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(54) HYBRID DRILL BIT AND DESIGN METHOD

HYBRIDBOHRMEISSEL UND KONSTRUKTIONSVVERFAHREN

TRÉPAN HYBRIDE ET SON PROCÉDÉ DE CONCEPTION

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates in general to earth-boring bits and, in particular, to an improved bit having a combination of rolling-cutters and fixed cutters and cutting elements and a method of design and operation of such bits.

BACKGROUND

10 **[0002]** 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. Patent No. 930,759, drilled the caprock at the Spindletop field near Beaumont, Texas, with relative ease. That venerable invention, within the first decade of the last century, could drill a scant fraction
15 of the depth and speed of the modern rotary rock bit. The original Hughes bit drilled for hours; the modern bit now drills for days. Modern bits sometimes drill for thousands of feet (hundreds of meters) instead of merely a few feet/meters. Many advances have contributed to the impressive improvements in rotary rock bits.

[0003] 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 drill string that is
20 rotated from the surface or by downhole motors or turbines. The cutters mounted on the bit roll and slide upon the bottom of the borehole as the drill string 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 drill string. The cuttings from the bottom and sides of the borehole are washed away and disposed by drilling fluid that is pumped down from the surface through the hollow, rotating drill string, and the nozzles
25 as orifices on the drill bit. Eventually the cuttings are carried in suspension in the drilling fluid to the surface up the exterior of the drill string.

[0004] Rolling-cutter bits dominated petroleum drilling for the greater part of the 20th century. With improvements in synthetic diamond technology that occurred in the 1970s and 1980s, the fixed blade cutter bit or drag bit became popular again in the latter part of the 20th century. Modern fixed blade cutter bits are often referred to as "diamond" or "PDC"
30 (polycrystalline diamond cutter bits) bits and are far removed from the original fixed bladecutter bits of the 19th and early 20th 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 element being arranged in selected location on blades or other structures on the bit body with the diamond tables facing generally in the direction of bit rotation. Fixed blade cutter bits have the advantage of being much more aggressive during drilling
35 and therefore drill much faster at equivalent weight-on-bit levels (WOB) than, for instance, a rolling-cutter bit. In addition, they have no moving parts, which make their design less complex and more robust. The drilling mechanics and dynamics of fixed blade cutter bits are different from those of rolling-cutter bits precisely because they are more aggressive in cutting and require more torque to rotate during drilling. During a drilling operation, fixed blade cutter bits are used in a manner similar to that for rolling-cutter bits, the fixed blade cutter bits also being rotated against a formation being drilled
40 under applied weight-on-bit to remove formation material. The cutting elements on the fixed blade cutters are continuously engaged as they scrape material from the formation, while in a rolling-cutter bit the cutting elements on each rolling cutter indent the formation intermittently with little or no relative motion (scraping) between the cutting element and the formation. A rolling-cutter bit and a fixed blade cutter bit each have particular applications for which they are more suitable than the other. The much more aggressive fixed blade cutter bit is superior in drilling in a softer formation to a medium hard formation while the rolling-cutter bit excels in drilling hard formations, abrasive formations, or any combination
45 thereof.

[0005] In the prior art, some earth-boring bits use a combination of one or more rolling cutters and one or more fixed blade cutters. Some of these combination-type drill bits are referred to as hybrid bits. Previous designs of hybrid bits, such as U.S. Patent 4,343,371, to Baker, III, have used rolling-cutters to do most of the formation cutting, especially in
50 the center of the hole or bit. Another type of hybrid bit is described in U.S. Patent 4,444,281, to Schumacher, has equal numbers of fixed blade cutters and rolling-cutters in essentially symmetrical arrangements. In such bits, the rolling-cutters do most of the cutting of the formation while the fixed blade cutters act as scrapers to remove uncut formation indentations left by the rolling-cutters as well as cuttings left behind by the rolling-cutters. While such a hybrid bit improves the cutting efficiency of the hybrid bit over that of a rolling-cutter bit in softer formations, it has only a small or marginal effect on
55 improving the overall performance in harder formations. When comparing a fixed blade cutter bit to a rolling-cutter bit, the high cutting aggressiveness of a fixed blade cutter bit frequently causes such bit to reach the torque capacity or limit of a conventional rotary table drilling systems or motors, even at a moderate level of weight-on-bit during drilling, particularly on larger diameter drill bits. The reduced cutting aggressiveness of a rolling-cutter bit, on the other hand,

frequently causes the rolling-cutter bit to exceed the weight-on-bit limits of the drill string before reaching the full torque capacity of a conventional rotary table drive drilling system.

[0006] GB 2 183 694 A discloses a hybrid drill bit having a cone, a nose, and a shoulder. The body of the drill bit has a centerline as the axis of rotation. Several fixed blade cutters are attached to the bit body about the centerline and two rolling cutters are mounted for rotation on a bit leg secured to the bit body about the centerline. A plurality of cutting elements is arranged in a first position a first radial distance in the cone of the hybrid bit from the centerline of the bit body on a leading edge of the fixed blade cutter. A first cutting element on the rolling cutters is arranged in a first position a second radial distance from the centerline of the bit body on the rolling cutter.

[0007] US 2005/087370 A1 discloses a method for varying cutting aggressiveness of a hybrid bit having a bit body and three rolling cutters mounted for rotation on a bit leg depending downwardly from the body. A plurality of cutting elements is arranged on each rolling cutter. The aggressiveness of the bit is defined as a function of penetration rate of the bit during drilling. The aggressiveness is adjusted by adjusting the effective projection between at least two adjacent cutting elements on a rolling cutter.

[0008] The object of the invention is to provide a method for varying cutting aggressiveness of a hybrid drill bit and a corresponding hybrid drill bit having a high aggressiveness.

CLOSEST PRIOR ART DOCUMENT

[0009] US 4 343 371 A discloses a hybrid rock bit having a pair of opposing roller cones with cutting elements extending from and disposed on the surface. The bit further consists of a pair of opposing drag bit leg segments on opposite sides of the cutter cones having a plurality of strategically positioned diamond cutting elements extending from and mounted to the surface of the drag bit leg. As the cones roll on the borehole bottom, inner inserts in rows "A," "B," "C," and "D" of each of the opposed cones cut deep, relatively narrow kerfs in the borehole bottom. The ridges that remain adjacent to the kerfs are subsequently removed by the drag bit leg segments.

[0010] This object is achieved by a method comprising the features of claim 1. Preferred ways to carry out the method of the invention are claimed in claims 2 to 7.

[0011] The above object is further achieved by a hybrid drill bit comprising the features of claim 8. Preferred embodiments of the hybrid drill bit of the invention are claimed in claims 9 to 12.

[0012] A hybrid earth-boring bit comprising a bit body having a central axis, at least one, preferably three fixed blade cutters, depending downwardly from the bit body, each fixed blade cutter having a leading edge, and at least one rolling-cutter, preferably three rolling-cutters, mounted for rotation on the bit body. A fixed blade cutter and a rolling-cutter forming a pair of cutters on the hybrid bit body. When there are three rolling-cutters, each rolling-cutter is located between two fixed blade cutters.

[0013] A plurality of cutting elements is arranged on the leading edge of each fixed blade cutter and a plurality of cutting elements is arranged on each of the rolling-cutters. The rolling-cutters each have cutting elements arranged to engage formation in the same swath or kerf or groove as a matching cutting element on a fixed blade cutter. In the pair of cutters, the matching fixed blade cutter being arranged to be either trailing, leading, or opposite the rolling-cutter to adapt the hybrid bit to the application by modifying the cutting aggressiveness thereof to get the best balance between the rate-of penetration of the bit and the durability of the bit for the pair of cutters.

[0014] A method for designing a hybrid earth-boring bit of the present invention permits or allows the cutting aggressiveness of a hybrid bit to be adjusted or selected based on the relationship of at least a pair of cutters comprising a fixed blade cutter and a rolling-cutter, of a plurality of fixed blade cutters and rolling-cutters, wherein the relationship includes a fixed blade cutter leading a rolling-cutter in a pair of cutters, a rolling cutter leading a fixed blade cutter in a pair of cutters, a rolling-cutter being located opposite a fixed blade cutter in a pair of cutters on the bit, and the angular relationship of a fixed blade cutter and a rolling-cutter of a pair of cutter regarding the amount of leading or trailing of the cutter from an associated cutter of the pair of cutters. The cutting aggressiveness of a hybrid bit of the present invention being achieved by defining a cutting aggressiveness of a hybrid drill bit and the various combinations of pair of a fixed blade cutter and a rolling-cutter, when compared to each other and to different types of drill bits, such as a rolling-cutter drill bit and a fixed blade cutter drill bit, either as the ratio of torque to weight-on-bit or as the ratio of penetration rate to weight-on-bit. The cutting aggressiveness for a hybrid bit of the present invention being adjusted by performing at least one of the following steps:

- adjusting the angular distance between each rolling-cutter and each fixed blade cutter of a pair of cutters of the bit;
- adjusting the effective projection of the cutting elements on a rolling cutter;
- arranging the cutting elements of a fixed blade cutter and the cutting elements of a rolling-cutter so that at least one cutting element of a rolling-cutter and at least one cutting element of a fixed blade cutter cut the same swath or kerf or groove during a drilling operation; and
- arranging a pair of at least one cutting element of a fixed blade cutter and cutting element of a rolling-cutter so that

the rolling cutter either leads the fixed blade cutter ($<180^\circ$ angular distance], the rolling-cutter opposes the fixed blade cutter [$=180^\circ$ angular distance], or trails the fixed blade cutter [$>180^\circ$ angular distance].

[0015] Other features and advantages of the present invention become apparent with reference to the drawings and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a graph illustrating the relative aggressiveness of a rolling-cutter bit, a fixed blade cutter bit having polycrystalline diamond cutters or PDC bit, and embodiments of hybrid bits of the present inventions.

FIG. 2 is an elevation view of a hybrid earth-boring bit illustrative of the present invention.

FIG. 3 is a bottom plan form view of the hybrid earth-boring bit of FIG. 2.

FIG. 3A is a view of cutting elements of a three fixed blade cutters and cutting elements of three rolling-cutters of embodiments of a hybrid bit of the present inventions of FIGS. 1 through 3.

FIG. 3B is a view of cutting elements of a first fixed blade cutter and cutting elements of a first rolling-cutter of an embodiment of a hybrid bit of the present invention;

FIG. 3C is a view of cutting elements of a second fixed blade cutter and cutting elements of a second rolling-cutter of an embodiment of a hybrid bit of the present invention;

FIG. 3D is a view of cutting elements of a third fixed blade cutter and cutting elements of a third rolling-cutter of an embodiment of a hybrid bit of the present invention;

FIG. 3E is a view of FIG. 3 showing a rolling-cutter and a fixed blade cutter of a hybrid bit of FIG. 3 of the present invention.

FIG. 3F is a view of FIG. 3 showing another fixed blade cutter and another rolling-cutter of a hybrid bit of FIG. 3 of the present invention.

FIG. 4 is a bottom plan form view of another embodiment of a hybrid earth-boring bit of the present invention.

FIGS. 5 and 6 are partial schematic views of rolling-cutters and cutting elements of rolling-cutters interfacing with the formation being drilled.

MODE(S) FOR CARRYING OUT THE INVENTION

[0017] Turning now to the drawing figures, and particularly to FIG. 1, the characteristics of various embodiments of the present invention are described. FIG. 1 is a graph of rate-of-penetration (ROP on y-axis) versus weight-on-bit (WOB on x-axis) for earth-boring bits such as a fixed blade cutter bit, a hybrid bit of the present invention, and a three rolling-cutter bit (three roller cone bit). The data for the bits illustrated in solid unbroken lines of the graph was generated using 121/4/ inch bits on the Hughes Christensen simulator in The Woodlands, Texas. The conditions were 4000 pounds (1815.6 kilograms) per square inch (2.54 cm²) of bottom-hole pressure, 120 bit revolutions per minute, and 9.5 pounds (4.306 kilograms) per gallon (3.78 liters) drilling fluid or mud while drilling Carthage marble. The broken lines illustrate expected rate-of-penetration (ROP on y-axis) versus weight-on-bit (WOB on x-axis) for different configurations of hybrid earth-boring bits of the present inventions. The data used and reflected in FIG. 1 is intended to be general and to reflect general characteristics for the three types of bits, such as fixed blade cutter bits having PDC cutting elements, hybrid bits including variations thereof of the present inventions, and rolling-cutter bits (roller cone bits) whose cutting aggressiveness characteristics are illustrated.

[0018] The solid lines on the graph show the cutting performance characteristics of three different types of earth-boring bits: a three rolling-cutter bit (three roller cones), a six blade fixed cutter bit having PDC cutting elements, and a "hybrid" bit having both (three) rolling-cutters and (three) fixed blade cutters having PDC cutting elements on the fixed blade cutters (in the "rolling- cutter leading" configuration of the present invention, as described hereinbelow). As shown, each type of bit has a characteristic line. The six fixed blade cutter bit having PDC cutting elements has the highest ROP for a given WOB resulting in a line having the steepest slope of the line showing cutting performance of the bit. The three rolling-cutter bit (three roller cone bit) has the lowest ROP for a given WOB resulting in a line having the shallowest slope of the line showing cutting performance of the bit. The hybrid bit of the present invention exhibits intermediate ROP for a given WOB resulting in a line having an intermediate slope of the line showing cutting performance of the bit between the line for the fixed blade cutter bit and the three rolling-cutter bit.

[0019] The slope of the line (curve) plotted for ROP versus WOB for a given bit can be termed or defined as the bit's cutting aggressiveness or simply "Aggressiveness" as used herein. "Aggressiveness," for purposes of this application and the inventions described herein, is defined as follows:

(1) Aggressiveness = Rate of Penetration (ROP) / Weight on Bit (WOB)

Thus aggressiveness, as the mathematical slope of a line, has a value greater than zero. Measured purely in terms of aggressiveness, it would seem that fixed blade cutter bits would be selected in all instances for drilling. However, other factors come into play. For example, there are limits on the amount of WOB and torque to turn the bit that can be applied, generally based on either the drilling application or the capacity of the drill string and drilling rig. Similarly, as WOB and ROP increase, the drill string torque requirements for a bit increase rapidly, especially with fixed blade cutter bits, and cause harmful vibrations. Rolling-cutter bits, on the other hand, require high WOB which, in the extreme, may buckle a bottom hole assembly or exceed the load bearing capacity of the cutter bearings of the rolling-cutters of the rolling-cutter bit. Accordingly, different types of bits, whether a fixed blade cutter bit, a rolling-cutter bit, or a hybrid bit, have different advantages in different situations. One aspect of the present invention is to provide a method for the design of a hybrid earth-boring bit so that its aggressiveness characteristics can be tailored or varied to the drilling application.

[0020] FIGS. 2, 3, and 4 illustrate embodiments of hybrid earth-boring bits 11 according to the present invention. Hybrid bit 11 comprises a bit body 13 that is threaded or otherwise configured at its upper extent for connection into a drill string. Bit body 13 may be constructed of steel, or of a hard-metal (e.g., tungsten carbide) matrix material with steel inserts. Bit body 13 has an axial center or centerline 15 that coincides with the axis of rotation of hybrid bit 11 in most instances. The illustrated hybrid bit 11 is a 12-1/4 inch bit. The hybrid bit 11 shown in FIG. 3 is used to exemplify the techniques of adjusting the aggressiveness of a hybrid bit according to the present invention, i.e., cutter leading, "blade-leading," and "cutter-blade opposite," as described herein. One of the embodiments of the hybrid bits of the present inventions illustrated in FIG. 3, is likely not a desirable production hybrid bit design when the hybrid bit is an all blade-leading design because aggressiveness of the hybrid bit is too great for certain types of formations, but not all types of formations. That is, if the hybrid bit is a hybrid bit having an all blade-leading design, it acts more as a fixed blade cutter bit. As illustrated in FIG. 1, aggressiveness of such hybrid bit is high which might adversely affect its durability and dynamic stability.

[0021] Illustrated in FIG. 2 and FIG. 3, at least one bit leg (two of three are shown in FIG. 2) 17, 19, 21 depends axially downwardly from the bit body 13. In the illustrated embodiment, a lubricant compensator is associated with each bit leg to compensate for pressure variations in the lubricant provided for the bearing. In between each bit leg 17, 19, 21, at least one fixed blade cutter (again three are shown) 23, 25, 27 depends axially downwardly from bit body 13.

[0022] A rolling cutter 29, 31, 33 is mounted for rotation (typically on a journal bearing, but rolling-element or other bearings may be used as well) on each bit leg 17, 19, 21. Each rolling-cutter 29, 31, 33 has a plurality of cutting elements 35, 37, 39 arranged in generally circumferential rows thereon. In the illustrated embodiment, cutting elements 35, 37, 39 are tungsten carbide inserts, each insert having an interference fit into bores or apertures formed in each rolling cutter 29, 31, 33. Alternatively, cutting elements 35, 37, 39 can be integrally formed with the cutter and hardfaced, as in the case of steel- or milled-tooth cutters. Materials other than tungsten carbide, such as polycrystalline diamond or other super-hard or super-abrasive materials, can also be used for rolling-cutter cutting elements 35, 37, 39 on rolling-cutters 29, 31, 33.

[0023] A plurality of cutting elements 41, 43, 45 are arranged in a row on the leading edge of each fixed blade cutter 23, 25, 27. Each cutting element 41, 43, 45 is a circular disc of polycrystalline diamond mounted to a stud of tungsten carbide or other hard metal, which is in turn soldered, brazed or otherwise secured to the leading edge of each fixed blade cutter. Thermally stable polycrystalline diamond (TSP) or other conventional fixed-blade cutting element materials may also be used. Each row of cutting elements 41, 43, 45 on each of the fixed blade cutters 23, 25, 27 extends from the central portion of bit body 13 to the radially outermost or gage portion or surface of bit body 13. On at least one of the rows on one of the fixed blade cutters 23, 25, 27, a cutting element 41 on a fixed-blade cutter 23 is located at or near the central axis or centerline 15 of bit body 13 ("at or near" meaning some part of the fixed cutter is at or within about 1 mm of the centerline 15). In the illustrated embodiment, the radially innermost cutting element 41 in the row on fixed blade cutter 23 has its circumference tangent to the axial center or centerline 15 of the bit body 13 and hybrid bit 11.

[0024] A plurality of flat-topped, wear-resistant inserts 51 formed of tungsten carbide or similar hard metal with a polycrystalline diamond cutter attached thereto are provided on the radially outermost or gage surface of each fixed blade cutter 23, 25, 27. These serve to protect this portion of the bit from abrasive wear encountered at the sidewall of the borehole. Also, a row or any desired number of rows of back-up cutters 53 is provided on each fixed blade cutter 23, 25, 27 between the leading and trailing edges thereof. Back-up cutters 53 may be aligned with the main or primary cutting elements 41, 43, 45 on their respective fixed blade cutters 23, 25, 27 so that they cut in the same swath or kerf or groove as the main or primary cutting elements on a fixed blade cutter. Alternatively, they may be radially spaced apart from the main fixed-blade cutting elements so that they cut in the same swath or kerf or groove or between the same swaths or kerfs or grooves formed by the main or primary cutting elements on their respective fixed blade cutters. Additionally, back-up cutters 53 provide additional points of contact or engagement between the bit 11 and the formation

being drilled, thus enhancing the stability of hybrid bit 11.

[0025] In the embodiments of the inventions illustrated in FIG. 3, rolling-cutters 29, 31, 33 are angularly spaced approximately 120 degrees apart from each other (measured between their axes of rotation). The axis of rotation of each rolling-cutter 29, 31, 33 intersecting the axial center 15 of bit body 13 or hybrid bit 11, although each or all of the rolling-cutters 29, 31, 33 may be angularly skewed by any desired amount and (or) laterally offset so that their individual axes do not intersect the axial center of bit body 13 or hybrid bit 11. As illustrated, a first rolling-cutter 29 is spaced apart 58 degrees from a first fixed blade 23 (measured between the axis of rotation of rolling cutter 29 and the centerline of fixed blade 23 in a clockwise manner in FIG. 3) forming a pair of cutters. A second rolling-cutter 31 is spaced 63 degrees from a second fixed blade 25 (measured similarly) forming a pair of cutters; and a third rolling-cutter 33 is spaced 53 degrees apart from a third fixed blade 27 (again measured the same way) forming a pair of cutters.

[0026] In FIG. 3A, a cutting profile for the fixed cutting elements 41, 45, 43 on fixed blade cutters 23, 25, 27 and cutting elements 35, 37, 39 on rolling-cutters 29, 33, 31 are generally illustrated. As illustrated, an inner most cutting element 41 on fixed blade cutter 23 is tangent to the axial center 15 of the bit body 13 or hybrid bit 11. The innermost cutting element 43 on fixed blade cutter 27 is illustrated. Also, innermost cutting element 45 on fixed blade cutter 25 is also illustrated. A cutting element 35 on rolling-cutter 29 is illustrated having the same cutting depth or exposure and cutting element 41 on fixed blade cutter 23 each being located at the same centerline and cutting the same swath or kerf or groove. Some cutting elements 41 on fixed blade cutter 23 are located in cone of the hybrid bit 11, while other cutting elements 41 are located in the nose and shoulder portion of the hybrid bit 11 having cutting elements 35 of rolling cutter 29 cutting the same swath or kerf or groove generally in the nose and shoulder of the hybrid bit 11 out to the gage thereof. Cutting elements 35, 37, 39 on rolling-cutters 29, 33, 31 do not extend into the cone of the hybrid bit 11 but are generally located in the nose and shoulder of the hybrid bit 11 out to the gage of the hybrid bit. Further illustrated in FIG. 3A are the cutting elements 37, 39 on rolling-cutters 31 and 33 and their relation to the cutting elements 43 and 45 on fixed blade cutters 27, 25 cutting the same swath or kerf or groove either being each being centered thereon or offset in the same swath or kerf or groove during a revolution of the hybrid drill bit 11. While each cutting element 41, 43, 45 and cutting element 35, 37, 39 has been illustrated having the same exposure of depth of cut so that each cutting element cuts the same amount of formation, the depth of cut may be varied in the same swath or kerf or groove, if desired.

[0027] Illustrated in FIG. 3B is a cutting profile for the fixed cutting elements 41 on fixed blade cutter 23 and cutting elements 35 on rolling-cutter 29 in relation to the each other, the fixed blade cutter 23 and the rolling-cutter 29 forming a pair of cutters on hybrid bit 11. As illustrated, some of the cutting elements 41 on fixed blade cutter 23 and cutting element 35 on rolling-cutter 29 both have the same center and cut in the same swath or kerf or groove while other cutting elements 41' on fixed blade cutter 23 and cutting element 35' on rolling cutter 29 do not have the same center but still cut in the same swath or kerf or groove. As illustrated, all the cutting elements 41 and 41' on fixed blade cutter 23 and cutting elements 35 and 35' on rolling cutter 29 have the same exposure to cut the same depth of formation for an equal cut of the formation during a revolution of the hybrid drill bit 11, although this may be varied as desired. Further illustrated in FIG. 3B in broken lines, backup cutting elements 53 on fixed blade 23 located behind cutting elements 41 may have the same exposure of cut as cutting elements 41 or less exposure of cut as cutting elements 41 and have the same diameter or a smaller diameter than a cutting element 41. Additionally, backup cutting elements 53 while cutting in the same swath or kerf or groove 41' as a cutting element 41 may be located off the center of a cutting element 41 located in front of a backup cutting element 53 associated therewith. In this manner, cutting elements 41 and backup cutting elements 53 on fixed blade 23 and cutting elements 35 on rolling cutter 29 will all cut in the same swath or kerf or groove while being either centered on each other or slightly off-centered from each other having the same exposure of cut or, in the alternative, a lesser exposure of cut.

[0028] Illustrated in FIG. 3C is a cutting profile for the fixed cutting elements 43 on fixed blade cutter 27 in relation to the cutting elements 37 on rolling-cutter 33, the fixed blade cutter 27 and the rolling-cutter 33 forming a pair of cutters on hybrid bit 11. As illustrated, some of the cutting elements 43 on fixed blade cutter 27 and cutting element 37 on rolling-cutter 33 both have the same center and cutting in the same swath or kerf or groove while other cutting elements 43' on fixed blade cutter 27 and cutting element 37' on rolling cutter 33 do not have the same center but cut in the same swath or kerf or groove. As illustrated, all the cutting elements 43 and 43' on fixed blade cutter 27 and cutting elements 37 and 37' on rolling cutter 33 have the same exposure to cut the same depth of formation for an equal cut of the formation during a revolution of the hybrid drill bit 11, although this may be varied as desired. Further illustrated in FIG. 3C in broken lines, backup cutting elements 53 on fixed blade 27 located behind cutting elements 43 may have the same exposure of cut as cutting elements 43 or less exposure of cut as cutting elements 43 and have the same diameter or a smaller diameter than a cutting element 43. Additionally, backup cutting elements 53 while cutting in the same swath or kerf or groove as a cutting element 43 may be located off the center of a cutting element 43 associated therewith. In this manner, cutting elements 43 and backup cutting elements 53 on fixed blade cutter 27 and cutting elements 37 on rolling cutter 33 will all cut in the same swath or kerf or groove while being either centered on each other or slightly off-centered from each other having the same exposure of cut or, in the alternative, a lesser exposure of cut.

[0029] Illustrated in FIG. 3D is a cutting profile for the fixed cutting elements 45 on fixed blade cutter 25 in relation to

cutting elements 39 on rolling-cutter 31 forming a pair of cutters on hybrid bit 11. As illustrated, some of the cutting elements 45 on fixed blade cutter 25 and cutting element 39 on rolling-cutter 31 both have the same center and cutting in the same swath or kerf or groove while other cutting elements 45' on fixed blade cutter 25 and cutting element 39' on rolling cutter 31 do not have the same center but cut in the same swath or kerf or groove. As illustrated, all the cutting elements 45 and 45' on fixed blade cutter 25 and cutting elements 39 and 39' on rolling cutter 31 have the same exposure to cut the same depth of formation for an equal cut of the formation, although this may be varied as desired. As illustrated, all the cutting elements 45 and 45' on fixed blade cutter 25 and cutting elements 39 and 39' on rolling-cutter 31 have the same exposure to cut the same depth of formation for an equal cut of the formation during a revolution of the hybrid drill bit 11. Further illustrated in FIG. 3D in broken lines, backup cutting elements 53 on fixed blade 25 located behind cutting elements 45 may have the same exposure of cut as cutting elements 45 or less exposure of cut as cutting elements 45 and have the same diameter or a smaller diameter than a cutting element 45. Additionally, backup cutting elements 53 while cutting in the same swath or kerf or groove as a cutting element 45 may be located off the center of a cutting element 45 associated therewith. In this manner, cutting elements 45 and backup cutting elements 53 on fixed blade cutter 25 and cutting elements 39 on rolling cutter 31 will all cut in the same swath or kerf or groove while being either centered on each other or slightly off-centered from each other having the same exposure of cut or, in the alternative, a lesser exposure of cut.

[0030] When considering a pair of cutters of the hybrid bit 11 including a rolling cutter and a fixed blade cutter, each having cutting elements thereon, having the same exposure of cut, and located at the same radial location from the axial center of the hybrid bit 11 cutting the same swath or kerf or groove, adjusting the angular spacing between rolling cutters 29, 31, 33, and fixed blade cutters 23, 25, 27 is one way in which to adjust the cutting aggressiveness or aggressiveness of a hybrid bit 11 according to the present invention. When considering a pair of cutters having cutting elements thereon having the same exposure of cut and located at the same radial location from the axial center of the hybrid bit 11 cutting the same swath or kerf or groove on the hybrid bit 11, the closer a rolling cutter 29 is to a fixed blade cutter 23 of the pair of cutters of the hybrid bit 11, the rolling-cutter 29 is the primary cutter of the pair with the fixed blade cutter 23 cutting less of the pair. Spacing a rolling cutter 29 closer to a fixed blade cutter 23 of a pair of cutters on the hybrid bit 11 causes the rolling cutter 29 to have a more dominate cutting action of the pair of cutters thereby causing the hybrid bit 11 to have a less cutting aggressiveness or aggressiveness. Spacing a rolling-cutter 29 farther away from a fixed blade cutter 23 of a pair of cutters on the hybrid bit 11 allows or causes the cutting elements of the fixed blade cutter 23 to dominate the cutting action of the pair of cutters thereby increasing the cutting aggressiveness or aggressiveness of the hybrid bit 11.

[0031] Another way of altering the cutting aggressiveness of a hybrid bit 11 is by having a rolling cutter to lead a trailing fixed blade cutter of a pair of cutters (including one of each type of cutter) or to have a fixed blade cutter lead a trailing rolling cutter of a pair of cutters (including one of each type of cutter). As illustrated in drawing FIG. 1, when a fixed blade cutter leads a rolling cutter of a pair of cutters of a hybrid bit 11 (see line HBLC), the hybrid bit 11 has more cutting aggressiveness cutting more like a fixed blade cutter polycrystalline diamond (PDC) bit. As illustrated in FIG. 1, when a rolling cutter leads a fixed blade cutter of a pair of cutters of a hybrid bit 11 (see line HCLB), the aggressiveness decreases with the hybrid bit having aggressiveness more like a rolling-cutter (roller cone) bit.

[0032] In the illustrated hybrid bit 11 of FIG. 3E, for the purposes of illustrating different embodiments of the present invention, one rolling cutter 29 "leads" its trailing fixed blade cutter 23 as a pair of cutters. As illustrated in FIG. 3F as another embodiment of the present invention, one fixed blade cutter 25 "leads" its trailing rolling cutter 33 as a pair of cutters. By "leads" it is meant that the cutting elements on the adjacent, trailing structure (whether fixed blade cutter or rolling cutter) are arranged to fall in the same swath or kerf or groove as that made by the cutting elements on the leading structure (whether a fixed blade cutter or rolling cutter), as indicated by phantom lines in FIG. 3E or FIG. 3F. Thus, the cutting elements 41 on fixed blade cutter 23 fall in the same swath or kerf or groove (see FIG. 3A, FIG. 3B) as the cutting elements 35 on rolling cutter 29. Similarly, the cutting elements 37 on rolling-cutter 33 fall in the same swath or kerf or groove (see FIG. 3A, FIG. 3C) as cutting elements 45 on fixed blade cutter 25. when a rolling cutter leads a trailing fixed blade cutter, cutting aggressiveness or aggressiveness of the hybrid bit 11 is decreased. Conversely, when a fixed blade cutter leads a trailing rolling-cutter, cutting aggressiveness or aggressiveness of the hybrid bit 11 is increased. Such is illustrated in FIG. 1 in the broken lines labeled HCLB and HBLC therein.

[0033] Also, in the embodiments of FIG. 3, rolling cutter 31 has its cutting elements 39 arranged to lead the cutting elements 43 on the opposing (if not directly opposite, i.e., 180 degrees) fixed blade cutter 27. Thus, being angularly spaced-apart approximately 180 degrees on the hybrid bit 11, fixed blade cutter 27 and rolling-cutter 31 bear load approximately equally on the hybrid bit 11. In most cases, where there are an equal number of fixed blade cutters and rolling-cutters, each fixed blade cutter should be "paired" with a rolling-cutter such that the cutting elements on the paired fixed blade cutter and rolling-cutter fall in the same swath or kerf or groove when drilling a formation. All rolling cutters can lead all fixed blade cutters, making a less aggressive bit (see solid line HCLB in FIG. 1); or all fixed blade cutters can lead all rolling-cutters, making a more aggressive bit (see broken line HBLC in FIG. 1), or the all cutting elements of a rolling-cutter can fall in the same swath or kerf or groove as the cutting elements on an opposing fixed blade (see

broken line HCOB in FIG. 1), or any combination thereof on a hybrid bit of the present invention.

[0034] FIG. 4 illustrates an embodiment of the earth-boring hybrid bit 111 according to the present invention that is similar to the embodiments of FIG. 3 in all respects, except that cutting elements 135, 137, 139 on each of the rolling cutters-129, 133, 131 respectively are arranged to cut in the same swath or kerf or groove as the cutting elements 145, 141, 143 on the opposite or opposing fixed blade cutters 125, 122, 127 respectively. Thus, the cutting elements 135 on rolling cutter 129 fall in the same swath or kerf or groove as the cutting elements 145 on the opposing fixed blade cutter 125. The same is true for the cutting elements 139 on rolling cutter 131 and the cutting elements 143 on the opposing fixed blade cutter 127; and the cutting elements 137 on rolling cutter 133 and the cutting elements 141 on opposing fixed blade cutter 123. This can be called a "cutter-opposite" arrangement of cutting elements. In such an arrangement, rather than the cutting elements on a fixed blade cutter or rolling-cutter "leading" the cutting elements on a trailing rolling-cutter or fixed blade cutter, the cutting elements on a fixed blade cutter or rolling-cutter "oppose" those on the opposing or opposite rolling-cutter or fixed blade cutter.

[0035] The hybrid bit 111 of FIG. 4, having the "cutter-opposite" configuration of pairs of cutters, appears to be extremely stable in comparison to all configurations of "cutter-leading" pairs of cutters or all "blade-leading" pairs of cutters. Additionally, based on preliminary testing, the hybrid bit 111 of FIG. 4 out drills a conventional rolling-cutter bit and a conventional fixed blade cutter bit having polycrystalline diamond cutting elements (PDC bit), as well as other hybrid bit configurations ("cutter-leading") in hard sandstone. For example, a conventional 12-1/4 inch rolling-cutter bit drills the hard sandstone at 11 feet/hour (3.35 meters/hour), a conventional fixed blade cutter bit having polycrystalline diamond cutting elements (PDC bit) at 13 feet/hour (3.96 meters/hour), the hybrid bit with "cutter-leading" pair of cutters configuration at 14 feet/hour (4.26 meters/hour) and the hybrid bit with "cutter-opposite" pair of cutters configuration at 21 feet/hour (6.40 meters/hour). Some different types of hard sandstone is the material that is most difficult to drill using fixed blade cutter bits having polycrystalline diamond cutting elements (PDC bits) due to a level of scatter vibrations. In that particular application, the balanced loading resulting from the "cutter-opposite" pair of cutters configuration of a hybrid bit is believed to produce the dramatic difference over other types and configurations of bits. In softer formations (soft and medium-hard), it is believed that the more aggressive "blade-leading" pair of cutter hybrid bit configurations will result in the best penetration rate. In any event, according to the preferred embodiment of the present invention, the aggressiveness of a hybrid bit can be tailored or varied to the particular drilling and formation conditions encountered.

[0036] Still another way to adjust or vary the aggressiveness of the hybrid bit 11 is to arrange the cutting elements 35, 37, 39 on the rolling-cutters 29, 31, 33 so that they project deeper into the formation being drilled than the cutting elements 41, 43, 45 on the fixed blade cutters 23, 25, 27. The simplest (and least effective) way to do this is to adjust the projection of some or all of the cutting elements 35, 37, 39 on the rolling-cutters 29, 31, 33 from the surface of each rolling cutter 29, 31, 33 so that they project in the axial direction (parallel to the bit axis 15) further than some or all of the cutting elements 41, 43, 45 on fixed blades cutters 23, 25, 27. In theory, the extra axial projection of a cutting element of the cutting elements on the rolling cutters causes the cutting element to bear more load than an associated cutting element on a fixed blade cutter and protects an associated cutting element of the fixed blade cutter.

[0037] In practice, it is a combination of the projection of each cutting element of a rolling-cutter from the surface of its rolling cutter, combined with its angular spacing (pitch) from adjacent cutting elements that governs whether the cutting elements of a rolling-cutter actually bear more of the cutting load than an associated cutting element on a fixed blade cutter. This combination is referred to herein as "effective projection," and is illustrated in FIGS. 5 and 6. As shown in FIG. 5, the effective projection A of a given cutting element of a rolling-cutter, or that projection of the cutting element available to penetrate into earthen formation, is limited by the projection of each adjacent cutting element and the angular distance or pitch C between the adjacent cutting elements and the given cutting element. FIG. 6 illustrates "full" effective projection B in that the pitch is selected so that the adjacent cutting elements on either side of a given cutting element permit penetration of the cutting element to a depth equal to its full projection from the surface of a rolling-cutter.

[0038] From the exemplary embodiment described above, a method for designing a hybrid earth-boring bit of the present invention permits or allows the cutting aggressiveness of a hybrid bit to be adjusted or selected based on the relationship of at least a pair of cutters comprising a fixed blade cutter and a rolling-cutter, of a plurality of fixed blade cutters and rolling-cutters, wherein the relationship includes a fixed blade cutter leading a rolling-cutter in a pair of cutters, a rolling-cutter leading a fixed blade cutter in a pair of cutters, a rolling-cutter being located opposite a fixed blade cutter in a pair of cutters on the bit, and the angular relationship of a fixed blade cutter and a rolling-cutter of a pair of cutter regarding the amount of leading or trailing of the cutter from an associated cutter of the pair of cutters. The cutting aggressiveness of a hybrid bit of the present invention being achieved by defining a cutting aggressiveness of a hybrid drill bit and the various combinations of pair of a fixed blade cutter and a rolling-cutter, when compared to each other and to different types of drill bits, such as a rolling-cutter drill bit and a fixed blade cutter drill bit, either as the ratio of torque to weight-on-bit or as the ratio of penetration rate to weight-on-bit. The cutting aggressiveness for a hybrid bit of the present invention being adjusted by performing at least one of the following steps:

adjusting the angular distance between each rolling-cutter and each fixed blade cutter of a pair of cutters of the bit;

adjusting the effective projection of the cutting elements on a rolling cutter;

arranging the cutting elements of a fixed blade and the cutting elements of a rolling-cutter so that at least one cutting element of a rolling-cutter and at least one cutting element of a fixed blade cut the same swath or kerf or groove during a drilling operation; and

arranging a pair of at least one cutting element of a fixed blade cutter and cutting element of a rolling-cutter so that the rolling cutter either leads the fixed blade cutter [$<180^\circ$ angular distance], the rolling cutter opposes the fixed blade cutter [$=180^\circ$ angular distance], or trails the fixed blade cutter [$>180^\circ$ angular distance].

[0039] As described above, decreasing the angular distance between a leading rolling-cutter and fixed blade cutter decreases aggressiveness of the pair of cutters, while increasing the distance therebetween increases aggressiveness of the pair of cutters. Increasing the effective projection on cutting elements of a rolling-cutter by taking into account the pitch between them increases the aggressiveness and the converse is true. Finally, designing the cutting elements on a fixed blade to lead the cutting elements on the trailing rolling-cutter increases aggressiveness, while having a rolling-cutter leading its trailing fixed blade cutter has the opposite effect. According to this method, aggressiveness is increased, generally, by causing the scraping action of the cutting elements and fixed blades and to dominate over the crushing action of the cutting elements and the rolling-cutters.

[0040] Increased aggressiveness is not always desirable because of the erratic torque responses that generally come along with it. The ability to tailor a hybrid bit to the particular application can be an invaluable tool to the bit designer.

[0041] The invention has been described with reference to preferred or illustrative embodiments thereof. It is thus not limited, but is susceptible to variation and modification without departing from the scope of the invention.

Claims

1. A method for varying cutting aggressiveness of a hybrid bit (11) having at least one fixed blade cutter (23, 25, 27) and at least one rolling cutter (29, 31, 33), the method comprising:

forming a hybrid drill bit (11) having a bit body (13) having a centerline (15) as the axis of rotation of the bit body (13), having at least one fixed blade cutter (23, 25, 27) attached to the bit body (13) about the centerline (15), and having at least one rolling cutter (29, 31, 33) mounted for rotation on a bit leg (17, 19, 21) secured to the bit body (13) about the centerline (15), the angle between the fixed blade cutter (23, 25, 27) and the at least one rolling cutter (29, 31, 33) being any angle other than 90 degrees;

attaching at least one cutting element (41, 43, 45) arranged in a first position a first radial distance from the centerline (15) of the bit body (13) on a leading edge of the fixed blade cutter (23, 25, 27).

attaching a first cutting element (35, 37, 39) on the rolling cutter (29, 31, 33) arranged in a first position a second radial distance from the centerline (15) of the bit body (13),

characterized in that

the first cutting element (35, 37, 39) of the at least one rolling cutter (29, 31, 33) arranged in the first position follows a cutting element (41, 43, 45) arranged in a first position on a leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39; 41, 43, 45) cut the same swath or kerf or groove either being centered thereon or offset in the same swath or kerf or groove during a revolution of the bit (11); and the angular spacing between at least one rolling cutter (29, 31, 33) and fixed blade cutter (23, 25, 27) is adjusted

2. The method of claim 1, further comprising: attaching a second cutting element (35, 37, 39) on the at least one rolling cutter (29, 31, 33) at a second position at a second radial distance from the centerline (15) to follow a cutting element (41, 43, 45) arranged in a first position on a leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39, 41, 43, 45) fall in the same kerf during drilling operation.

3. The method of claim 2, further comprising: spacing one of the first cutting element (35, 37, 39) and the second cutting element (35, 37, 39) attached to the at least one rolling cutter (29, 31, 33) such that only one of the first cutting element (35, 37, 39) and the second cutting element (35, 37, 39) engages independently during cutting a formation using the hybrid bit (11).

4. The method of claim 2, further comprising: spacing each of the first cutting element (35, 37, 39) and the second cutting element (35, 37, 39) attached to the at least one rolling cutter (29, 31, 33) such that each of the first cutting element (35, 37, 39) and the second cutting element (35, 37, 39) has a portion thereof engaging simultaneously

during cutting a formation using the hybrid bit (11).

- 5 5. The method of claim 1, wherein the first radial distance and the second radial distance are one of the same distance from the centerline (15) of the bit body (13), different distances from the centerline (15) of the bit body (13), and approximately the same distance from the centerline (15) of the bit body (13).

6. The method of claim 1, further comprising:

10 attaching at least one cutting element (41, 43, 45) arranged in a second position a second radial distance from the centerline (15) of the bit body (13) on a leading edge of the fixed blade cutter (23, 25, 27);
attaching at least one cutting element (35, 37, 39) on the rolling cutter (29, 31, 33) arranged in a second position a second radial distance from the centerline (15) to follow a cutting element (41, 43, 45) arranged in a second position on the leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39, 41, 43, 45) fall in the same kerf during drilling operation.

- 15 7. The method of claim 5, further comprising:

20 attaching another cutting element (35, 37, 39) on the rolling cutter (29, 31, 33) arranged in a first position a first radial distance from the centerline (15) of the bit body (13) to follow the cutting element (41, 43, 45) arranged in a first position on the leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39, 41, 43, 45) fall in the same kerf during drilling operation; and
attaching another cutting element (35, 37, 39) on the rolling cutter (29, 31, 33) arranged in a second position a second radial distance from the centerline (15) of the bit body (13) to follow the cutting element (41, 43, 45) arranged in a second position on the leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39, 41, 43, 45) fall in the same kerf during drilling operation.

8. A hybrid drill bit having at least one fixed blade cutter (23, 25, 27), at least one rolling cutter (29, 31, 33), a cone, nose, and shoulder, wherein the hybrid drill bit (11) comprises:

30 a bit body (13) having a centerline (15) as the axis of rotation of the bit body (13), having at least one fixed blade cutter (23, 25, 27) attached to the bit body (13) about the centerline (15), and having at least one rolling cutter (29, 31, 33) mounted for rotation on a bit leg (17, 19, 21) secured to the bit body (13) about the centerline (15);
at least one cutting element arranged in a first position a first radial distance in the cone of the hybrid bit (11) from the centerline (15) of the bit body (13) on a leading edge of the fixed blade cutter (23, 25, 27); and
35 a first cutting element on the rolling cutter (29, 31, 33) arranged in a first position a second radial distance from the centerline (15) of the bit body (13) on the rolling cutter (29, 31, 33), the second radial distance from the centerline (15) of the bit body (13) being in at least one of the nose and the shoulder of the hybrid bit (11) and outboard of the cone of the hybrid bit (11), **characterized in that**
40 a first cutting element (35, 37, 39) on the rolling cutter (29, 31, 33) arranged in a first position a second radial distance from the centerline (15) follows a cutting element (41, 43, 45) arranged in a first position on the leading edge of the fixed blade cutter (23, 25, 27) such that said cutting elements (35, 37, 39; 41, 43, 45) cut the same swath or kerf or groove either being centered thereon or offset in the same swath or kerf or groove during a revolution of the bit (11).

- 45 9. The hybrid bit of claim 8, wherein the at least one rolling cutter (29, 31, 33) comprises a rolling cutter (29, 31, 33) located in one of the nose and the shoulder of the hybrid bit (11).

10. The hybrid bit of claim 8, comprising at least two fixed blade cutters (23, 25, 27) and at least one rolling cutter (29, 31, 33).

- 50 11. The hybrid bit of claim 8, comprising at least two fixed blade cutters (23, 25, 27) and at least two rolling cutters (29, 31, 33).

12. The hybrid bit of claim 8, comprising three fixed blade cutters (23, 25, 27) and three rolling cutters (29, 31, 33).

Patentansprüche

1. Verfahren zur Veränderung der Schneidaggressivität eines Hybridmeißels (11), der wenigstens ein feststehendes Blattschneidelement (23, 25, 27) und wenigstens ein Rollenschneidelement (29, 31, 33) aufweist, wobei das Verfahren umfasst:

- Ausbilden eines Hybridbohrmeißels (11) mit einem Meißelkörper (13), der eine Mittellinie (15) als Drehachse des Meißelkörpers (13), wenigstens ein feststehendes Blattschneidelement (23, 25, 27), das um die Mittellinie (15) herum an dem Meißelkörper (13) angebracht ist, und wenigstens ein Rollenschneidelement (29, 31, 33) aufweist, das für eine Drehung auf einem um die Mittellinie (15) herum an dem Meißelkörper (13) befestigten Meißelschenkel (17, 19, 21) montiert ist, wobei der Winkel zwischen dem feststehenden Blattschneidelement (23, 25, 27) und dem wenigstens einen Rollenschneidelement (29, 31, 33) irgendein Winkel außer 90 Grad ist;

- Anbringen wenigstens eines Schneidelements (41, 43, 45), das an einer ersten Position in einem ersten Radialabstand von der Mittellinie (15) des Meißelkörpers (13) an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordnet ist;

- Anbringen eines ersten Schneidelements (35, 37, 39) an dem Rollenschneidelement (29, 31, 33), das an einer ersten Position in einem zweiten Radialabstand von der Mittellinie (15) des Meißelkörpers (13) angeordnet ist,

dadurch gekennzeichnet,

- **dass** das erste Schneidelement (35, 37, 39) des an der ersten Position angeordneten wenigstens einen Rollenschneidelements (29, 31, 33) einem an einer ersten Position an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) dieselbe Schneise oder Kerbe oder Nut schneiden, wobei sie während einer Umdrehung des Meißels (11) entweder auf diese zentriert oder in derselben Schneise oder Kerbe oder Nut versetzt sind; und

- **dass** der Winkelabstand zwischen wenigstens einem Rollenschneidelement (29, 31, 33) und einem feststehenden Blattelement (23, 25, 27) eingestellt wird.

2. Verfahren nach Anspruch 1, das weiterhin umfasst:

- Anbringen eines zweiten Schneidelements (35, 37, 39) an dem wenigstens einen Rollenschneidelement (29, 31, 33) an einer zweiten Position in einem zweiten Radialabstand von der Mittellinie (15), so dass es einem an einer ersten Position an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) während des Bohrvorgangs in dieselbe Kerbe fallen.

3. Verfahren nach Anspruch 2, das weiterhin umfasst:

- Beabstanden eines des ersten Schneidelements (35, 37, 39) und des zweiten Schneidelements (35, 37, 39), die an dem wenigstens einen Rollenschneidelement (29, 31, 33) angebracht sind, derart, dass während des Schneidens einer Formation unter Verwendung des Hybridmeißels (11) nur eines des ersten Schneidelements (35, 37, 39) und des zweiten Schneidelements (35, 37, 39) unabhängig angreift.

4. Verfahren nach Anspruch 2, das weiterhin umfasst:

- Beabstanden jedes des ersten Schneidelements (35, 37, 39) und des zweiten Schneidelements (35, 37, 39), die an dem wenigstens einen Rollenschneidelement (29, 31, 33) angebracht sind, derart, dass jedes des ersten Schneidelements (35, 37, 39) und des zweiten Schneidelements (35, 37, 39) einen Abschnitt von sich aufweist, der während des Schneidens einer Formation unter Verwendung des Hybridmeißels (11) gleichzeitig angreift.

5. Verfahren nach Anspruch 1, wobei der erste Radialabstand und der zweite Radialabstand entweder derselbe Abstand von der Mittellinie (15) des Meißelkörpers (13) oder unterschiedliche Abstände von der Mittellinie (15) des Meißelkörpers (13) oder ungefähr derselbe Abstand von der Mittellinie (15) des Meißelkörpers (13) sind.

6. Verfahren nach Anspruch 1, das weiterhin umfasst:

- Anbringen wenigstens eines Schneidelements (41, 43, 45), das an einer zweiten Position in einem zweiten

Radialabstand von der Mittellinie (15) des Meißelkörpers (13) an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordnet ist;

- Anbringen wenigstens eines Schneidelements (35, 37, 39) an dem Rollenschneidelement (29, 31, 33), das an einer zweiten Position in einem zweiten Radialabstand von der Mittellinie (15) angeordnet ist, so dass es einem an einer zweiten Position an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) während des Bohrvorgangs in dieselbe Kerbe fallen.

7. Verfahren nach Anspruch 5, das weiterhin umfasst:

- Anbringen eines weiteren Schneidelements (35, 37, 39) an dem Rollenschneidelement (29, 31, 33), das an einer ersten Position in einem ersten Radialabstand von der Mittellinie (15) des Meißelkörpers (13) angeordnet ist, so dass es dem an einer ersten Position an der voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) während des Bohrvorgangs in dieselbe Kerbe fallen; und

- Anbringen eines weiteren Schneidelements (35, 37, 39) an dem Rollenschneidelement (29, 31, 33), das an einer zweiten Position in einem zweiten Radialabstand von der Mittellinie (15) des Meißelkörpers (13) angeordnet ist, so dass es dem an einer zweiten Position an der voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) während des Bohrvorgangs in dieselbe Kerbe fallen.

8. Hybridbohrmeißel, der wenigstens ein feststehendes Blattschneidelement (23, 25, 27) wenigstens ein Rollenschneidelement (29, 31, 33), einen Kegel, eine Nase und eine Schulter aufweist, wobei der Hybridbohrmeißel (11) umfasst:

- einen Meißelkörper (13), der eine Mittellinie (15) als Drehachse des Meißelkörpers (13), wenigstens ein feststehendes Blattschneidelement (23, 25, 27), das um die Mittellinie (15) herum an dem Meißelkörper (13) angebracht ist, und wenigstens ein Rollenschneidelement (29, 31, 33) aufweist, das für eine Drehung auf einem um die Mittellinie (15) herum an dem Meißelkörper (13) befestigten Meißelschenkel (17, 19, 21) montiert ist,

- wenigstens ein Schneidelement, das an einer ersten Position in einem ersten Radialabstand in dem Kegel des Hybridmeißels (11) von der Mittellinie (15) des Meißelkörpers (13) an einer voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordnet ist; und

- ein erstes Schneidelement an dem Rollenschneidelement (29, 31, 33), das an einer ersten Position in einem zweiten Radialabstand von der Mittellinie (15) des Meißelkörpers (13) an dem Rollenschneidelement (29, 31, 33) angeordnet ist, wobei der zweite Radialabstand von der Mittellinie (15) des Meißelkörpers (13) in wenigstens einem der Nase und der Schulter des Hybridmeißels (11) und außerhalb des Kegels des Hybridmeißels (11) liegt;

dadurch gekennzeichnet,

- **dass** ein erstes Schneidelement (35, 37, 39) an dem an einer ersten Position in einem zweiten Radialabstand von der Mittellinie (15) angeordneten Rollenschneidelement (29, 31, 33) einem an einer ersten Position an der voreilenden Kante des feststehenden Blattschneidelements (23, 25, 27) angeordneten Schneidelement (41, 43, 45) derart folgt, dass die Schneidelemente (35, 37, 39; 41, 43, 45) dieselbe Schneise oder Kerbe oder Nut schneiden, wobei sie während einer Umdrehung des Meißels (11) entweder auf diese zentriert oder in derselben Schneise oder Kerbe oder Nut versetzt sind.

9. Hybridmeißel nach Anspruch 8, wobei das wenigstens eine Rollenschneidelement (29, 31, 33) ein Rollenschneidelement (29, 31, 33) umfasst, das sich entweder in der Nase oder der Schulter des Hybridmeißels (11) befindet.

10. Hybridmeißel nach Anspruch 8, der wenigstens zwei feststehende Blattschneidelemente (23, 25, 27) und wenigstens ein Rollenschneidelement (29, 31, 33) umfasst.

11. Hybridmeißel nach Anspruch 8, der wenigstens zwei feststehende Blattschneidelemente (23, 25, 27) und wenigstens zwei Rollenschneidelemente (29, 31, 33) umfasst.

12. Hybridmeißel nach Anspruch 8, der drei feststehende Blattschneidelemente (23, 25, 27) und drei Rollenschneidelemente (29, 31, 33) umfasst.

Revendications

1. Procédé permettant de faire varier l'agressivité de coupe d'un trépan hybride (11) ayant au moins un organe coupant à lame fixe (23, 25, 27) et au moins un organe coupant roulant (29, 31, 33), le procédé comprenant :

la formation d'un trépan hybride (11) ayant un corps de trépan (13) ayant un axe (15) comme axe de rotation du corps de trépan (13), ayant au moins un organe coupant à lame fixe (23, 25, 27) fixé au corps de trépan (13) autour de l'axe (15), et ayant au moins un organe coupant roulant (29, 31, 33) monté pour effectuer une rotation sur un bras de trépan (17, 19, 21) fixé au corps de trépan (13) autour de l'axe (15), l'angle entre l'organe coupant à lame fixe (23, 25, 27) et l'au moins un organe coupant roulant (29, 31, 33) étant n'importe quel angle autre que 90 degrés ;

la fixation d'au moins un élément coupant (41, 43, 45) agencé dans une première position à une première distance radiale par rapport à l'axe (15) du corps de trépan (13) sur un bord avant de l'organe coupant à lame fixe (23, 25, 27),

la fixation d'un premier élément coupant (35, 37, 39) sur l'organe coupant roulant (29, 31, 33) agencé dans une première position à une deuxième distance radiale par rapport à l'axe (15) du corps de trépan (13),

caractérisé en ce que

le premier élément coupant (35, 37, 39) de l'au moins un organe coupant roulant (29, 31, 33) agencé dans la première position suit un élément coupant (41, 43, 45) agencé dans une première position sur un bord avant de l'organe coupant à lame fixe (23, 25, 27) de telle sorte que lesdits éléments coupants (35, 37, 39 ; 41, 43, 45) coupent la même percée ou saignée ou entaille soit en étant centrés dessus soit décalés dans la même percée ou saignée ou entaille pendant une révolution du trépan (11) et

l'espace angulaire est ajusté de entre au moins un organe coupant roulant (29, 31, 33) et un organe coupant à lame fixe (23, 25, 27).

2. Procédé selon la revendication 1, comprenant en outre : la fixation d'un deuxième élément coupant (35, 37, 39) sur l'au moins un organe coupant roulant (29, 31, 33) dans une deuxième position à une deuxième distance radiale à partir de l'axe (15) pour suivre un élément coupant (41, 43, 45) agencé dans une première position sur un bord avant de l'organe coupant à lame fixe (23, 25, 27) de telle sorte que lesdits éléments de coupe (35, 37, 39, 41, 43, 45) tombent dans la même saignée durant une opération de forage.

3. Procédé selon la revendication 2, comprenant en outre : l'espacement d'un élément parmi le premier élément coupant (35, 37, 39) et le deuxième élément coupant (35, 37, 39) fixés à l'au moins un organe coupant roulant (29, 31, 33) de telle sorte qu'un seul des premier élément coupant (35, 37, 39) et deuxième élément coupant (35, 37, 39) s'engage indépendamment pendant la coupe d'une formation à l'aide du trépan hybride (11).

4. Procédé selon la revendication 2, comprenant en outre : l'espacement de chacun des premier élément coupant (35, 37, 39) et deuxième élément coupant (35, 37, 39) fixés à l'au moins un organe coupant roulant (29, 31, 33) de telle sorte que chacun des premier élément coupant (35, 37, 39) et deuxième élément coupant (35, 37, 39) a une partie de celui-ci s'engageant simultanément pendant la coupe d'une formation à l'aide du trépan hybride (11).

5. Procédé selon la revendication 1, dans lequel la première distance radiale et la deuxième distance radiale sont l'une parmi la même distance par rapport à l'axe (15) du corps de trépan (13), différentes distances par rapport à l'axe (15) du corps de trépan (13), et approximativement la même distance par rapport à l'axe (15) du corps de trépan (13).

6. Procédé selon la revendication 1, comprenant en outre :

la fixation d'au moins un élément coupant (41, 43, 45) agencé dans une deuxième position à une deuxième distance radiale par rapport à l'axe (15) du corps de trépan (13) sur un bord avant de l'organe coupant à lame fixe (23, 25, 27) ;

la fixation d'au moins un élément coupant (35, 37, 39) sur l'organe coupant roulant (29, 31, 33) agencé dans une deuxième position à une deuxième distance radiale par rapport à l'axe (15) pour suivre un élément coupant (41, 43, 45) agencé dans une deuxième position sur le bord avant de l'organe coupant fixe (23, 25, 27) de telle sorte que lesdits éléments coupants (35, 37, 39, 41, 43, 45) tombent dans la même saignée pendant une opération de forage.

7. Procédé selon la revendication 5, comprenant en outre :

la fixation d'un autre élément coupant (35, 37, 39) sur l'organe coupant roulant (29, 31, 33) agencé dans une première position à une première distance radiale par rapport à l'axe (15) du corps de trépan (13) pour suivre l'élément coupant (41, 43, 45) agencé dans une première position sur le bord avant de l'organe coupant à lame fixe (23, 25, 27) de telle sorte que lesdits éléments coupants (35, 37, 39, 41, 43, 45) tombent dans la même saignée pendant une opération de forage ; et

la fixation d'un autre élément coupant (35, 37, 39) sur l'organe coupant roulant (29, 31, 33) agencé dans une deuxième position à une deuxième distance radiale par rapport à l'axe (15) du corps de trépan (13) pour suivre l'élément coupant (41, 43, 45) agencé dans une deuxième position sur le bord avant de l'organe coupant à lame fixe (23, 25, 27) de telle sorte que lesdits éléments coupants (35, 37, 39, 41, 43, 45) tombent dans la même saignée pendant une opération de forage.

8. Trépan hybride ayant au moins un organe coupant à lame fixe (23, 25, 27), au moins un organe coupant roulant (29, 31, 33), un cône, un nez et un épaulement, dans lequel le trépan hybride (11) comprend :

un corps de trépan (13) ayant un axe (15) comme axe de rotation du corps de trépan (13), ayant au moins un organe coupant à lame fixe (23, 25, 27) fixé au corps de trépan (13) autour de l'axe (15), et ayant au moins un organe coupant roulant (29, 31, 33) monté pour effectuer une rotation sur un bras de trépan (17, 19, 21) fixé au corps de trépan (13) autour de l'axe (15) ;

au moins un élément coupant agencé dans une première position à une première distance radiale dans le cône du trépan hybride (11) par rapport à l'axe (15) du corps de trépan (13) sur un bord avant de l'organe coupant à lame fixe (23, 25, 27) ; et

un premier élément coupant sur l'organe roulant (29, 31, 33) agencé dans une première position à une deuxième distance radiale par rapport à l'axe (15) du corps de trépan (13) sur l'organe coupant roulant (29, 31, 33), la deuxième distance radiale par rapport à l'axe (15) du corps de trépan (13) étant dans au moins un élément parmi le nez et l'épaulement du trépan hybride (11) et à l'extérieur du cône du trépan hybride (11), **caractérisé en ce qu'**

un premier élément coupant (35, 37, 39) sur l'organe coupant roulant (29, 31, 33) agencé dans une première position à une deuxième distance radiale par rapport à l'axe (15) suit un élément coupant (41, 43, 45) agencé dans une première position sur le bord avant de l'organe coupant à lame fixe (23, 25, 27) de telle sorte que lesdits éléments coupants (35, 37, 39 ; 41, 43, 45) coupent la même percée ou saignée ou entaille soit en étant centrés dessus soit décalés dans la même percée ou saignée ou entaille pendant une révolution du trépan (11).

9. Trépan hybride selon la revendication 8, dans lequel l'au moins un organe coupant roulant (29, 31, 33) comprend un organe coupant roulant (29, 31, 33) situé dans un élément parmi le nez et l'épaulement du trépan hybride (11).

10. Trépan hybride selon la revendication 8, comprenant au moins deux organes coupants à lame fixe (23, 25, 27) et au moins un organe coupant roulant (29, 31, 33).

11. Trépan hybride selon la revendication 8, comprenant au moins deux organes coupants à lame fixe (23, 25, 27) et au moins deux organes coupants roulants (29, 31, 33).

12. Trépan hybride selon la revendication 8, comprenant trois organes coupants à lame fixe (23, 25, 27) et trois organes coupants roulants (29, 31, 33).

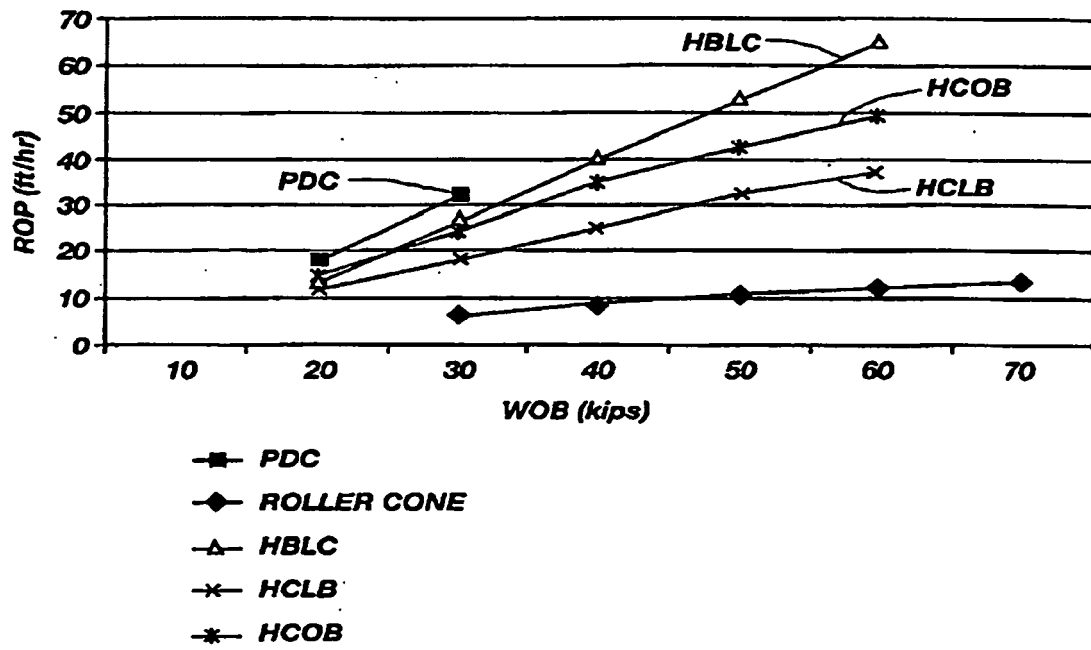


FIG. 1

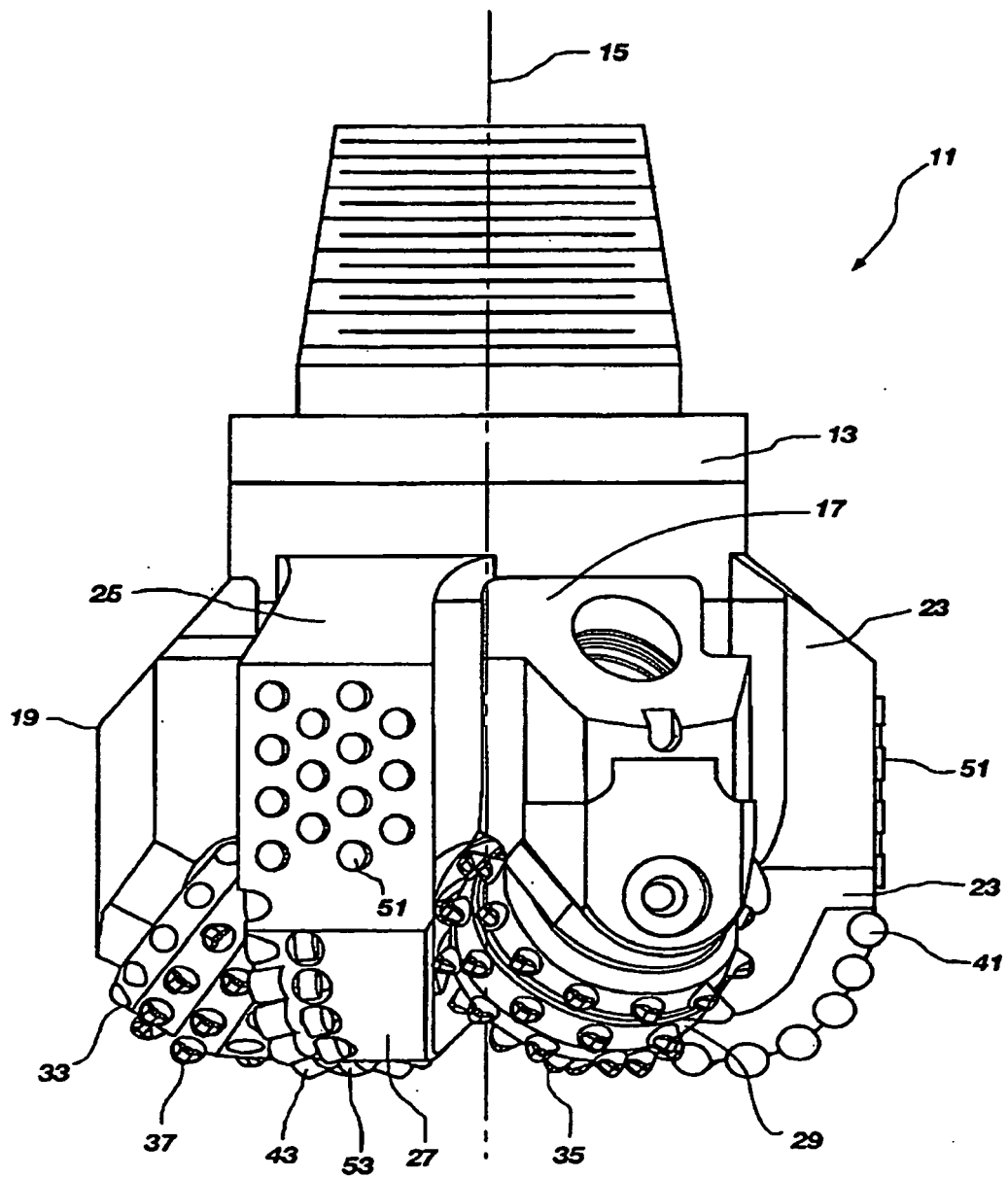


FIG. 2

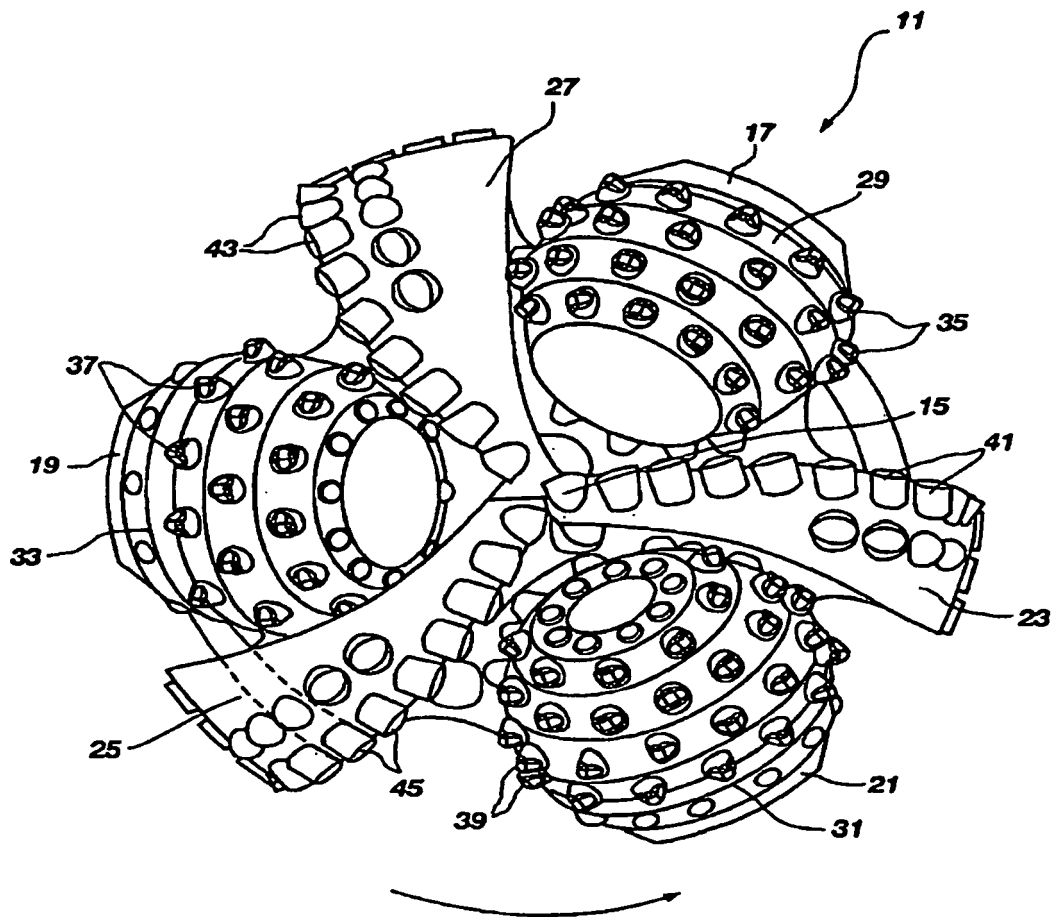


FIG. 3

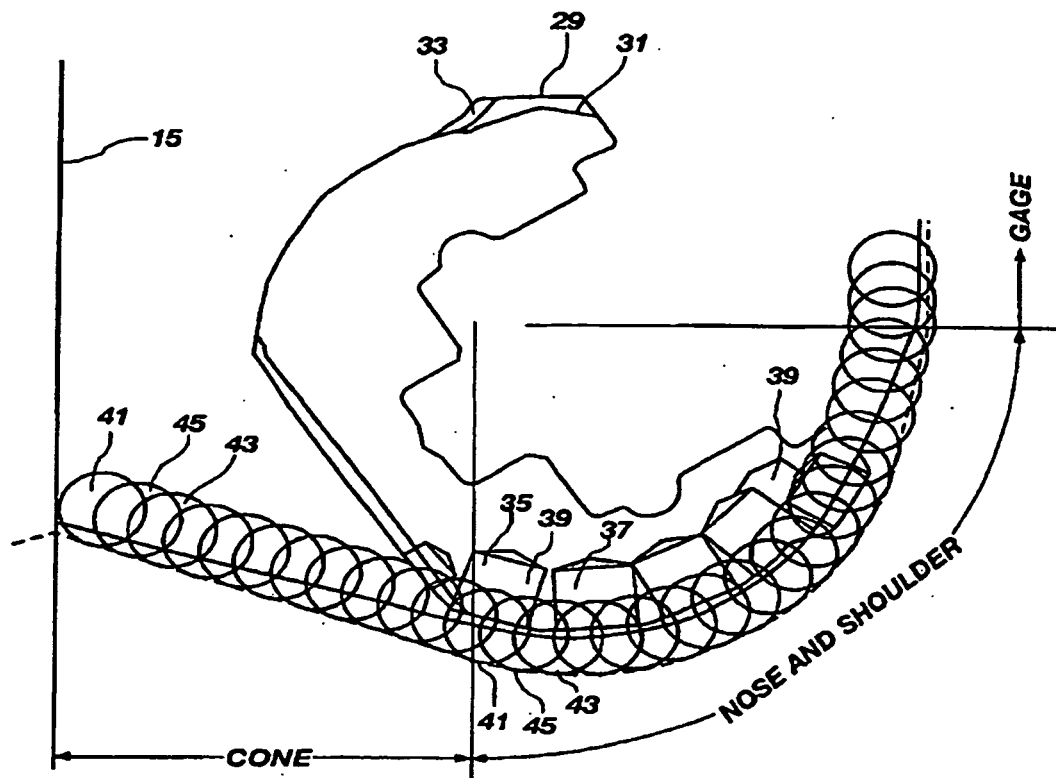


FIG. 3A

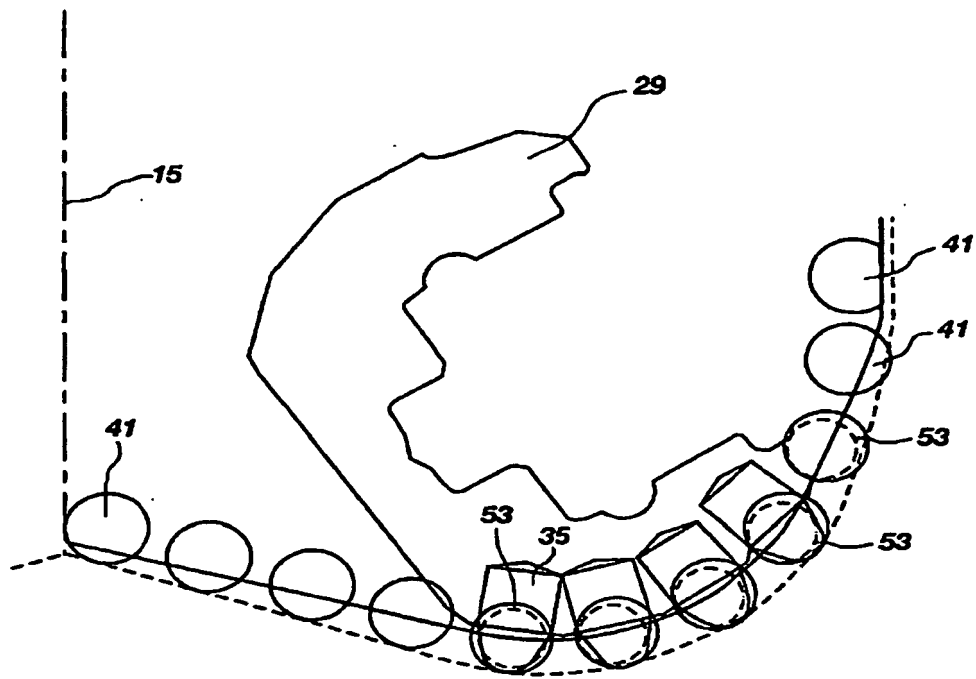


FIG. 3B

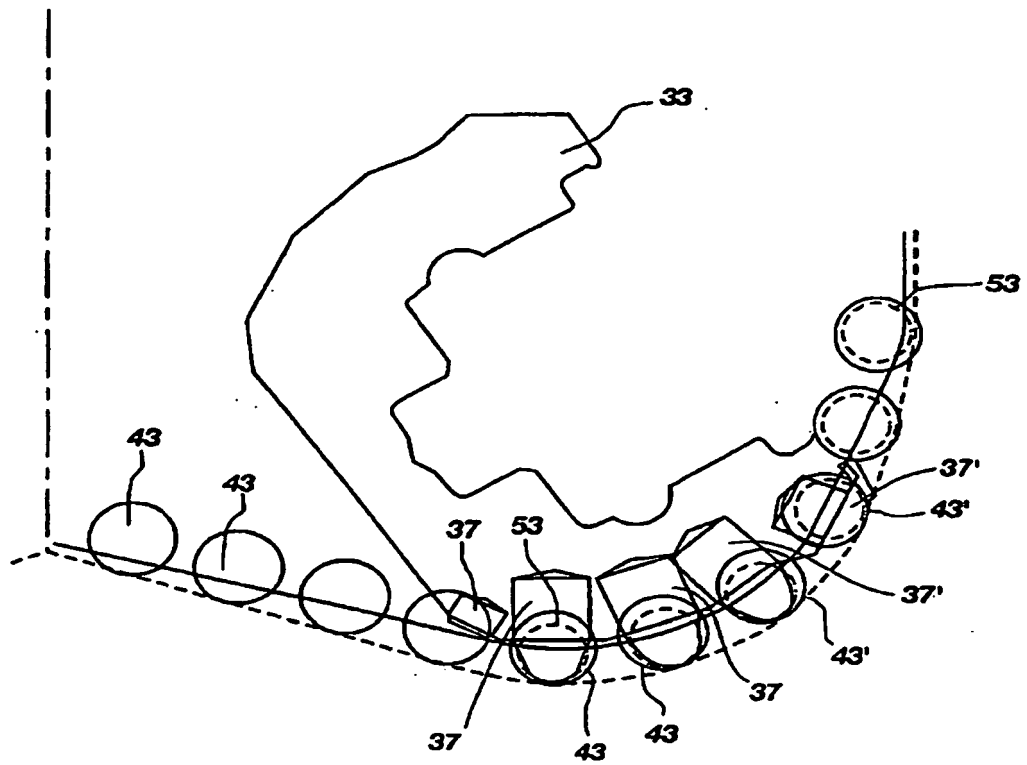


FIG. 3C

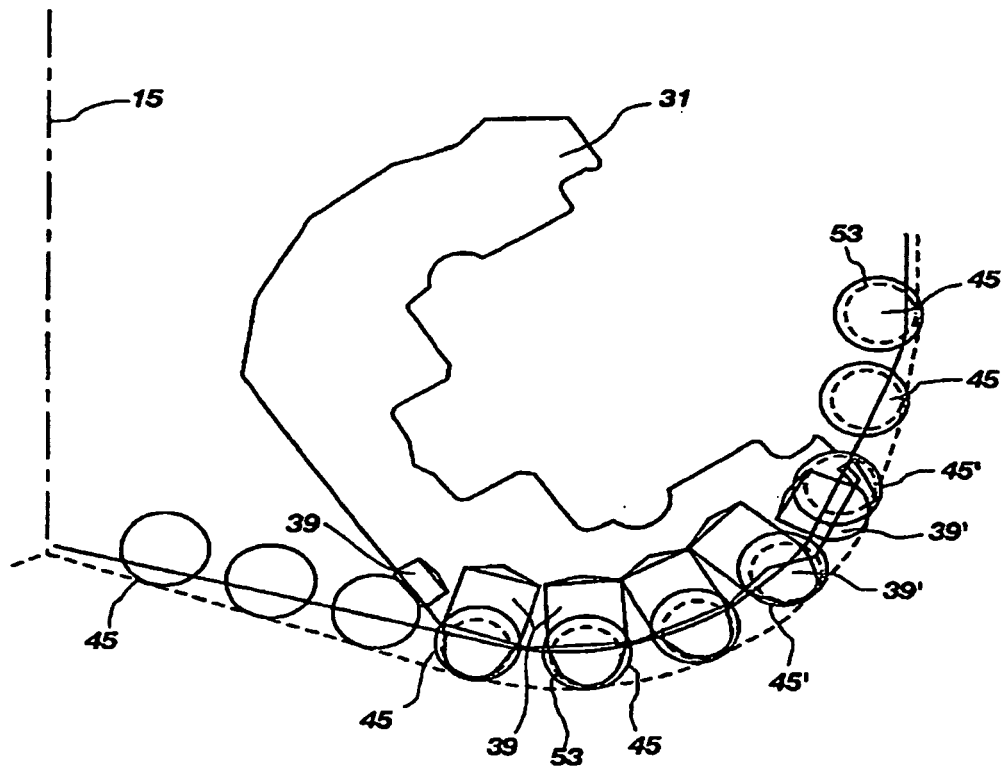


FIG. 3D

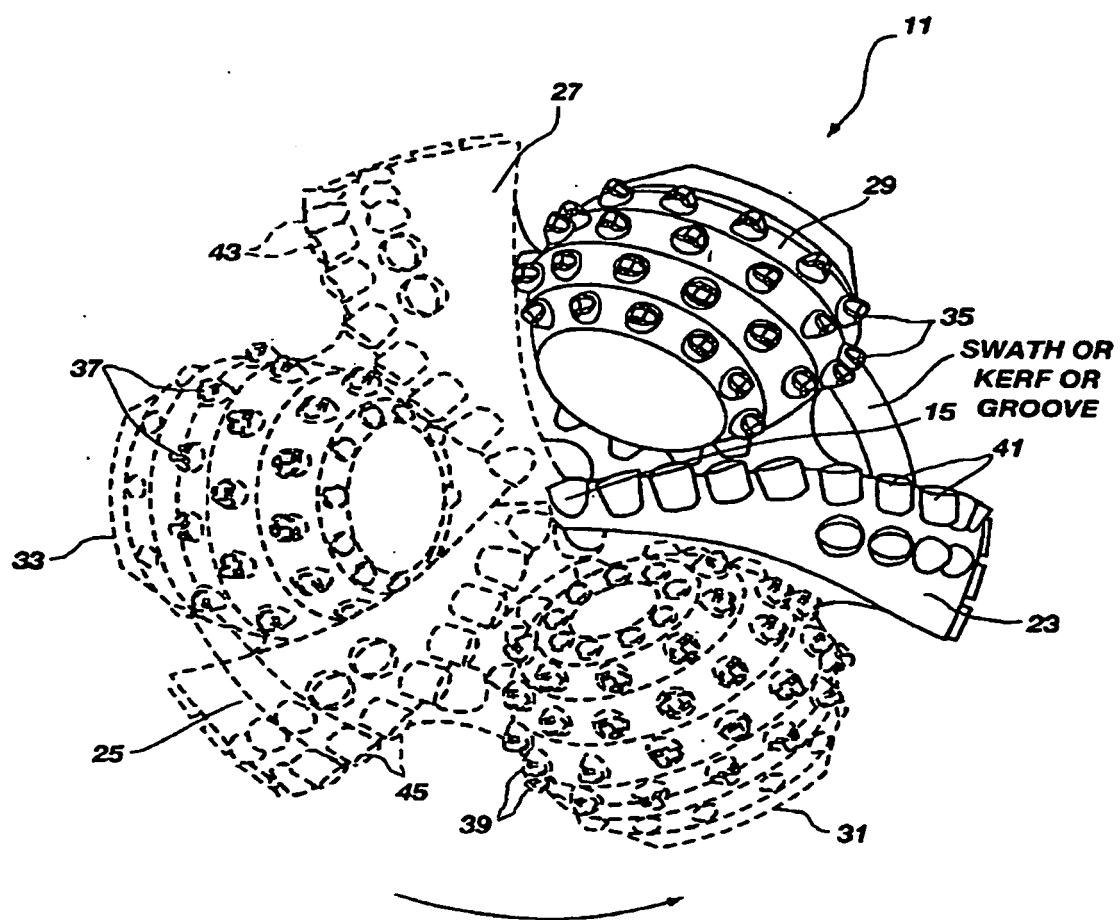


FIG. 3E

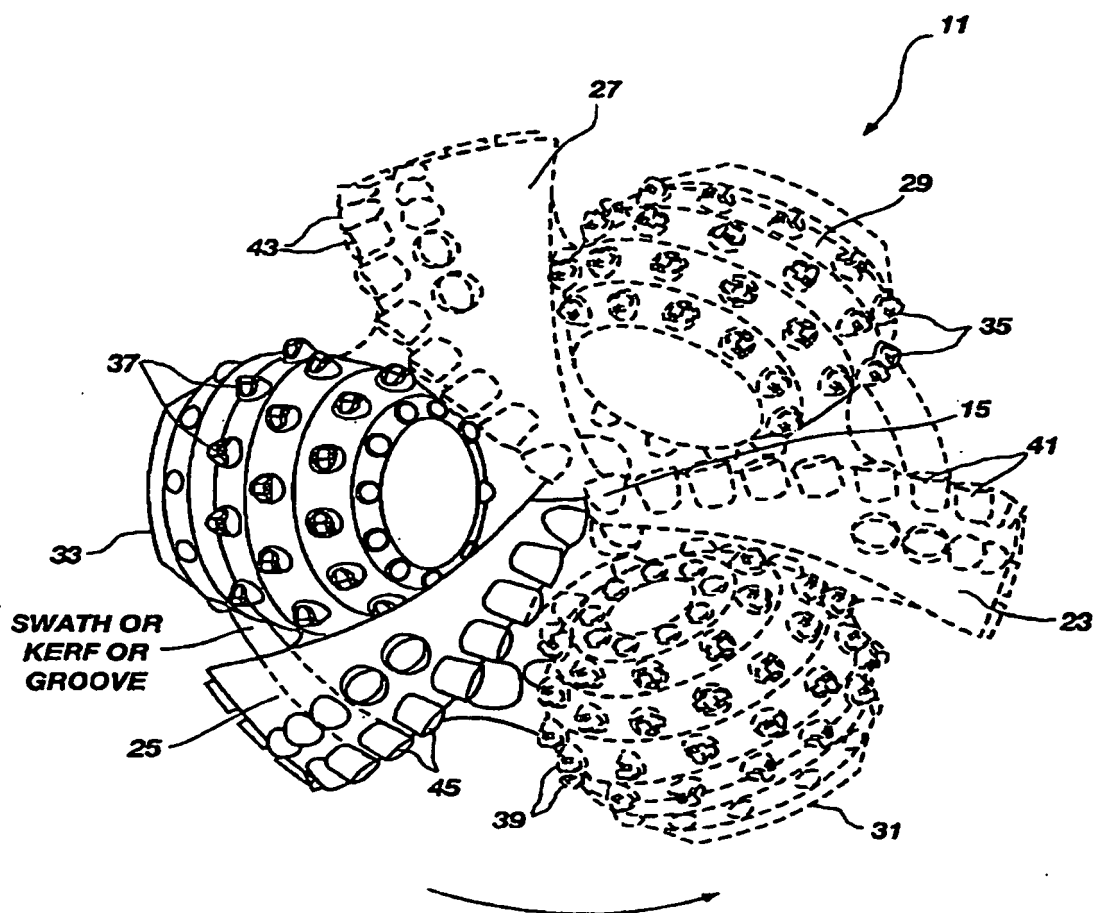


FIG. 3F

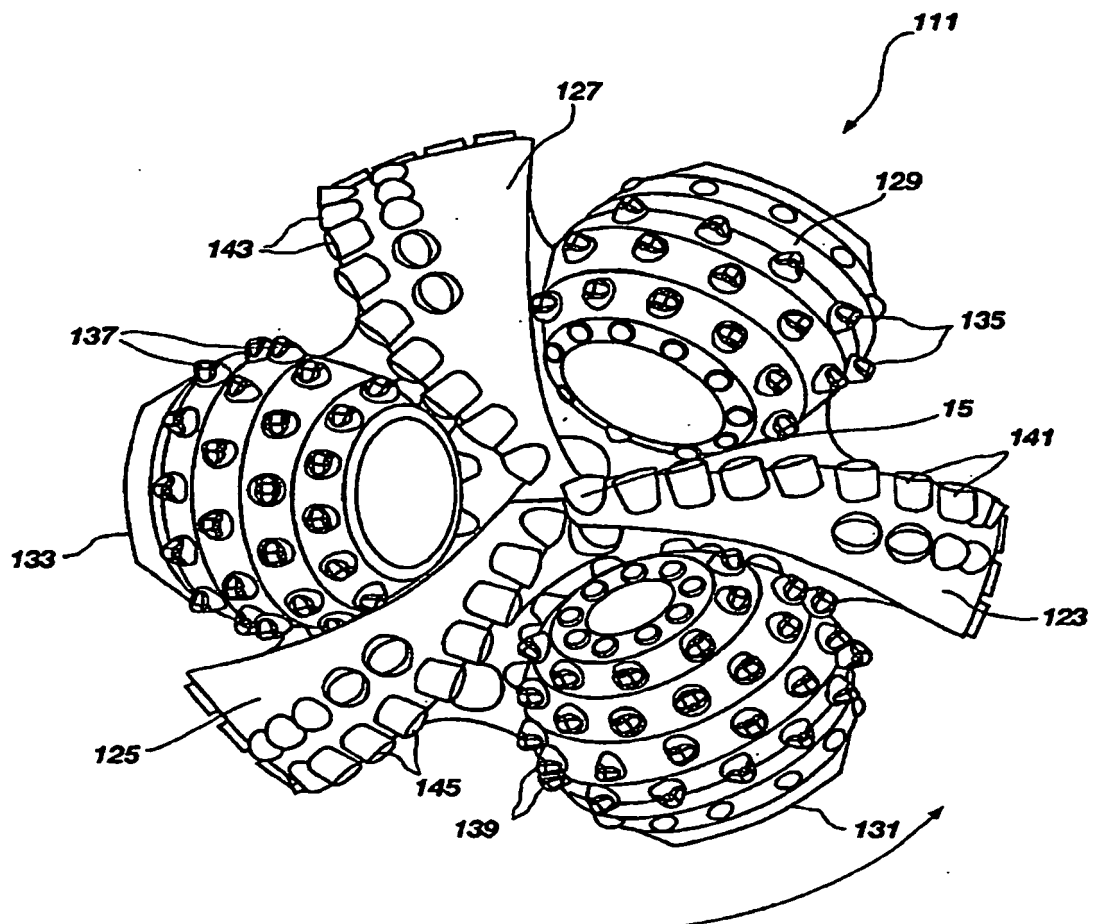


FIG. 4

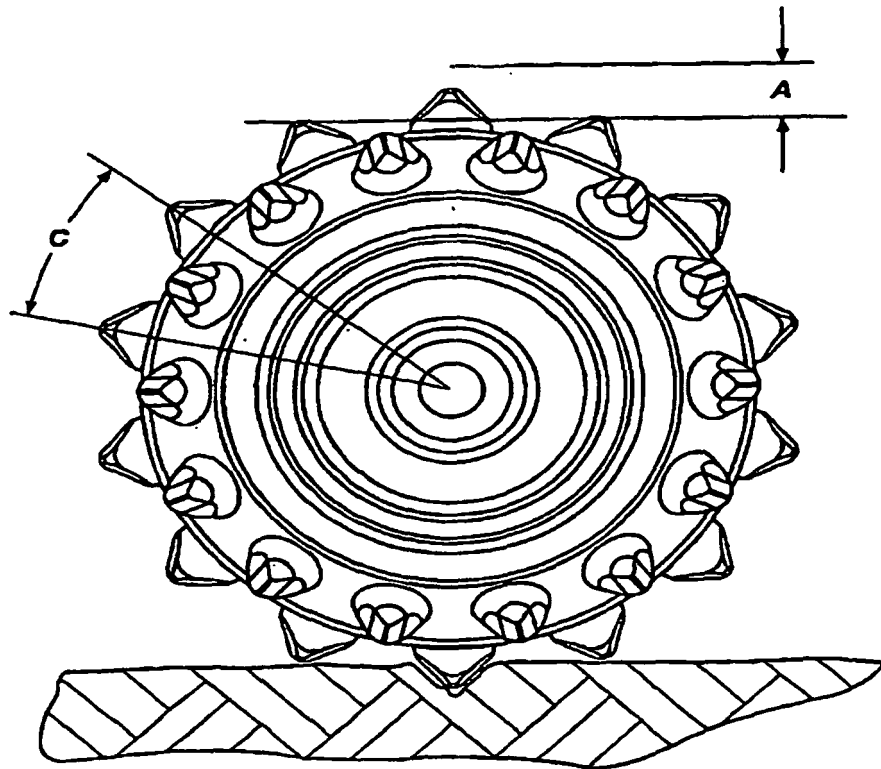


FIG. 5

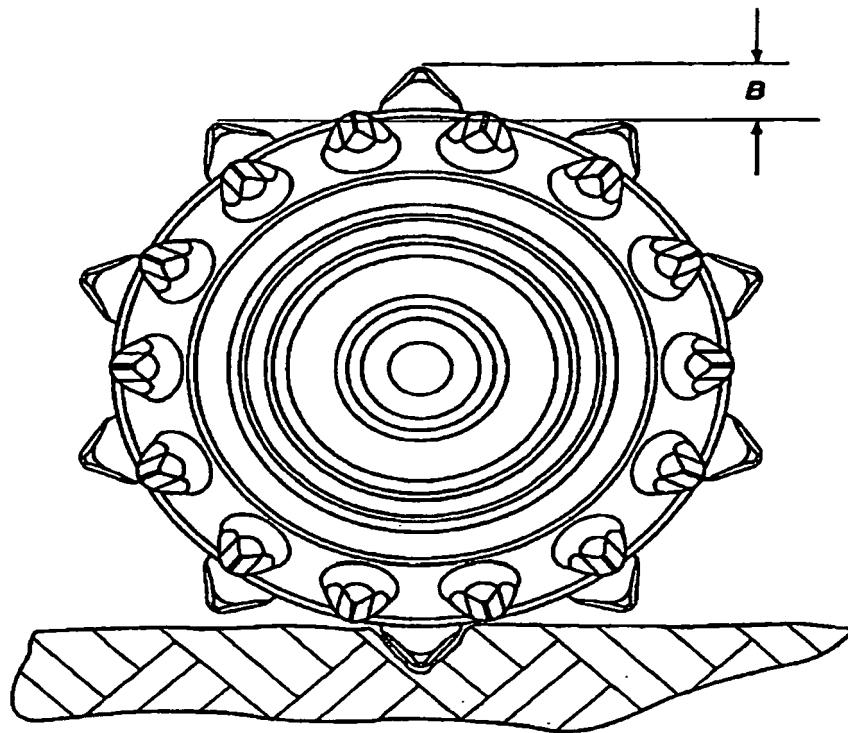


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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