This invention relates generally to earth boring tools and in particular to a novel drill bit that is suitable for percussion drilling.

Prior art percussion bits can be classified into two categories: (1) the chisel type, and (2) the rolling cutter type.

The chisel type is the more prevalent of the two, its popularity being based primarily on its rugged construction, which is strikingly similar to that of the common chisel. In one of its simplest forms it is a single, massive piece of metal with wedge-shaped pieces of tungsten carbide secured to its lower end. There are usually modifications such as connecting means at its upper end and provisions for blasting the bottom of the hole with air. Basically, however, it is nothing more than a large chisel.

The disadvantage of the chisel type bit is its inability to hold gage, that is, it wears rapidly at its outer cutting surface. As a consequence, the diameter of the bit and the hole decrease as drilling progresses. This is permissible in mining operations such as blast hole drilling where the hole size is not particularly critical. In drilling oil and gas wells, however, the hole size must be approximately uniform so that casing of a selected size may be inserted and secured in the hole. Therefore, the chisel type bit is unsuitable for such drilling operations.

The second category of percussion bits, the rolling cutter type, is distinguished by the ability to hold gage. These bits are usually similar to the one described in the U.S. patent issued to Mortan et al., No. 2,687,875. Wear is distributed over the large, rotating surfaces of the cutters, a feature that increases their life at all points, including the gage surfaces. These bits were initially developed for drilling under a static load and have proved outstanding for that application. Unfortunately, they do not have the ruggedness that characterizes the chisel type bit, a feature that is needed to withstand repeated impact loads. For example, the head sections, which support the bearing spindles on which the cutters are mounted, are usually welded together and these welds crack easily under the high level cyclical loads of percussion drilling. Attempts have been made to adapt this bit type to percussion drilling by correcting this and other weaknesses, but success has been limited.

The object of this invention is to combine the advantages of the chisel type bit and the rolling cutter bit. The invention consists of a solid, rugged bit body (similar to the chisel type bit) equipped with rolling cutters assembled in a unique manner so as to withstand the large, fluctuating loads of percussion drilling.

This and other objects will become apparent hereinafter in the drawings in which:

FIGURE 1 is a perspective view showing the invention in its assembled form.

FIGURE 1-A illustrates in fragmentary perspective an alternate form of cutting structure on the bit body.

FIGURE 2 is a side elevational view of the bit body showing in detail its construction.

FIGURE 3 is a sectional view of the bit body taken as indicated by the lines and arrows 3-3 of FIGURE 2, with the addition of the assembled cutters, the ring and a drill string member.

FIGURE 3-A is a fragmentary section showing an alternate bearing configuration.

FIGURE 3-B is a fragmentary section showing another alternate bearing configuration and also an alternate type of cutting structure on the cutters.

FIGURE 4 is a perspective view, partially in section, showing the preferred configuration of the cutter retaining ring.

In describing the preferred embodiment of the invention, specific terminology is used to add clarity. The invention is not limited, however, by this specific terminology to the particular structure described, but encompasses all equivalent structures that function in a similar manner to accomplish a similar result.

Referring now to FIGURE 1 to give a broad description of the invention, the numeral 10 designates the body portion of the drill bit with cutting elements 11 formed on its lower end and connecting means 12 formed on its upper end. (Spindled connectors are also common in percussion drilling but are not illustrated; any prior art connecting means may be used with the invention.) At least one but preferably a plurality of cutters 13 are mounted on bearing spindles 22, which protrude outwardly and upwardly in cantilever fashion (shown in FIGURES 2 and 3 but not visible in FIGURE 1), and are formed integrally with the lower portion of body 10. A ring 14 having downwardly protruding skirts 15 is secured to the body 10. The skirts 15 retain the cutters 13 on the bearing spindles 22, providing a simply constructed and strong structure that eliminates the need for welds.

FIGURE 1 and the broad description above disclose the basic concept of the invention and its salient features, but do not reveal the structural details that contribute so much to its strength. The concept of a cutter retainer which consists of a ring with protruding skirts permits, for example, the use of a unitized bit body 10 that is made of a single, strong and massive piece of material.

The strong construction of the bit body is shown in FIGURES 2 and 3, where the numeral 16 represents a cylindrical surface on body 10 that confronts a matching surface 17 (see FIGURE 4) on the inside of ring 14. A radially extending surface or shell 18 intersects the cylindrical surface 16 to provide a positioning stop for the lower surface 30 of ring 14 that butts against shelf 18. Extending downwardly from shelf 18 is a conical surface 19 that intersects a lower conical surface 35. The conical shape of these surfaces is not essential but is merely a convenient way to flare the body metal outwardly and downwardly to provide strong support for cutting elements 11 and 27. Furthermore, the shape of these surfaces is beneficial in providing additional space for the flushing fluid and cuttings as they move from the bore hole bottom upwardly along the exterior of the drill bit.

A flat and vertical surface 34 joins cylindrical surface 16 in such a manner that both surfaces appear as a line in FIGURE 3. Flat surface 34 is required in this embodiment to provide clearance for the passage of skirts 15 by the bit body 10 during assembly. Obviously, if conical surface 19 were to extend uninterrupted around the bit body, the skirts 15 could not reach their final, intended position.

Cavities 21, defined by cylindrical surface 36 on one side and bearing spindle 22 on the other, are formed on opposite sides of the bit body 10, providing space for cutters 13. A thrust surface 32 that matches an opposed surface on each cutter 13 is also formed on the
body 10, preferably having a deposit 37 of suitable bearing metal. In addition, bearing metal of a similar nature is deposited in suitable slots 38 on the surface of bearing spindle 22.

Below the bearing spindles 22 is a substantially horizontal surface 28 in which are inserted a multiplicity of wear resistant inserts 11 selected from the sintered metal carbides, preferably tungsten carbide. These inserts are spaced at different radial distances from the drill axis of rotation 26 except near the outer periphery of the bit where a plurality of outermost or heel inserts 27 are disposed to rotate at the corner of the bore hole. Experience has shown that large amounts of energy are expended in drilling the corner of a bore hole; thus, more inserts are required at that location.

The inserts 11 and 27 are preferably elongated and cylindrical, and are secured by well known means such as by interference fit or by one of the brazing techniques. The heel inserts 27 are angularly disposed so that their buried ends lie within the bit body conical surface 35. The inner inserts 11 are preferably aligned with their longitudinal axis parallel with the bit axis 26 so that the forces transferred through them are compressive and pass directly to the bottom of the drilled hole. Lands 42 are sometimes used (they are necessary only in rare instances) to give additional support to the inserts to prevent breakage.

Cutters 13 are mounted so that they cooperate with heel inserts 27 to disintegrate the corner of the bore hole. This feature is beneficial in protecting the heel inserts 27 from excessive wear. Furthermore, the heel inserts break up any rock teeth that tend to form on the bore hole bottom, thus keeping the cones from "tracking," a condition that slows the penetration rate of the bit. The tracking problem arises when the cutters 39 on the teeth of each cutter fall in the indentations made on the bore hole bottom by the crests of other teeth. The indentations continue to grow deeper while the ridges between them grow higher. As the crests 39 of the teeth slide down these ridges, the teeth are worn by the abrasives in the earth's formations. The heel inserts 27, by cooperating with the teeth of the cutters 13 and destroying the ridges as they form, tend to eliminate the tracking problem.

The cutters 13 have webs 40 that connect the crest 39 of the teeth at their outer ends. This provides a large surface that may be covered with wear resistant material, such as tungsten carbide in a suitable binder, to prevent the cutters from wearing too quickly. It is usually best to provide relief slots 41 that permit cuttings to move away from the wall of the hole and also make a milling cutter of the outer portions of the cutters.

Very few inserts 11 are required at the inner portions of the bit and they are disposed in body 10 in almost a straight row. Obviously, excessive amounts of metal are undesirable on the bottom of the bit because room must be provided for the escape of cuttings from the bore hole bottom. For this reason the excess metal is removed by forming grooves 28 in an oblique fashion as is shown in FIGURES 1 and 2, perhaps more clearly in FIGURE 1.

To remove the cuttings from the bore hole bottom, a central passage 24 is formed in the upper part of the bit body 10. At least one passage 23 directs the fluid to the bore hole bottom where the cuttings are entrained and removed from the hole. Preferably, a plurality of passages are used, at least some of which are angularly disposed, as are the passageways 25 of FIGURE 1. This configuration is beneficial in blasting the corner of the hole with a high velocity stream of fluid that removes quickly the cuttings that tend to lie dormant in this hard-to-reach location.

The interference ring 14 is illustrated in FIGURE 4 where the skirts 15 are shown, including the inner surfaces 43 that abut the ends 52 of bearing spindles 22 after assembly to retain cutters 13. The cylindrical surface 17 of the ring is a few thousandths of an inch smaller in diameter (.003 inch interference on a cylindrical surface of 3% diameter for a 6% inch diameter bit was found suitable) than the matching cylindrical surface 16 of the bit body 10. To prevent the ring 14 from rotating with respect to the bit body 10 during assembly, it is preferable to have guide means such as key seat 44 that conforms a matching key to the bit body (not shown). The inner surface 43 of ring 15 has a groove 45 filled with a good bearing metal such as silver, silver alloy, iron or cobalt based alloy. The cutters 13 are generally pushed inwardly at the gage of the hole during drilling and this coaxes them so that they contact deposit 37 on surface 32 of the bit body 10 and groove 45 of the ring 14.

In view of the detailed description above, the numerous advantages of the invention should be apparent, especially its simple and rugged construction. The unitized bit body 10, for example, is fabricated of only one massive piece of metal that offers durability to the bit. The cutters, secured to the body by novel means, provides resistance to gage wear. The novel retaining means eliminates the need for welds. Thus the invention combines the advantages of prior art bits and provides a long needed advance in the drilling art.

Various modifications of the structure will occur to those of average skill in the art, but particularly noteworthy is the fact that the invention is not limited to the cutting elements 11 and 27 shown in FIGURE 1, FIGURE 1-A, for example, illustrates a modification having chisel-like cutting elements 46 that are well known in the art. This and other old cutting structures are within the scope of the invention since the inventive concept encompasses a novel body construction and cone retaining means and is not limited to the cutting structures shown and described.

Although the bearings of spindles 22 and cutters 13 are preferably of the journal type as is shown in FIGURE 3, the invention is not limited to journal bearings, but encompasses all old art devices such as the roller bearing of FIGURE 3-A. Here the spindle is designated by numeral 47, which has an annular groove 48 into which are inserted rollers 49. Rolling cutter 50 is inserted over the rollers 49 and the interference ring is assembled so that skirt 51 confronts the end of spindle 47 to retain cutter 50 thereon. This construction is not preferred, however, since, the rollers 49 absorb energy during impact loading, thereby decreasing the efficiency of the bit.

FIGURE 3-B is similar to FIGURE 3-A in that it illustrates an anti-friction bearing consisting of balls 53 mounted in matching raceways in bearing spindle 47 and cutter 54. Journal surface 55 in cutter 54 and surface 62 on bearing spindle 47 constitute a journal bearing that cooperates with the anti-friction bearing to support the various forces. In this embodiment cutter 54 is assembled on bearing spindle 47, and then the balls 53 are inserted through drilled hole 63 in bearing spindle 47. Then a plug 56 is inserted into drilled hole 63 and the skirt 51 of the interference ring is assembled, retainer the plug 56 which in turn retains the balls 53 in their raceways. In this embodiment the advantages of eliminating welds is achieved by the use of a ring with protruding skirts 51, and is thus within the inventive concept.

In view of the bearing modifications illustrated in FIGURES 3-A and 3-B, it is apparent that many old art bearing structures are operable with the invention. Hence, the invention is not limited to the modification illustrated; rather, the wide range of the applicability of the invention is shown thereby.

Another modification of the invention is illustrated in FIGURE 3-B where the cutter 54 is illustrated as having a plurality of wear resistant inserts 57. These inserts are generally cylindrical in cross-section and are secured by interference fit in matching, cylindrical holes in the cutter 54.

One criterion for the selection of cutters is the type of formation to be drilled. Wear of the cutters 13 and in-
serts 11 and 27 of body 10 should be balanced and this depends to a large extent on the formations drilled. Tests on various granites, for example, indicated that wear is better balanced by using milled cutters 13 and cylindrical inserts with blunt, protruding ends in the bit body 10. When cutters with inserts, such as cutter 54 of FIGURE 3-B, were used, the cutters lasted much longer than the cutting elements of the bit body. It is better design practice to balance the wear between the various parts and for this reason the milled cutters are preferred. It may prove economically feasible, however, to disassemble the bit on the drilling location and assemble the partially worn cutters on new bit bodies. If so, the inserts cutters 54 of FIGURE 3-B may prove to be the better of the two type illustrated.

The number of bearing spindles and cutters and their location with respect to the rest of the drill is not especially critical as far as the basic concept is concerned. Cutters 13 may be moved upwardly from the location shown in FIGURE 1 so that they merely ream the hole. Conversely, they can be moved downwardly so that cutter crests 39 and webs 40 cut a kerf on the bore hole bottom. In the latter arrangement the body inserts 11 cut only the resulting core, and heel inserts 27 may be eliminated.

As is clearly illustrated, it is preferable to have at least two cutters, although one cutter may be used. When using two oppositely located cutters, the bit will rotate more consistently about longitudinal axis 26, whereas the use of only one cutter frequently causes the bit to rotate about an axis other than axis 26. The use of more than two cutters produces results in this regard similar to the use of two cutters, and the decision to illustrate a two cutter design is prompted merely by the resulting simplification of construction.

The bearing spindles 22 have been described as being integral with bit body 10 and this is indeed the preferred arrangement. Nevertheless, the spindles 22 can be made separately and inserted into the bit body 10 by interference fit or by other suitable means. Although this arrangement is undoubtedly weaker than the integral structure, the advantage of using the ring as a cutter retainer still obtains and thus this modification is within the inventive concept.

Ring 14 is preferably an interference ring, which encompasses rings secured to the bit body by such old art methods of assembly as the shrink fit and the press fit. On the other hand the ring 14 may be retained by the drill string member 56 of FIGURE 3. In this embodiment the shoulder 59 of the drill collar 58 engages shoulders 60 and 61 of ring 14 and bit body 10 during assembly and thereafter ring 14 cannot be removed without removing the drill collar.

The bit body 10 of FIGURE 1 has been described as being flat or horizontal across its lower surface 26. The invention, however, is not limited to such constructions but encompasses rounded, concave, convex or stopped surfaces. The flat configuration is thought best, however, and for that reason is illustrated in the drawing.

Considerable geometrical details have been recited in describing the preferred embodiment, especially in relation to the bit body 10. These details should not be taken as limiting the invention, for there are perhaps infinite geometrical variations that are possible. These details are given to enable those in the art to understand how the invention is preferably made.

The invention has been described as one especially suitable for percussion drilling. Testing has in fact been restricted to percussion drilling because this is where most fatigue problems reside at present. The invention nevertheless has utility as a drill bit suitable for conventional, rotary drilling. There are numerous drill bits that have a body portion and rolling cutters. None of them, however, have the novel structure of the present invention.

I claim:

In a rotary-percussion bit of the type having a solid massive body with an upper end adapted to be connected to a drill string member and a lower end extending diametrically substantially the full width of a borehole to be cut, there being fixed percussive cutting elements secured in and protruding downwardly from said lower end and disposed to cut a full borehole while the bit is rotated and subjected to percussion during drilling, the improvement comprising at least one bearing spindle secured to said bit body and extending upwardly and outwardly therefrom with its outer end terminating unsecured in cantilever fashion, a rolling cutter rotatably mounted on said bearing spindle, said cutter being disposed to assist said percussive cutting elements. In cutting the outer portion of the borehole formed by said elements during drilling, and a ring member secured to the bit body above said bearing spindle, said ring having a downwardly extending skirt which confronts the unsupported end of the bearing spindle to retain the cutter thereon.

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