 16 wherein the angle is between 40 and 70 degrees.

18. The drill bit of claim 16, further comprising a root adjacent to the first angled surface, wherein said root does not comprise a flat surface.

19. A percussion drilling assembly comprising:

a top sub;

a driver sub with a first plurality of V-shaped splines, wherein each spline comprises a pair of angled surfaces configured to form an angle of between 20 and 90 degrees;

a case disposed between said top sub and said driver sub;

a piston disposed within said case; and

a bit with a second plurality of V-shaped splines engaged with said first plurality of V-shaped splines.

20. The percussion drilling assembly of claim 19 wherein the angle is between 40 and 70 degrees.

21. The percussion drilling assembly of claim 19 wherein the driver sub further comprises a root between a first angled surface from a first spline and a second angled surface from a second spline, wherein the root does not comprise a flat surface.

22. The percussion drilling assembly of claim 19 wherein the root comprises a curved surface that intersects the first angled surface and the second angled surface.

23. A method of drilling into the earth comprising the steps of:

providing a drill bit with an elongate body and a first plurality of splines on said elongate body;

providing a drive collar with a second plurality of splines that slideably engage said first plurality of splines;

providing a piston;

impacting said piston against said drill bit;

impacting said drill bit against the earth; and

rotating said drive collar and said drill bit, wherein at least one of said first plurality of splines comprises a base portion, an apex, a root, and a planar surface between said apex and said root, wherein the base portion is wider than the apex and a first plane parallel to said planar surface is oriented at an angle between 10 degrees and 45 degrees to a second plane extending from a center of said drill bit to a midpoint of said apex.

24. The method of claim 23 wherein the angle is between 20 and 35 degrees.

* * * * *