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(54) **MODULAR HYBRID DRILL BIT**

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(57) **ABSTRACT**

An earth-boring bit comprising a bit body is configured at its upper end for connection into a drillstring. A fixed blade depends axially downwardly from the bit body. An axially extending slot is formed in the bit body adjacent the fixed blade. A bit leg is received and retained in the slot by engagement between the slot and correspondingly shaped bit leg, wherein the bit leg cannot be removed from the slot except by axial movement relative to the bit body. A rolling cutter is secured to the bit leg at its lower extent. A fastener secures the bit leg against movement relative to the bit body and extends through oblong apertures in the bit leg and into the bit body, wherein the bit leg can be moved axially relative to the bit body to adjust the projection of the rolling cutter relative to the fixed blade. The slot defines a pair of generally opposed sides connected by a third side, the generally opposed sides being inclined toward one another to define a dovetail that corresponds with the shape of the bit leg. The bit body further comprises a shank that is configured for connection into the drillstring at its upper extent and has a generally cylindrical receptacle formed in its lower extent; and a bit body portion having a generally cylindrical upper extent, the receptacle being and dimensioned to receive the upper extent of the bit body, wherein the shank and bit body portions are secured together by welding.

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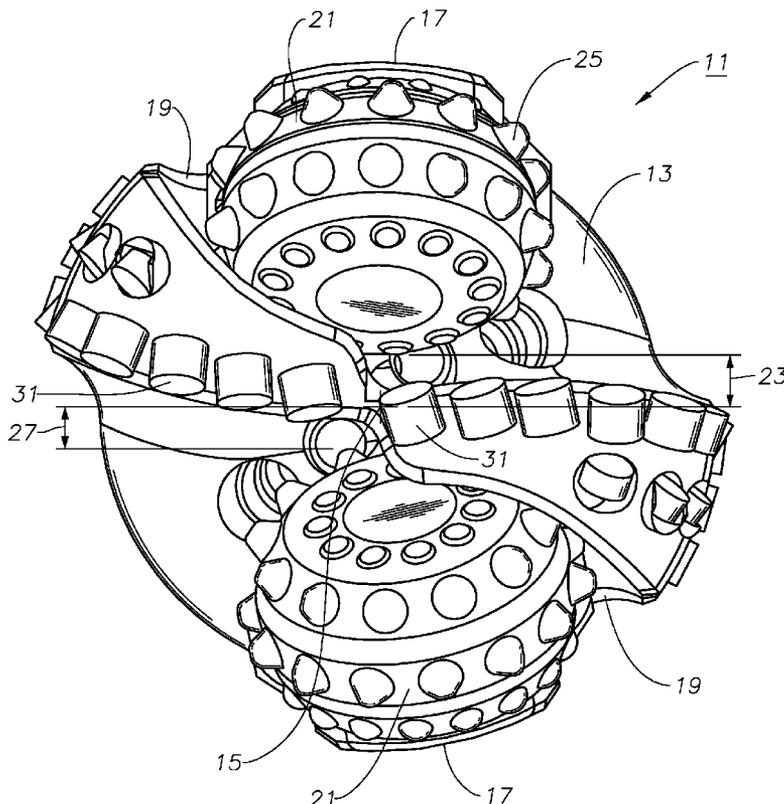


Fig. 1

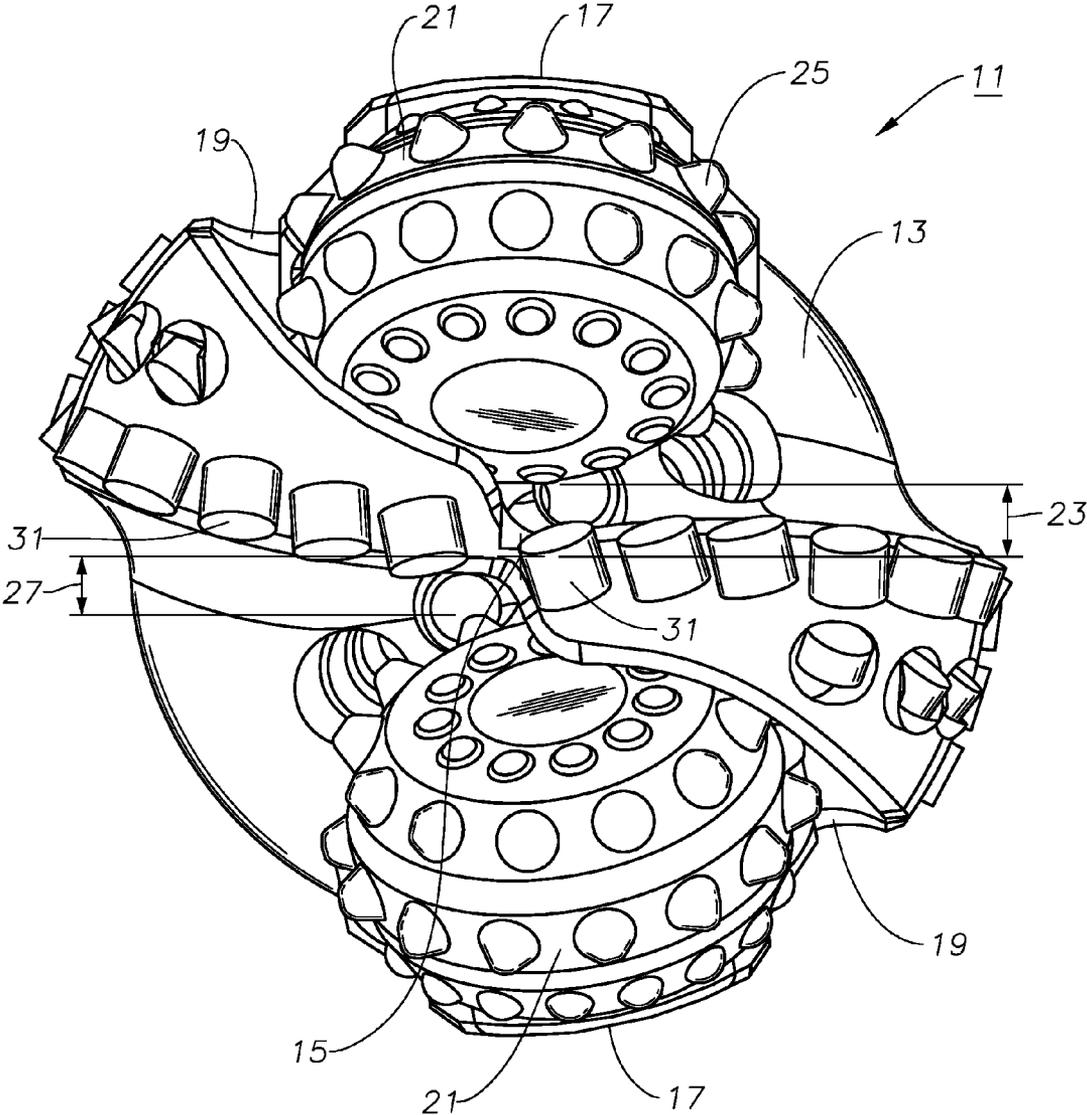


Fig. 2

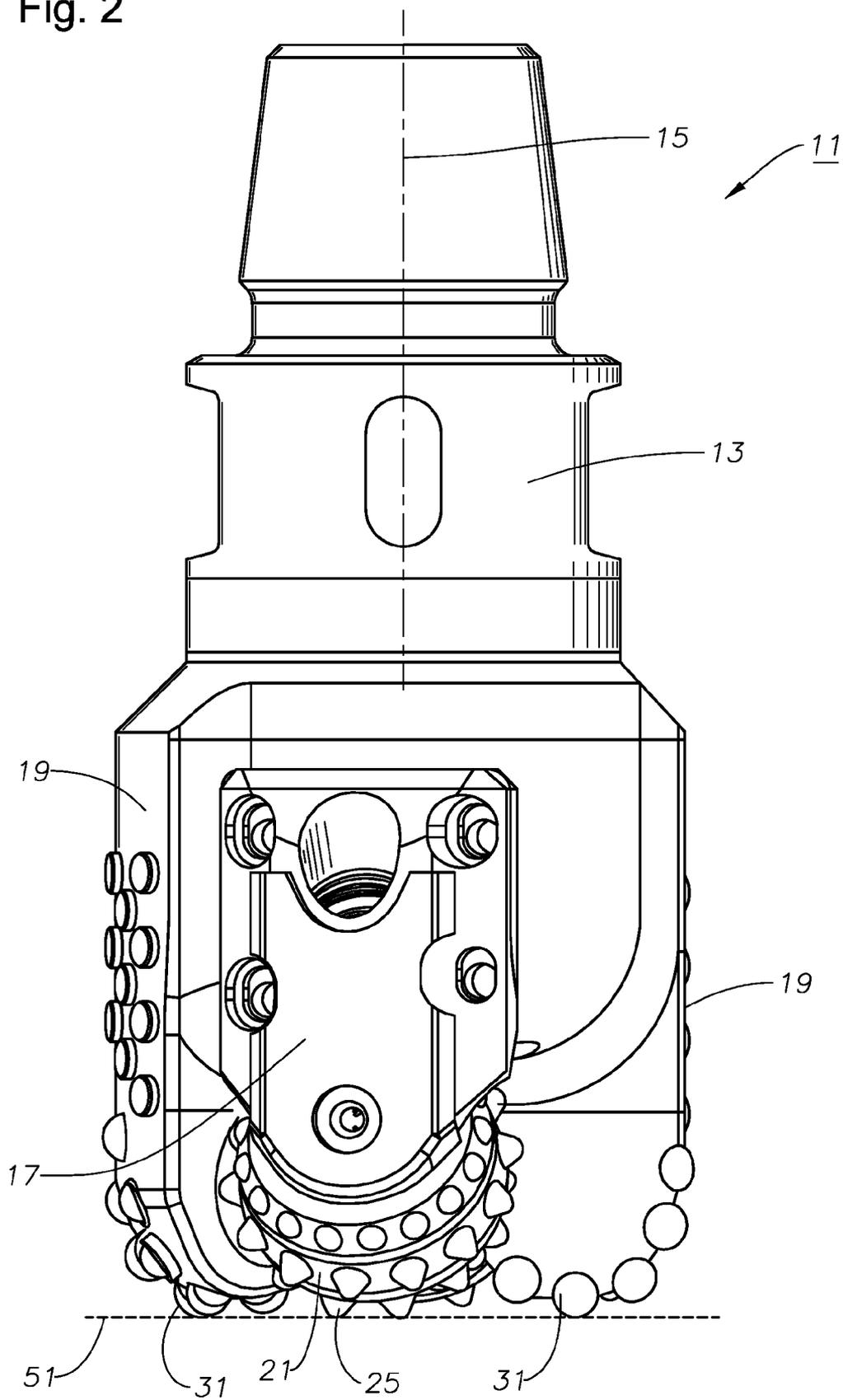
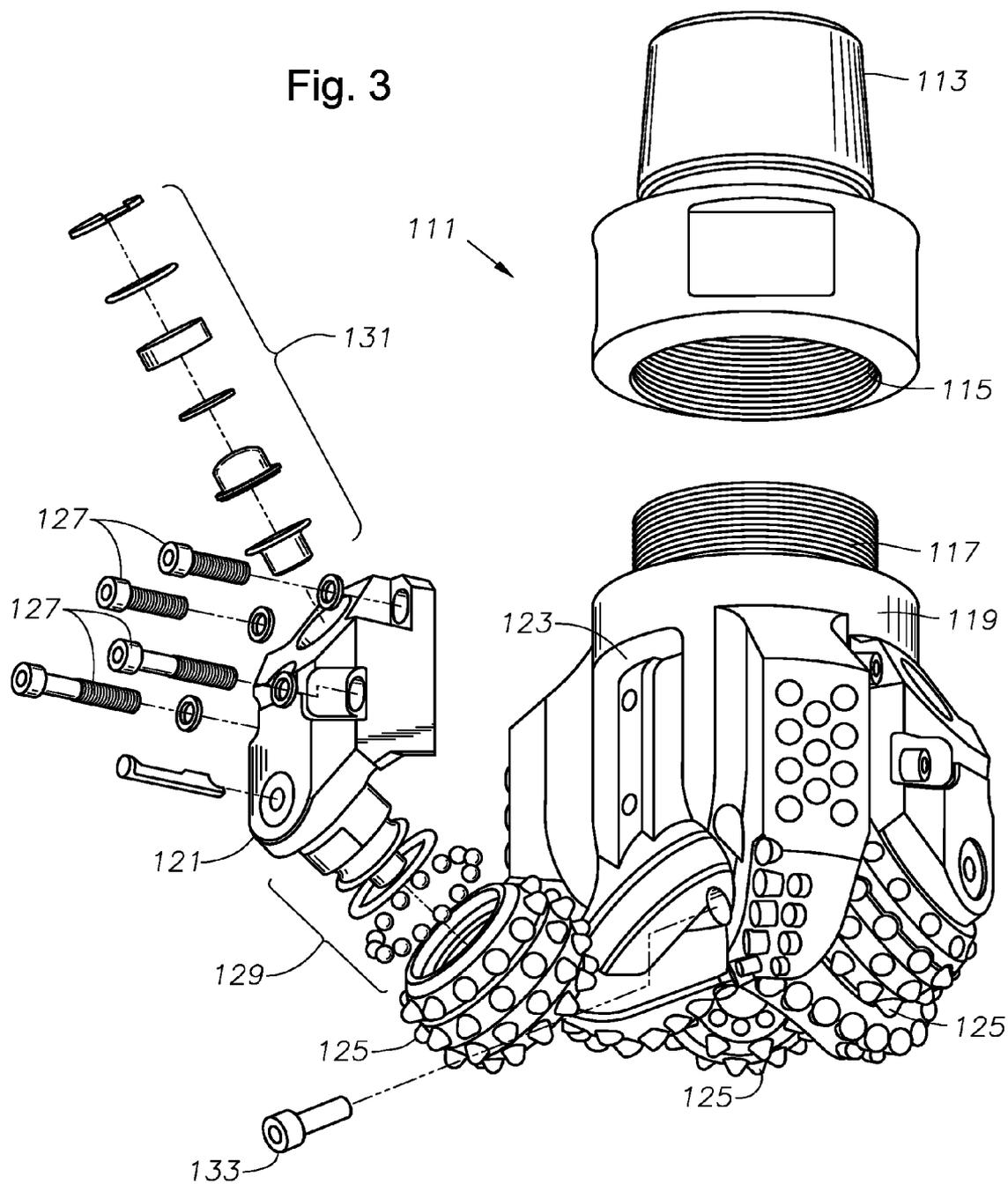


Fig. 3



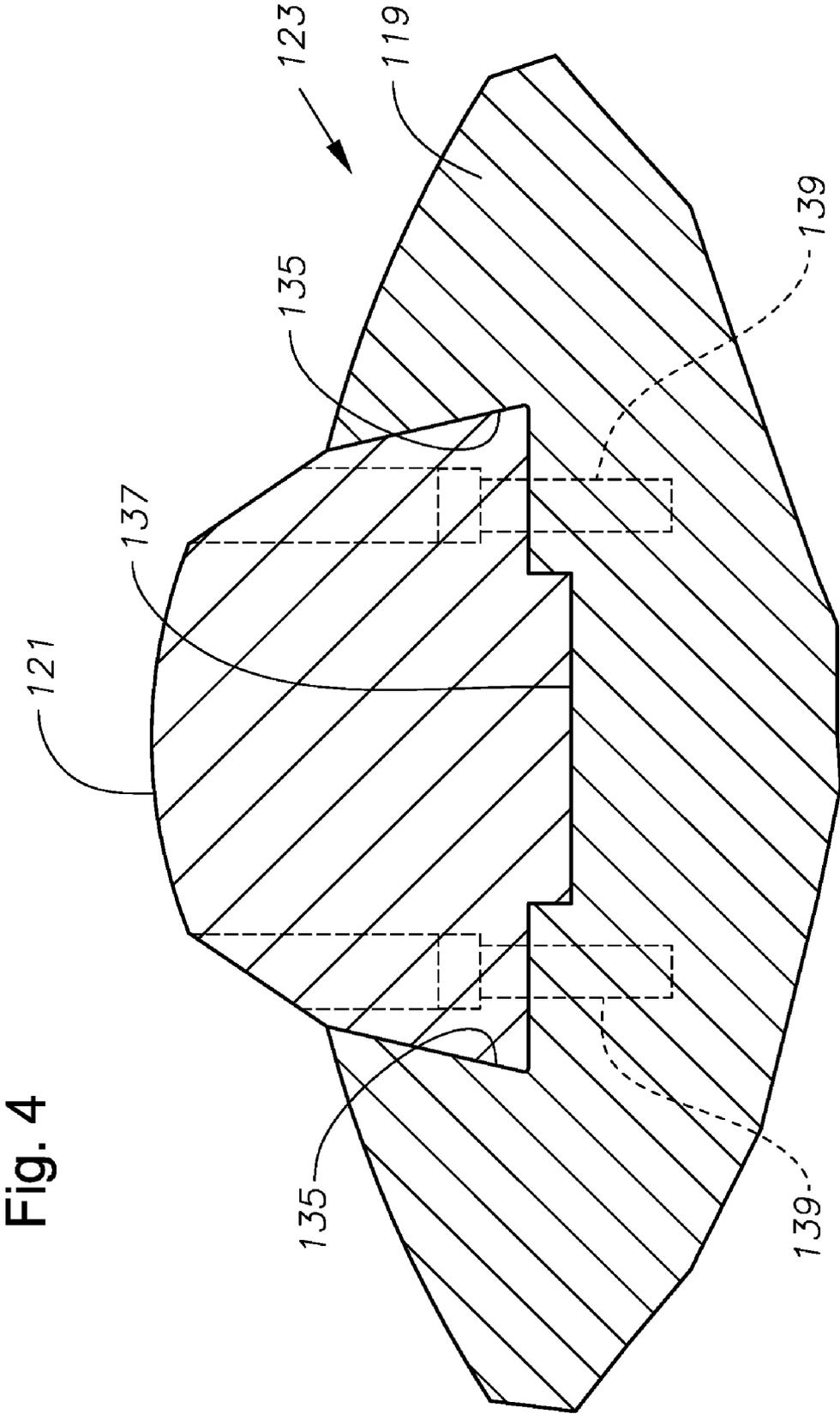


Fig. 4

## MODULAR HYBRID DRILL BIT

### BACKGROUND OF THE INVENTION

**[0001]** 1. Technical Field

**[0002]** The present invention relates in general to earth-boring drill bits and, in particular, to a bit having a combination of rolling and fixed cutters and cutting elements and a method of drilling with same.

**[0003]** 2. Description of the Related Art

**[0004]** The success of rotary drilling enabled the discovery of deep oil and gas reservoirs and production of enormous quantities of oil. The rotary rock bit was an important invention that made the success of rotary drilling possible. Only soft earthen formations could be penetrated commercially with the earlier drag bit and cable tool, but the two-cone rock bit, invented by Howard R. Hughes, U.S. Pat. No. 930,759, drilled the caprock at the Spindletop field, near Beaumont, Tex. with relative ease. That venerable invention, within the first decade of the last century, could drill a scant fraction of the depth and speed of the modern rotary rock bit. The original Hughes bit drilled for hours, the modern bit drills for days. Modern bits sometimes drill for thousands of feet instead of merely a few feet. Many advances have contributed to the impressive improvements in rotary rock bits.

**[0005]** In drilling boreholes in earthen formations using rolling-cone or rolling-cutter bits, rock bits having one, two, or three rolling cutters rotatably mounted thereon are employed. The bit is secured to the lower end of a drillstring that is rotated from the surface or by a downhole motor or turbine. The cutters mounted on the bit roll and slide upon the bottom of the borehole as the drillstring is rotated, thereby engaging and disintegrating the formation material to be removed. The rolling cutters are provided with cutting elements or teeth that are forced to penetrate and gouge the bottom of the borehole by weight from the drillstring. The cuttings from the bottom and sides of the borehole are washed away by drilling fluid that is pumped down from the surface through the hollow, rotating drillstring, and are carried in suspension in the drilling fluid to the surface.

**[0006]** Rolling-cutter bits dominated petroleum drilling for the greater part of the 20<sup>th</sup> century. With improvements in synthetic or manmade diamond technology that occurred in the 1970s and 1980s, the fixed-cutter, or “drag” bit, became popular again in the latter part of the 20<sup>th</sup> century. Modern fixed-cutter bits are often referred to as “diamond” or “PDC” (polycrystalline diamond compact) bits and are far removed from the original fixed-cutter bits of the 19<sup>th</sup> and early 20<sup>th</sup> centuries. Diamond or PDC bits carry cutting elements comprising polycrystalline diamond compact layers or “tables” formed on and bonded to a supporting substrate, conventionally of cemented tungsten carbide, the cutting elements being arranged in selected locations on blades or other structures on the bit body with the diamond tables facing generally in the direction of bit rotation. Diamond bits have an advantage over rolling-cutter bits in that they generally have no moving parts. The drilling mechanics and dynamics of diamond bits are different from those of rolling-cutter bits precisely because they have no moving parts. During drilling operation, diamond bits are used in a manner similar to that for rolling cutter bits, the diamond bits also being rotated against a formation being drilled under applied weight on bit to remove formation material. Engagement between the diamond cutting elements and the borehole bottom and sides shears or scrapes material from the formation, instead of using a crushing action as is

employed by rolling-cutter bits. Rolling-cutter and diamond bits each have particular applications for which they are more suitable than the other; neither type of bit is likely to completely supplant the other in the foreseeable future.

**[0007]** In the prior art, some earth-boring bits use a combination of one or more rolling cutters and one or more fixed blades. Some of these combination-type drill bits are referred to as hybrid bits. Previous designs of hybrid bits, such as is described in U.S. Pat. No. 4,343,371 to Baker, III, have provided for the rolling cutters to do most of the formation cutting, especially in the center of the hole or bit. Other types of combination bits are known as “core bits,” such as U.S. Pat. No. 4,006,788 to Garner. Core bits typically have truncated rolling cutters that do not extend to the center of the bit and are designed to remove a core sample of formation by drilling down, but around, a solid cylinder of the formation to be removed from the borehole generally intact.

**[0008]** Rolling-cutter bits tend to fail when the bearing or seal fails and one or more cutters stop rotating or rotating easily. Bearing failure is most often caused by loss of lubricant from the bit or damage to the bearing as a result of severe operating conditions. In some cases, the bearing failure is so catastrophic that a cutter falls off of the bearing, which can lead to costly and time-consuming fishing operations to recover the lost cutter. Typically, rolling-cutter bits cannot successfully be refurbished because of irreparable bearing damage. Diamond bits rarely have such a catastrophic failure. Instead, individual diamond cutters tend to be lost and the bit body is slowly worn away such that it is no longer within drilling specifications. Diamond bits can be refurbished by replacing lost cutters until the bit body is too worn.

**[0009]** Another type of hybrid bit is described in U.S. Pat. No. 5,695,019 to Shamburger, Jr., wherein the rolling cutters extend almost entirely to the center. Fixed cutter inserts **50** (FIGS. **2** and **3**) are located in the dome area **2** or “crotch” of the bit to complete the removal of the drilled formation. Still another type of hybrid bit is sometimes referred to as a “hole opener,” an example of which is described in U.S. Pat. No. 6,527,066. A hole opener has a fixed threaded protuberance that extends axially beyond the rolling cutters for the attachment of a pilot bit that can be a rolling cutter or fixed cutter bit. In these latter two cases the center is cut with fixed cutter elements but the fixed cutter elements do not form a continuous, uninterrupted cutting profile from the center to the perimeter of the bit.

**[0010]** Although each of these bits is workable for certain limited applications, an improved hybrid earth-boring bit with enhanced drilling performance would be desirable.

### SUMMARY OF THE INVENTION

**[0011]** It is a general object of the present invention to provide an improved earth-boring bit of the hybrid variety. This and other objects are achieved by providing an earth-boring bit comprising a bit body configured at its upper end for connection into a drillstring. At least one fixed blade depends axially downwardly from the bit body. An axially extending slot is formed in the bit body adjacent the fixed blade. A bit leg is received and retained in the slot by engagement between the slot and correspondingly shaped bit leg. At least one rolling cutter is secured to the bit leg at its lower extent.

**[0012]** According to an illustrative embodiment of the invention, at least one fastener secures the bit leg against movement relative to the bit body and the fastener extends

through oblong apertures in the bit leg and into the bit body, wherein the bit leg can be moved axially relative to the bit body to adjust the projection of the rolling cutter relative to the fixed blade.

[0013] According to an illustrative embodiment of the invention, the slot is formed by at least three sides, and at least one acute angle is formed by two adjacent sides. The slot defines a pair of generally opposed sides connected by a third side, the generally opposed sides being inclined toward one another to define a dovetail that corresponds with the shape of the bit leg.

[0014] According to an illustrative embodiment of the invention, the bit body further comprises a shank that is configured for connection into the drillstring at its upper extent and has a generally cylindrical receptacle formed in its lower extent; and a bit body portion having a generally cylindrical upper extent, the receptacle being and dimensioned to receive the upper extent of the bit body, wherein the shank and bit body portions are secured together by welding.

[0015] According to an illustrative embodiment of the invention, the earth-boring bit further comprises a nozzle removably secured in the bit body, the nozzle receptacle configured to receive a nozzle; a bearing formed integrally with the bit leg, the rolling cutter mounted for rotation on the bearing; and a lubricant compensator removably secured in the bit leg, the lubricant compensator in fluid communication with the bearing.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0016] So that the manner in which the features and advantages of the present invention, which will become apparent, are attained and can be understood in more detail, more particular description of embodiments of the invention as briefly summarized above may be had by reference to the embodiments thereof that are illustrated in the appended drawings which form a part of this specification. It is to be noted, however, that the drawings illustrate only some embodiments of the invention and therefore are not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0017] FIG. 1 is a side elevation view of the embodiment of the hybrid earth-boring bit constructed in accordance with the present invention;

[0018] FIG. 2 is a bottom plan view of an embodiment of the hybrid earth-boring bit of FIG. 1 constructed in accordance with the present invention;

[0019] FIG. 3 is an exploded view of another embodiment of the hybrid earth-boring bit of FIG. 1 constructed in accordance with the present invention; and

[0020] FIG. 4 is a fragmentary view of a portion of the earth-boring bit of FIG. 3, illustrating the configuration of the axial slot in accordance with the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring to FIGS. 1-2, an illustrative embodiment of a modular hybrid earth-boring drill bit is disclosed. The bit 11 comprises a bit body 13 having an axis 15 that defines an axial center of the bit body 13. A plurality (e.g., two shown) of bit legs or heads 17 extend from the bit body 13 in the axial direction. The bit body 13 also has a plurality (e.g., also two shown) of fixed blades 19 that extend in the axial direction. The number of each of legs 17 and fixed blades 19 is at least one but may be more than two (as in the case of the embodi-

ment illustrated in FIG. 3). In one embodiment, the centers of the legs 17 and fixed blades 19 are symmetrically spaced apart from each other about the axis 15 in an alternating configuration.

[0022] Rolling cutters 21 are mounted to respective ones of the bit legs 17. Each of the rolling cutters 21 is shaped and located such that every surface of the rolling cutters 21 is radially spaced apart from the axial center 15 (FIG. 2) by a minimal radial distance 23. A plurality of rolling-cutter cutting inserts or elements 25 are mounted to the rolling cutters 21 and radially spaced apart from the axial center 15 by a minimal radial distance 27. The minimal radial distances 23, 27 may vary according to the application, and may vary from cutter to cutter, and/or cutting element to cutting element.

[0023] In addition, a plurality of fixed cutting elements 31 are mounted to the fixed blades 19. At least one of the fixed cutting elements 31 is located at the axial center 15 of the bit body 13 and adapted to cut a formation at the axial center. In one embodiment, the at least one of the fixed cutting elements 31 is within approximately 0.040 inches of the axial center. Examples of rolling-cutter cutting elements 25 and fixed cutting elements 31 include tungsten carbide inserts, cutters made of super-hard material such as polycrystalline diamond, and others known to those skilled in the art.

[0024] FIGS. 3 and 4 illustrate the modular aspect of the bit constructed according to the present invention. FIG. 3 is an exploded view of the various parts of the bit 111 disassembled. The illustrative embodiment of FIG. 3 is a three-cutter, three-blade bit. The modular construction principles of the present invention are equally applicable to the two-cutter, two-blade bit 11 of FIGS. 1 and 2, and hybrid bits with any combination of fixed blades and rolling cutters.

[0025] As illustrated, bit 111 comprises a shank portion or section 113, which is threaded or otherwise configured at its upper extent for connection into a drillstring. At the lower extent of shank portion 113, a generally cylindrical receptacle 115 is formed. Receptacle 115 receives a correspondingly shaped and dimensioned cylindrical portion 117 at the upper extent of a bit body portion 119. Shank 113 and body 119 portions are joined together by inserting the cylindrical portion 117 at the upper extent of body portion 119 into the cylindrical receptacle 115 in the lower extent of shank 113. For the 12¼ inch bit shown, the receptacle is a Class 2 female thread that engages with a mating male thread at the upper extent of the body. The circular seam or joint is then continuously bead welded to secure the two portions or sections together. Receptacle 115 and upper extent 117 need not be cylindrical, but could be other shapes that mate together, or could be a sliding or running fit relying on the weld for strength. Alternatively, the joint could be strengthened by a close interference fit between upper extent 119 and receptacle 115. Tack welding around the seam could also be used.

[0026] A bit leg or head 121 (three are shown for the three-cutter embodiment of FIG. 3) is received in an axially extending slot 123 (again, there is a slot 123 for each leg or head 121). As shown in greater detail in FIG. 4, slot 123 is dovetailed (and leg 121 correspondingly shaped) so that only axial sliding of leg 121 is permitted and leg 121 resists radial removal from slot 123. A plurality (four) of bolts 127 and washers secure each leg 121 in slot 123 so that leg 121 is secured against axial motion in and removal from slot 123. A rolling cutter 125 is secured on a bearing associated with each leg 121 by a ball lock and seal assembly 129. The apertures in leg 121 through which bolts 127 extend are oblong, which

permits the axial positioning of leg 121 within slot 123, which in turn permits selection of the relative projection of the cutting elements on each rolling cutter. A lubricant compensator assembly 131 is also carried in each leg 121 and supplies lubricant to the bearing assembly and compensates for pressure variations in the lubricant during drilling operations. A preferred compensator is disclosed in commonly assigned U.S. Pat. No. 4,727,942 to Galle and Zahradnik. At least one nozzle 133 is received and retained in the bit body portion 119 to direct a stream of drilling fluid from the interior of bit 111 to selected locations proximate the cutters and blades of the bit.

[0027] FIG. 4 is a fragmentary section view of bit body 119 illustrating the configuration of slot 123. As previously noted, slot 123 has a pair of adjacent opposing sides 135 that are inclined toward one another at an acute included angle (from vertical) to define a dovetail. A third side, which may be curved or flat, connects the two opposing sides 135. A rectilinear 137 recess is formed within the third side for additional engagement between the bit leg and bit body. As stated, bit leg 121 is provided with a corresponding shape so that once assembled together, bit leg 121 resists removal from slot 123 except by axial force. Preferably, for the 12¼ inch bit illustrated, slot 123 is approximately 3.880 inches wide at its widest point, opposing sides 135 are inclined at an angle of approximately 15 degrees and converge to define an included angle of approximately 30 degrees. Recess 137 is approximately 1.880 inches wide and approximately 0.385 inches deep. The corresponding surfaces of bit leg 121 are similarly dimensioned, but between 0.005 and 0.010 inch smaller to provide a sliding or running fit within the slot. A close interference fit could also be used to enhance strength, at the cost of ease of assembly. A blind threaded hole or aperture 139 is formed in bit body 119 to receive each of the fasteners or bolts 127 (FIG. 3). Alternatively, the opposed sides 135 of slot 123 could be "straight," but such a construction will not be as strong as the "dovetailed" construction and may unduly strain bolts 127.

[0028] Thus, in accordance with the present invention, the threaded shank is separable from the bit body and each bit leg and associated rolling cutter is also separable from the bit body (along with the associated lubricant compensator, bearing and seal assembly). Thus, as the bit wears, various parts may be replaced as appropriate. If the bearing associated with a cutter loses lubricant and fails, the entire bit leg assembly can be replaced as needed. If the bit body wears to the degree that it will no longer support fixed cutters (or other parts of the bit assembly), it can be replaced. If the shank is damaged, it can be replaced. Although the welded joint is not typically considered a replaceable joint, in this instance, the weld can be removed, a new shank or body portion fitted, and there will be ample material remaining to permit re-welding of the two together.

[0029] While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention as hereinafter claimed, and legal equivalents thereof.

We claim:

1. An earth-boring bit comprising:

- a bit body configured at its upper end for connection into a drillstring;
- at least one fixed blade depending axially downwardly from the bit body;

- an axially extending slot formed in the bit body adjacent the fixed blade;

- a bit leg received and retained in the slot by engagement between the slot and correspondingly shaped bit leg, wherein the bit leg cannot be removed from the slot except by axial movement relative to the bit body; and
- at least one rolling cutter secured to the bit leg at its lower extent.

2. The earth-boring bit according to claim 1, further comprising:

- at least one fastener securing the bit leg against movement relative to the bit body.

3. The earth-boring bit according to claim 2, wherein the fasteners extend through oblong apertures in the bit leg and into the bit body, wherein the bit leg can be moved axially relative to the bit body to adjust the projection of the rolling cutter relative to the fixed blade.

4. The earth-boring bit according to claim 1, wherein the slot is formed by at least three sides, and at least one acute angle is formed by two adjacent sides.

5. The earth-boring bit according to claim 1, wherein the slot defines a pair of generally opposed sides connected by a third side, the generally opposed sides being inclined toward one another to define a dovetail that corresponds with the shape of the bit leg.

6. The earth-boring bit according to claim 1, wherein the bit body further comprises:

- a bit body portion having an upper extent; and
- a shank that is configured for connection into the drillstring at its upper extent and configured for connection to the bit body at its lower extent, wherein the shank and bit body portions are secured together by welding.

7. The earth-boring bit according to claim 1, further comprising:

- a nozzle removably secured in the bit body, the nozzle receptacle configured to receive a nozzle;
- a bearing formed integrally with the bit leg, the rolling cutter mounted for rotation on the bearing; and
- a lubricant compensator removably secured in the bit leg, the lubricant compensator in fluid communication with the bearing.

8. An earth-boring bit comprising:

- a shank configured at its upper extent for connection into a drillstring and having a lower extent;
- a body portion configured to connect to the lower extent of the shank, the shank and body portions being removably secured together to form a bit body;
- at least one fixed blade depending axially downwardly from the bit body;
- an axially extending slot formed in the bit body adjacent the fixed blade;
- a bit leg received and retained in the slot by engagement between the slot and correspondingly shaped bit leg;
- at least one rolling cutter secured to the bit leg at its lower extent; and
- at least one fastener securing the bit leg against movement relative to the bit body.

9. The earth-boring bit according to claim 8, wherein the fasteners extend through oblong apertures in the bit leg and into the bit body, wherein the bit leg can be moved axially relative to the bit body to adjust the projection of the rolling cutter relative to the fixed blade.

10. The earth-boring bit according to claim 8, wherein the slot is formed by at least three sides and at least one acute angle is formed by two adjacent sides.

11. The earth-boring bit according to claim 8, wherein the slot defines a pair of generally opposed sides connected by a third side, the generally opposed sides being inclined toward one another to define a dovetail that corresponds with the shape of the bit leg.

12. The earth-boring bit according to claim 8, wherein: the upper extent of the bit body and the receptacle in the shank portion are generally cylindrical and the receptacle is dimensioned to receive the upper extent of the bit body, wherein the shank and bit body portions are secured together by welding.

13. The earth-boring bit according to claim 8, further comprising:

- a nozzle removably secured in the bit body, the nozzle receptacle configured to receive a nozzle;
- a bearing formed integrally with the bit leg, the rolling cutter mounted for rotation on the bearing; and
- a lubricant compensator removably secured in the bit leg, the lubricant compensator in fluid communication with the bearing.

14. The earth-boring bit according to claim 8, wherein the fasteners are bolts and the pin and body portions are secured together by welding.

15. An earth-boring bit comprising:

- a shank configured at its upper extent for connection into a drillstring and having a receptacle formed in its lower extent;
- a body portion having an upper extent shaped and dimensioned to be received in the receptacle in the lower extent of the shank, the shank and body portions being removably secured together;

at least one fixed blade depending axially downwardly from the body portion;

an axially extending slot formed in the body portion adjacent the fixed blade;

a bit leg received and retained in the slot by engagement between the slot and correspondingly shaped bit leg, the bit leg having a removable lubricant compensator assembly in fluid communication with a bearing at a lower extent of the bit leg;

at least one rolling cutter mounted for rotation on the bearing of the bit leg; and

at least one fastener securing the bit leg against axial movement relative to the bit body.

16. The earth-boring bit according to claim 15, wherein the fasteners extend through oblong apertures in the bit leg and into the bit body, wherein the bit leg can be moved axially relative to the bit body to adjust the projection of the rolling cutter relative to the fixed blade.

17. The earth-boring bit according to claim 15, wherein the slot is formed by at least three sides and at least one acute angle is formed by two adjacent sides.

18. The earth-boring bit according to claim 15, wherein the slot defines a pair of generally opposed sides connected by a third side, the generally opposed sides being inclined toward one another to define a dovetail that corresponds with the shape of the bit leg.

19. The earth-boring bit according to claim 15, wherein the fasteners are bolts and the pin and body portions are secured together by welding.

20. The earth-boring bit according to claim 15, wherein the receptacle in the shank and the upper extent of the body portion are generally cylindrical.

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