EXTENSIBLE DRILL BIT

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The present invention relates to earth drilling methods and apparatus and more particularly relates to an improved rotary bit for the drilling of oil wells, gas wells, and similar boreholes in the earth which is characterized by extendible blades through which the drilling fluid is delivered to the cutting surface. In still greater particularity, the invention relates to an improved rotary drill bit provided with controllably extensible tubular cutting elements which permit more effective circulation of drilling fluid within the borehole and which are usable for longer periods than rotary bits utilized heretofore.

Rotary methods are widely used for drilling oil wells, gas wells, and similar boreholes and have largely supplanted the use of cable tools and other equipment widely used in the past. Rotary drilling in general involves the use of a bit which is rotated against the formation being drilled into in order to produce forces sufficient to break down the formation beneath the bit. In most cases, the bit is attached to the lower end of a string of drill pipe which is turned from the earth's surface by means of a rotary table and associated equipment, although in some instance turbines and other down-hole power sources are utilized to avoid the necessity for rotating the entire drill string. Cuttings produced by the action of the bit on the formation are removed from the borehole by circulating a drilling fluid, a mixture of water and various clays, for example, downwardly into the bottom of the borehole through the drill string and withdrawing the fluid with entrained cuttings through the annular space between the drill string and the borehole wall. Bits of various types including roller bits, drag bits, ring bits and the like have been developed for use in rotary drilling operations.

Although rotary drilling is generally superior to other drilling systems from the standpoint of the rate at which a borehole can be advanced, certain difficulties normally encountered have made rotary drilling an expensive operation. To a larger extent the cost of rotary drilling depends upon the useful life of the drill bits employed. Conventional rotary bits have relatively short lives and hence must be replaced at frequent intervals. A drag bit or roller bit of the type normally used, for example, will ordinarily drill from about 200 feet to about 300 feet of borehole through a moderately hard abrasive formation before it must be replaced. In the drilling of oil and gas wells, boreholes of from 10,000 to 15,000 feet or more are not uncommon. The frequent replacement of drill bits required during the drilling of such boreholes is expensive, not only from the standpoint of the cost of the bits themselves, but also because the entire string of drill pipe must be pulled from the borehole and dismantled, section by section, each time that a new bit is installed. The time and labor required to lift several thousand feet of pipe out of the borehole, dismantle it, replace the bit, reassemble the pipe, and lower the drill string back into the borehole lead to considerable expense each time that a bit must be replaced.

An important factor governing the life of rotary drill bits is the efficiency with which the drilling fluid circulated in the borehole flushes out and removes cuttings produced by the action of the bit on the formation. The cooling and lubricating effects of the drilling fluid on the bit are also important. In recognition of these factors, efforts have been made to improve drilling fluid circulation at the bottom of the borehole through the use of jet nozzles for directing the drilling fluid against the cutting surfaces of the bit and the use of fluid courses in the body of the bit to control the flow of the drilling fluid into the annulus between the bit and the borehole wall. Some success along these lines has been attained but the possibilities for further extension of bit life in this manner appear limited. The present invention makes possible rotary bits which can be used for drilling boreholes greater distances than were feasible with earlier bits by providing controllably extensible tubular bit blades through which the drilling fluid can be circulated in order to achieve maximum effectiveness. The use of such blades results in decreased wear rates because of greater blade area presented to the formation, improves blade cooling because of better heat transfer between the blade and the drilling fluid, flushes cuttings from the path of the blade more effectively due to the discharge of drilling fluid at the point of contact between the blades and the formation at the bottom of the borehole, and increases the lubricating effect of the drilling fluid on the blade and borehole bottom due to more efficient fluid distribution. The improved bit life thus obtained, coupled with the use of extensible blades which continuously present a renewed cutting edge as wear occurs and means for preventing over-extension of the blades, results in a bit which is manifestly superior to rotary drill bits utilized in the past.

The exact nature and objects of the invention can be more fully understood by referring to the following detailed descriptions of rotary bits embodying the invention and methods for their application and to the accompanying drawing in which:

FIG. 1 is a vertical, sectioned view of a preferred embodiment of the invention taken along the lines 1—1 in FIGURE 2;

FIG. 2 is a cross-sectional view of the bit of FIG. 1 taken along the lines 2—2 in FIG. 1;

FIG. 3 is a cross-section view taken along the lines 3—3 in FIG. 1;

FIG. 4 is a cross-section through the blades and body of the bit as indicated by lines 4—4 in FIG. 1;

FIG. 5 is a cross-sectional view taken along the lines 5—5 of FIG. 1;

FIG. 6 illustrates a further blade embodiment useful in accordance with the invention; and,

FIG. 7 depicts a cross-section of a still further blade embodiment of the bit of the invention.

Turning now to FIG. 1, it will be seen that the bit depicted therein comprises a tubular generally cylindrical supporting member 11, an upper body section 12 enveloping and slidable with respect to supporting member 11, a lower body section 13 connected in fixed relationship to upper body section 12, a blade member 14 attached to the lower end of supporting member 11, and a shoe 15 which serves to connect the lower ends of lower body section 13. A valve 16, a spring 17, and supporting elements are disposed within supporting member 11.

Supporting member 11 is, as pointed out above, a tubular, generally cylindrical member and is provided at its upper end with threads or other connecting means adapted to permit its attachment to the lower member of a rotary drill string. This lower drill string member will normally
be a length of drill pipe or a drill collar, and is designated in FIG. 1 by reference numeral 18. In some cases, however, it may be preferred to connect the bit to a turbine or other down-hole power source either directly or by means of a suitable coupling. At its lower end, the supporting member 11 is threaded or otherwise adapted to permit its connection to blade member 14. As shown in the drawing, supporting member 11 is larger in diameter at the upper end than at the lower end and is tapered at an intermediate point. A cylindrical retainer 19 is provided in the upper end of supporting member 11 in the supporting member and a mating shoulder 21 on the retainer are provided to prevent the retainer from dropping downwardly within the supporting member. The outer diameter of the retainer should be greater than the bore of the drill pipe, drill collar, or coupling to which the bit is connected in order to prevent the retainer from being pushed upwardly out of the supporting member.

Conduits 22, 23, 24 and 25 are provided to permit the flow of drilling fluid from the bore of supporting member 11 below retainer 19 through the wall of this supporting member. The conduits emerge above the bore of the supporting member and begin to taper to a smaller diameter. Drilling fluid passing downwardly through the conduits is discharged into annular chamber 26 between upper body section 12 and the supporting member.

Valve 16 is positioned within the supporting member immediately below retainer 19. The inside diameter of the valve is smaller than the inner diameter of the retainer and the upper inside edge thereof is preferably flared to give a smooth flow pattern through the valve. O-rings or similar sealing elements 27 and 28 are set in grooves in the outer wall of valve 16 in order to provide a fluid-tight seal between the outer wall of the valve and the inner wall of supporting member 11. The sealing elements may be made of rubber, hemp, plastic or similar material. Valve 16 rests upon spring 17 which is in turn positioned upon shoulder 29 in supporting member 11. The pressure drop which occurs in the valve when drilling fluid is circulated downwardly through the bit causes the valve and spring 17 to move downwardly, opening the inlets to conduits 22, 23, 24, and 25. When the circulation and drilling fluid is discontinued, spring 17 forces the valve upwardly against retainer 19, blocking off the inlets to the conduits. Valve 16 thus operates in response to drilling fluid pressure and is normally open only while the drilling fluid is being circulated.

As mentioned heretofore, upper body section 12 is arranged concentrically with respect to supporting member 11. Seal 30, preferably of rubber or plastic, is set in an annular groove in the inner wall of the upper body section in order to prevent the escape of drilling fluid upwardly out of chamber 26. Lower body section 13 is attached to the lower end of section 12 by threads or other suitable fluid-tight means. Seal 31 prevents drilling fluid in chamber 26 from escaping downwardly between the supporting member 11 and lower body section 13. The seal is set in an annular groove in the inner wall of lower body section 13. Cylindrical bearing 32 resting on shoulder 29 of body section 13 prevents lateral movement of the supporting member with respect to the lower body section and serves to back up and support seal 31. Chamber 26 is thus an annular, fluid-tight chamber between the supporting member and the bit body into which drilling fluid may pass through conduits 22, 23, 24 and 25 when valve 16 is in a downward, open position. The chamber serves as a cylinder for the application of hydraulic thrust against the bit body independently of the supporting member 11. The body is free to move downwardly in response to such thrust without corresponding movement of the supporting member taking place.

The lower body section 13 of the bit is a generally cylindrical member having longitudinal slots therein which serve to accommodate the blades 14 of the bit. The cross-sectional views in FIGS. 3, 4 and 5 show these slots more clearly. The outer diameter of the lower body section is somewhat smaller than the diameter through the blade, so that the blades serve to limit the entry of fluid and cuttings into the hollow space within the body between the blades. These blades are retained in place by bolts 36 which are threaded into the body member. The head of the bolt may be spot-welded to the body after the bit has been assembled in order to prevent its becoming loose or disengaged during the operation of the bit. Diamond particles, tungsten carbide inserts or similar hard abrasive material is preferably provided on the lower surface of the shoe as indicated by reference numeral 53.

As shown in the drawing, blade element 14 is an integral unit which is threaded or otherwise connected to the lower end of supporting member 11. The blade member is bifurcated to form two individual cutting elements which are designated in the drawing as elements 14A and 14B. Each of these elements is generally tubular in form and defines a passageway which is open at the bottom and communicates at the top with chamber 37 in the upper part of the blade member. Chamber 37, in turn, communicates with the bore of supporting member 11, designated by reference numeral 38. The conduits defined by cutting elements 14A and 14B are shown in the drawing by reference numerals 39 and 40. As pointed out earlier, blade member 14 is free to move axially with respect to lower body section 13 and shoe 15.

Drilling fluid passing downwardly through the supporting member of the bit 11 enters chamber 37 in the blade member and then passes downwardly through conduits 39 and 40 in cutting elements 14A and 14B. The fluid is then discharged through the open end of the conduits and flows onto the bottom of the borehole.

Blade elements 14A and 14B as shown in FIGS. 1 through 5 of the drawing are generally triangular in shape. Each blade element thus presents two cutting edges to the formation underlying the borehole as the bit rotates. It is preferred that the leading cutting edge of each blade element be somewhat thicker than the second, or trailing, cutting edge. The trailing edge is supported by shoe 15 to a greater extent than is the leading edge and hence need not be as thick as the leading edge. These cutting edges of the blade elements should be surface hardened or wear resistant inserts for this purpose include industrial diamonds and particles of silicon carbide or tungsten carbide. The inserts may be embedded in matrices of softer alloy steel which is then welded or otherwise attached to the leading surfaces of the blade elements. "Tube Boritum," a commercial form of tungsten carbide, has been found eminently suitable for this use. Abrasive inserts on the blade surfaces in the bit shown in the drawing are indicated by reference numerals 41, 42, 43 and 44 in FIGS. 4 and 5.

In some cases it will be preferred to utilize a series of abrasive inserts spaced across each cutting surface in order to obtain a "fingering" action as the cutting edges wear down between the inserts. Each insert should extend substantially the length of the cutting element. Similar inserts may be employed on the outer reaming edges of the blades. These are indicated by numerals 45 and 46 in FIGS. 4 and 5.

A further blade embodiment which may be utilized is illustrated in FIG. 6 of the drawing and comprises a "sandwich" consisting of a center layer of tungsten carbide or similar wear resistant material surrounded by outer layers of alloy steel 48 and 49. Abrasive inserts 50 may be provided on the reaming edge of the blade element as...
Blades of the type shown in FIG. 6 are particularly effective in the bit of the invention. FIGURE 7 of the drawing illustrates a still further blade embodiment wherein abrasion resistant rods 51 are embedded in holes drilled in the blades at intervals across the width of the blade. It will be noted that these rods are spaced in a staggered relationship so that the inserts in the leading edge of the blade and those in the trailing edge follow separate paths as the bit is raised and lowered. The staggering of the inserts results in better cutting action and assists in maintaining the contour of the blades and the bottom of the borehole. It also promotes better distribution of the drilling fluid across the bottom of the borehole. Simultaneously, the bits are used in a downwardly more quickly between the inserts than at the points where the inserts are provided, the blade in use will assume an irregular toothed cutting edge which readily permits the passage of the drilling fluid out into the borehole. The rods should be inserted at substantially the center of the blade thickness in order 11 to provide as much backing in front and behind each rod as possible. The blades may be made somewhat thicker than would otherwise be the case if such rods are to be employed. Inserts 52 are provided on the inner and outer reaming edges of each blade to reduce gage wear and assist the reaming action of the blades.

The blade elements thus employed present a somewhat larger cross-sectional area to the formation underlying the borehole than do conventional blades used in ordinary drag bits. Each blade has a radial cutting edge which is substantially twice the length of the blade on a conventional bit. These factors, combined with the improved flushing, cooling and lubricating effects obtained as a result of the discharge of the drilling fluid at the blade lateral cutting edges, produce blade wear rates substantially lower than those otherwise encountered.

It will be recognized that modifications in the blade and generally configuration shown in the drawings may be made without departing from the scope of the present invention. The blade cross section may be varied, for example, in order to increase blade strength. Blade elements 14A and 14B may be made detachable from the upper part of the blade structure attached to supporting member 11. The angles, combined with the improved flushing, cooling and lubricating effects obtained as a result of the discharge of the drilling fluid at the blade lateral cutting edges, produce blade wear rates substantially lower than those otherwise encountered.

The downwind thrust exerted on lower body section 13 and shoe 15 by the drilling fluid in annular chamber 26 is normally only that amount necessary and sufficient to cause the bit to ride along the bottom surface of the borehole without the bit doing any appreciable amount of drilling. The axial loading on the blades of the bit on the other hand, is transmitted to the blades from the drill pipe through supporting member 11 and is regulated so that the blades penetrate into the rock underlying the borehole bottom a short distance and drill out the borehole as the bit rotates. The blade elements thus automatically and continuously present only that portion of their length which corresponds to the depth of cut desired. The depth of cut, in turn, is controlled and regulated in a conventional manner by adjusting the load imposed by the bit driving means. As the blade elements wear down due to the drilling action, they continuously move downward within the body member and thereby present fresh cutting edges.

As mentioned earlier, the compressibility of spring 17 should be such that the spring readily compresses while drilling fluid is being circulated, allowing valve 16 to move downwardly into open position when the circulation of drilling fluid is halted, the spring moves the valve upwardly and closes off the conduits 22 and 25. The valve is thus open continuously during the drilling operation and permits the automatic positioning of the blades and shoe so that fresh blade cutting surfaces are presented as wear occurs. When the valve is closed, the body is no longer free to move axially with respect to the supporting member blades and instead is held in fixed relationship thereto. The danger of over-extension of the blades while raising and lowering the bit into and out of the borehole is thus obviated, since the valve permits the bit to be raised and lowered with the blades and shoe in a fixed position with respect to one another.
The longitudinally disposed cutting surfaces or edges of the blade elements 14A and 14B in effect perform a gage reaming function. These cutting edges or surfaces should be substantially parallel to the longitudinal axis of the bit and equidistant therefrom in order that the entire length of the blade surfaces may be within the hole. The longitudinal cutting edges of the blade, like the lateral cutting edges, should be surface hardened or otherwise treated to make them abrasion resistant. Inserts of diamonds or tungsten carbide can be embedded within these longitudinal cutting edges to improve their effectiveness. The abrasive particles employed for this purpose should be relatively fine in size. Fine particles give a relatively smooth reaming action and do not result in the appreciable vibrations in hole gage which may be encountered if large particles are used. Diamond particles ranging in size from about 20 to 42 mesh have been employed for this purpose with considerable success. Other sizes may, of course, be more desirable in some instances, however, depending on the nature of the formation which is being drilled.

From the foregoing, it can be seen that the present invention provides improved rotary drill bit which has extensible cutting elements that are continuously supported adjacent the longitudinal and lateral cutting edges by the bit body and shoe. The cutting elements themselves define conduits through which the drilling fluid is circulated in order to achieve more efficient flushing of cuttings, cooling of the bit and lubricating action. Hydraulic valve means are provided to prevent over-extension of the bit blades when the bit is lifted above the bottom of the borehole, and thus failure which might occur if heavy loads were imposed upon extended blades is avoided. These improved features result in a bit which has substantially longer life than rotary bits utilized heretofore and thus permit more economical rotary drilling operations than have been possible in the past.

What is claimed is:

1. An improved rotary bit for drilling boreholes in the earth comprising in combination a tubular supporting member provided with means for connecting said supporting member to suitable bit-driving means and containing a lateral port; a hollow cutting element attached to and depending from said supporting member, said supporting member and cutting element defining a longitudinal passageway through said bit; a tubular body member longitudinally slideable with respect to said supporting member and cutting element and defining a chamber between said supporting member and body member communicating with said port, said body member extending downwardly and engaging said cutting element and valve means in said supporting member for controlling fluid flow through said port into said chamber.

2. A bit as defined by claim 1 wherein said cutting element is provided with a first cutting edge extending substantially parallel to the longitudinal axis of said bit and a second radial cutting edge.

3. A bit as defined by claim 1 wherein said cutting element is provided with leading and trailing radial cutting edges.

4. An improved rotary drill bit comprising in combination a hollow supporting member provided with means for transmitting rotary and axial thrust from suitable bit driving means; a tubular body member axially slideable on and co-rotatable with respect to said supporting member, said body member and supporting elements defining a chamber therebetween; a conduit for introducing drilling fluid from said supporting member into said chamber, a valve adapted to admit drilling fluid to said conduit in response to flow of drilling fluid through said supporting member; a cutting element depending from said supporting member and co-rotatable therewith, said cutting element being laterally supported within said body member; and a conduit in said cutting element for delivering drilling fluid from said supporting member to the lower surface of said cutting element.

5. An improved rotary drill bit comprising in combination a tubular supporting member provided with means for connecting said supporting member to a rotary drill string for the transmission of drilling fluid and rotary and axial thrust; a tubular body member axially slideable on said supporting member and co-rotatable therewith; a tubular blade member having longitudinal and radial cutting edges depending from said supporting member within said body member, said blade member being housed and laterally supported by said body member adjacent said cutting edges and said supporting member and blade member defining a fluid passageway through said bit; and valve and conduit means in said supporting member whereby drilling fluid is directed downwardly against said body member in response to flow of drilling fluid through said supporting member.

6. A bit as defined by claim 5 wherein said blade member is of substantially triangular cross-section.

7. A bit as defined by claim 5 wherein said blade member is provided with abrasive inserts on said longitudinal and radial cutting edges.

8. An improved bit for drilling well boreholes comprising in combination a supporting member containing a longitudinal fluid conduit and provided with means for connecting said supporting member to a rotary drill string for the transmission of drilling fluid and rotary and axial thrust; a bifurcated blade element attached to and depending from said supporting member in co-rotatable, axially-fixed relationship, said blade element having radial cutting edges and longitudinal reaming edges and containing conduits for the passage of drilling fluid from said supporting member to said radial cutting edges; a body member axially slideable on said supporting member and blade element, said body member containing longitudinal slots from which said blade element reaming edges extend; a shoe member affixed to the lower portion of said body member and extending adjacent said cutting edges; and means in said supporting member for exerting hydraulic force downwardly against said body member in response to the flow of drilling fluid in said supporting member.

9. A bit as defined by claim 8 wherein said blade element has leading and trailing radial cutting edges which define the lower ends of said conduits therein.

10. A bit as defined by claim 8 wherein abrasive particles are provided on the lower surface of said shoe.

11. A bit as defined by claim 8 wherein said means for exerting hydraulic force includes a valve which is spring loaded in a normally closed position.

12. A bit as defined by claim 8 wherein said cutting edges are provided with a wear-resistant facing.

13. A bit as defined by claim 8 wherein the radial cutting edges of said blade are made up of a wear resistant, abrasive material embedded between layers of metal.

14. A bit as defined by claim 8 wherein said blade element is provided with spaced inserts embedded in said radial cutting edges and arranged in staggered relationship.

15. An improved rotary drill bit comprising in combination a tubular supporting member having a lateral opening therein intermediate the ends thereof; a valve slideable in said supporting member in response to flow of drilling fluid through said supporting member, said valve covering said opening absent the flow of drilling fluid through said supporting member; a tubular body member axially slideable on said supporting member, said body and supporting member forming an annular chamber into which drilling fluid may pass through said opening when said valve is in an open position; elongated tubular blade
members attached to and depending from said supporting member within said body member, said body member being of a length to expose the lower ends of said blade members by axial movement relative to said blade members and said supporting member and blade members forming a passageway for the discharge of drilling fluid through said bit; and abrasion resistant inserts embedded in said blade members whereby wear of the ends of said blade members extending below said body member is reduced.

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