DRILL BIT WITH EXTENSIBLE BLADE

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The present invention is broadly concerned with the art of drilling boreholes in the earth and more especially with improved drill bits for use in such drilling. The drill bits of this invention are particularly characterized by having cutter elements which are extendable from the bit body in definite increments.

A common method of drilling oil wells, gas wells and similar boreholes in the earth's surface has been in recent years done by the rotary drilling method. Such methods, in general, involve the use of a bit which is rotated against the formation being drilled in order to produce a combination of scraping, grinding and percussive forces which break down the formation beneath the bit relatively rapidly. Rotation of the drill bit is effected by rotation at the surface a string of drill pipe which connects to the drill bit. The cuttings produced by the action of the bit are removed by a drilling fluid which is injected downwardly through the drill string and through the bottom of the borehole and is withdrawn through the annular space between the drill string and the borehole wall. The flow of the drilling fluid carries the cuttings with it. A variety of rotary bits of different designs including roller bits, drag bits, ring bits and the like, may be used in such rotary drilling operations.

It has been possible with conventional bits such as the types described above to drill to considerable depths. For example, in the petroleum industry it is not unusual to drill holes 10,000 feet or more in depth in the search for oil. While such performance is commendable, it is unfortunately also very expensive.

A substantial portion of the expenses incurred in earth drilling is caused by the fact that the drill bits now employed must frequently be replaced. For example, in moderately hard abrasive formations, a conventional roller bit may drill from about 200 to 500 feet before requiring replacement. This means that in drilling a borehole to a depth of 8,000 to 10,000 feet or more a very substantial number of bits must be used. To replace a bit in rotary drilling means that the entire string of drill string must be pulled from the borehole each time the bit has to be replaced. Pulling the drill string is a time consuming operation and becomes progressively more expensive as the depth of the borehole increases. In drilling operations carried out in great depths, the cost of changing bits usually greatly overshadows the cost of the bits themselves.

It is an object of the present invention to reduce drilling cost by providing drill bits that have improved operating lives. It is a further object of the invention to provide bits which have a blade which may be extendable from the bit body by definite increments as the blade is worn with each increment extension controlled at the surface. It is also an object to extend the life of the bit body. It is another object of the invention to provide means for sharpening and controlling the cutting profile of the blade of the bit without removing the bit from the borehole.

These objects of the invention will be expressly discussed or readily apparent in the description that follows. The objects are realized by the use of a bit having at least one blade which is mounted within the borehole of the bit. The cutter blade is extendible from the bit body in definite increments. Means are also provided so that the blade can be sharpened and its original cutting profile renewed before it is extended.

The invention may be better understood by reference to the attached drawings in which:

FIG. 1A is an upper portion and FIG. 1B is the lower portion of the longitudinal partial section view of a preferred embodiment of the invention taken along the line 1B—1B of FIG. 4;

FIG. 2 is a cross-section of FIG. 1A taken along the line 2—2;

FIG. 3 is a section taken across the line 3—3 of FIG. 1A;

FIG. 4 is a section taken across the line 4—4 of FIG. 1B;

FIG. 5 is a bottom view of the apparatus in FIG. 1B;

FIG. 6 is a partial section taken across the line 6—6 of FIG. 5;

FIG. 7 is an enlarged partial section taken across line 7—7 of FIG. 5 showing the contour of the heel and face of the body in relation to the cutting blade; and

FIG. 8 is an enlarged cutaway view showing the shaft and gripping collet.

Referring now to the drawing of FIG. 1A and FIG. 1B in particular, it is seen that the apparatus has a housing 10 which is connectable to a drill string 12 as by threads 14. The lower end of cylindrical member 16 is connected to bit body 12 by threads 18. Extending upwardly from bit body 16 is hollow support member 20. Hollow support member 20 may be an integral part of the bit body 16 or it may be connected thereto by conventional methods.

The lower end of bit body member 16 has slots 24 in which are mounted extendible blades 26. Blade 26 is fastened securely such as by welding to weight transmission shift 28. Body member 16 contains a bore 30 adapted to receive shift 28. Body member 16 also contains fluid passages 32.

Mounted within housing 10 is a traveling sleeve 34 having an upper section 34A and a lower section 34B connected by threaded joint 36. Threaded joint 36 is provided for ease of assembly of the apparatus. The upper end of traveling sleeve 34 defines a split orifice member 38. As illustrated in FIG. 2 orifice 38 is shown to be split into eight sections which fit snugly together when the orifice is in a position shown in FIG. 1A. Cylinder 10 has shoulders 40 which are contacted by shoulder members 42 of orifice 38 and prevents the upward movement of traveling sleeve 34. Bore portions 44 of cylinder 10 is such that when orifice 38 is inserted therein the sections of the split orifice fit snugly together. An enlarged bore portion 46 is immediately below and enlarged from the diameter of bore portion 44. Bore portion 46 has sloping shoulder members 48. Traveling sleeve 34 is provided with guide members 50 which slide freely within bore portion 46 of cylindrical member 10.

The contour of split orifice 38 is such that it can be closed by a ball 52. Ball 52 and split orifice 38 and the size of bore portion 44 and enlarged bore portion 46 of housing member 10 is such that when split orifice 38 is in the upper position as shown in FIG. 1A, ball 52 closes the orifice; however, when the traveling sleeve is moved downwardly with respect to housing member 10 such as to permit orifice 38 to expand into enlarged bore portion 46, ball 52 passes through the orifice.

Below bore portion 46, housing 10 has a further enlarged bore portion 54. Traveling sleeve 34 is centered within housing member 10 by guide vanes 56 and lower guide vanes 58 which may be made integral with cylindrical member or housing 10. It will be noted that guide members 56 and 58 are spaced about traveling sleeve 34 leaving passages 60 therebetween. As shown in FIG. 5, traveling sleeve 34 has ports 62 which establishes fluid flow.
communication between the interior of traveling sleeve 34 and passages 69.

Downward facing shoulder 64 and upward facing shoulder 66 on the interior of traveling sleeve 34 limit the travel of gripping sleeve 68 which surrounds shaft 28. A friction position retaining ring 70 is provided between gripping sleeve 68 and shaft 28. A gripping collar 72 surrounds shaft 28. Gripping collar 72 is more clearly shown in three dimensional view of FIG. 8. Gripping collar 72 is more clearly shown in three-dimensional view of FIG. 8. Gripping collar 72 contains a vertical slot 73 to give impregnation and contraction similarly as a piston ring. The interior of gripping collar 72 contains serrations 75 or the like. Gripping collar 72 has a sloping face 74 to complement the sloping face 76 of gripping sleeve 68. The lower end of gripping sleeve 68 is provided with an internal shoulder member 78 which retains collet seating spring 81 between shoulder 78 and collar 72. Gripping collar 72 is resetable when traveling sleeve 34 is moved upwardly relative to shaft 28.

Positioned within traveling sleeve 34 and below internal shoulder 66 are downward facing internal shoulder 80 and upwardly facing internal shoulder 82. Shoulder 66 may be a square shoulder; however, shoulder 82 is preferably a sloping shoulder. Connected to hollow support member 20 is extension member 84. Extension member 84 has a series of ports or holes 86 spaced about its circumference. Mounted within ports 86 are locking balls 88. At this point, it should be pointed out that shaft 28 has a series of external grooves 98 into which a position of the periphery of locking balls 88 fit when one of such grooves is opposite hole 86 in extension member 84 and internal face 92.

The balls 88 are held in grooves 90 by internal face 92 of traveling sleeve 34 hence locking weight transmission shaft 28 to drill string through body 16. Grooves 90 are designed such that balls 88 extend thereinto a distance approximately equal to the relief behind shoulder 82. This permits balls 88 to be released from groove 90 but retained in ports 86. Grooves 90 are such that downward force on shaft 28 tends to push balls 88 outwardly. A locking sleeve return spring 95 is positioned between the upper end of extension member 84 and downward facing shoulder 86. A friction position retaining ring 94 is positioned about shaft 28 in groove 96 within friction position retaining ring 94. Friction position retaining ring 94 is similar to retaining ring 70 that is, retaining ring 94 resists longitudinal movement between shaft 28 and hollow support member 20. The retaining ring should resist downward movement of shaft 28 under small downward force applied to shaft 28 such as caused by the weight of shaft 28 itself and unobstructed flow of fluid through the tool but permit movement upon application of great force thereto, say in the order of about 500 pounds.

A seal 98 is provided between shaft 28 and the body 16. Downwardly directed port means 100 are provided to establish a small amount of fluid communication between the bore of hollow support member 20 and the annular space between hollow support member 20 and the interior of cylindrical housing member 10 so that the actuating mechanism is flushed.

Turning now to FIG. 6 and FIG. 7 there is shown an especially preferred manner of constructing the shoe of bit body 16 and cutting blade 26. In front of slot 24, body 16 is cutting face 102 which is preferably provided with hard cutting particles such as tungsten carbide or diamonds or the like. The trailing or heel portion 104 is not primarily a cutting surface. The difference in height h between face 102 and heel 104 is equal to tangent μ times w wherein w is the thickness of blade 26 and μ (arc tangent h/w) is the desired face clearance angle of the cutting edge of blade 26. The angle μ may vary from the gage to the center of the bit because of the increasing helix angle from the gage inwardly. The reference "h" is the difference in elevation of the body of the bit at the leading and trailing edges of blade 26. h should be such that the arc tangent of h/w is equal to or greater than the helix angle generated by the penetration rate at the bit. The helix angle can be defined as the arc tangent of A/B in which A is the distance a point on blade 26 advances downwardly into the formation and B is the travel of that point over time at an infinite amount greater than the maximum helix angle cut by the blade at each such point along the edge of the blade. A maximum penetration rate is obtained from the best data available, such as from other wells drilled in the area and is used in computing the axial advance of the bit during one revolution, i.e. the value A. The value of B for each such point can be determined from adt where d1 is twice the radius of such point. The maximum helix angle is determined for each representative point along the blade for the maximum penetration rate from which the advance, or value of A, of the bit during one revolution may be determined. The construction of each blade is such that the edge is of an extremely hard and abrasive resistive material while the backing edge is of a softer less abrasive resistive material. In operation, as blade 26 wears it will very possibly wear unevenly. The bottom face 102 of the bit body is provided with hard cutting particles on its face leading blade 26. When the end of blade 26 is worn back to the body face, blade 26 will no longer cut but the hard cutting particles 103 on face 102 of body 16 will. The blade portion still jutting from the body face, i.e. above contour between face 102 and heel 104, will continue to cut until it is worn back to the profile of the body face which has been designed to be the desired blade profile. As shown above, the leading edge of the blade is of extremely hard abrasive resistant material while the backing edge is of a softer less abrasive material and the edge of the body heel 104 is recessed by distance h from the leading or cutting face 102. Cutting face 102 is raised with respect to body heel 104. Thus, when the leading edge of blade 26 is worn even with cutting face 102, continued rotation of the blade abrades it in a relatively straight line from the leading to trailing edge providing a face clearance angle of blade 26 equal to μ which is arc tangent h/w, thus, a sharpening action. After the blade has been sharpened it is then ready to be extended in a manner which will hereinafter be discussed.

Attention will now be directed briefly toward the operation of the device heretofore described. Rotary motion is imparted to the drill bit through drill string 12 and body member 10 to bit body 16. As blade 26 is in a slot within the bit body 16, rotational movement of bit body 16 is transmitted to blade 26. Downward force is applied through drill string 12, body member 10 to bit body 16. Downward force is also applied to blade 26. Hollow support member 20 is connected to bit body 16 at the one end and to extension member 84 at its upper end. Within extension member 84 are locking balls 88 which when traveling sleeve 34 is in the position shown in FIG. 1A and 1B hold balls 88 into engagement with grooves 90 of shaft 28. Downward thrust is thus transmitted through balls 88 to cutting blade 26. Drilling fluid is circulated downwardly through drill pipe 12, the disclining drilling apparatus and back upwardly in the annulus between drill pipe 12 and the wall of the borehole. Drilling is continued by rotating the bit and applying weight to the cutting blade. When drilling commences, blade 26 is extended a reasonable distance of distance beyond body 16. A distance of about one inch is commonly preferred. During the drilling operations the cutting will be done by blade 26 with essentially no cutting being done by the face of the body member 16. As drilling progresses blade 26 wears until it is worn essen-
ially even with the leading edge of the face 102 of the body. This will be detected at the surface by a reduced penetration rate of drilling. When this occurs the drilling is continued without another period of time in order to reach the bit head all the cutting edges of the blade portion still jutting from the body face will continue to cut until they are worn back to the profile of the body face, i.e., is essentially a straight line or plane defined by slot 24 intersecting cutting face 102 and heel 104 which is the desired blade profile as shown in FIG. 7. In general, it can be said for various incremental lengths of extensions of the blade that the radius varies depending upon such factors as the width w of blade 26 and the hardness and the softness of the composition of the leading and trailing edge of blade 26. The drilling time required for reshaping the bottom of cutting blade 26 is approximately 5 to 10% of the time which it takes for the blade to wear back when its extended incremental distance is about one inch which is commonly preferred.

When blade 26 has been reshaped or resharpened, the blade is ready to be extended beyond the face of bit body 16. The cooperation of various parts to accomplish this will now be discussed. In the operation of this system, drilling fluid is circulated downwardly through drill pipe 12 through split orifice 38 through the interior of traveling sleeve 34, out ports 62 and to the passage 68 between cylindrical housing member 10 and the exterior of traveling sleeve 34. A small portion of drilling fluid goes through the inside of sleeve 34 to flush and spread out ports 108. The drilling fluid continues downwardly through the annulus between sleeve 34 and body member 19 through annular space 105 to conduits 32 in the bit body 16 and thence outwardly through discharge ports 33.

Drilling fluid then circulates back to the surface through the annular space between the drilling apparatus and the walls of the borehole carrying the cuttings with it. When it is desired to advance cutting blade 26 all that is necessary is to drop ball 52 while maintaining the pressure on the drilling fluid being forced downwardly through the drill string 12. However, before the ball is dropped the drilling apparatus is lifted from the bottom of the well bore. When ball 52 comes in contact with the orifice 38, it closes the orifice. The hydraulic pressure on the fluid above ball 52 forces traveling sleeve 34 downwardly until shoulder members 42 of bit orifice 38 are expanded into bore portion 62 to pass therethrough and renews the downward pressure buildup on the traveling sleeve 34. Traveling sleeve 34 thus stops its downward movement and ball 52 is collected in cavity 53 above shaft 28. Cavity 53 should be large enough to hold all the balls to be dropped or alternatively the balls might be of a substance to dissolve after a certain contact with the drilling fluid. As traveling sleeve 34 moves downwardly it moves shoulder 82 below balls 88 thus permitting them to be released from engagement with grooves 90 of shaft 28. Continued downward movement of sleeve 34 engages shoulder 64 with the upper end of gripping sleeve 68. This downward force is transmitted through gripping sleeve 68 and gripping collet 72 to drive shaft 28 downwardly through friction portion retaining ring 94 and thus drive the bit blade 26 downwardly or extending from the face of body 16. The moment of sleeve 34 is stopped when the lower end of sleeve 34 contacts the upper end of support member 26. At this position shoulder member 42 of split orifice 38 has moved downwardly to bore portion 46; orifice 38 is expanded by the hydraulic force on ball 52 thus permitting ball 52 to pass therethrough. The downward distance which sleeve 34 travels without permitting the passage of ball 52 therethrough should be equal to the distance required of traveling sleeve 34 to travel to release balls 88 and to extend shaft 28 the sufficient distance to obtain the desired extension of cutting blade 26. The device is designed such that when the downward travel of sleeve 34 is stopped, balls 88 are opposite the next upper groove 90. The grooves 90 are spaced a distance apart equal to the desired extension of blade 25 for each such operation of advancement. Friction rings 70 and 94 stop shaft 28 from going out farther due to inertia.

When traveling sleeve 34 has stopped its downward movement, traveling sleeve return spring 95 drives the sleeve 34 upwardly with the movement of upwardly facing shoulder 82 driving locking balls 88 into engagement with groove 90 aligned therewith and continued upward movement of sleeve 34 locks balls 88 in this engagement. Gripping collet 72 is retracted on shaft 28 a step up from its previous position a distance equal to the distance between grooves 90. The apparatus is then ready to be lowered against the bottom of the borehole to resume drilling operations.

It will be understood that the apparatus and system contained in the above description are not exclusive and illustrative and not limited and that numerous modifications may be made therein without departing from the scope of the invention.

What is claimed is:

1. A bit assembly for the rotary drilling of boreholes in the earth using a drill string suspended from the surface of the earth comprising in combination: a cylindrical housing member adapted to be attached to said drill string; a bit body member adapted to be attached to said drill string, said body being characterized in having a fluid passageway longitudinally therethrough and a longitudinal slot therein open at the lower end of said body; a blade-like cutter element of a character to be supported in the slot of said body member; a hollow extension member attachable to said bit body and extending upwardly into said housing and forming an annular space between the interior of said housing and the exterior of said extension member, such annular space being in fluid communication with the passageway of said bit body member, said extension member having laterally spaced ports about its periphery and near its upper end; a first bore portion in the upper end of said housing; a second bore portion in said housing below said first bore portion and of a greater diameter than said first bore portion; a downwardly sloping internal shoulder between said first bore portion and said second bore portion; a traveling sleeve member insertable within said housing, said sleeve having a split orifice at its upper end having longitudinal segments whose edges are apart when said orifice is in said second bore portion and are forced into contact when said orifice is in said first bore portion; said sleeve also having an upper internal shoulder having a downwardly directed face, a lower internal shoulder having a sloping upwardly directed face, intermediate internal shoulders having upper and lower faces and spaced between said upper and said lower shoulders; a longitudinal shaft attached to one end of said blade and insertable through said hollow extension member and said sleeve, said shaft having a plurality of lateral grooves about its outer surface; a gripping sleeve and collet means spaced apart about said shaft and positioned between said upper shoulder member and said lower member within said sleeve, said gripping sleeve and collet being of a character to permit said shaft to travel downwardly through said sleeve but resist upward movement through said sleeve; a locking sleeve return spring positioned between the extended said extension member and the lower side of said intermediate shoulder; a ball within each said port and of a character to engage said groove of said shaft when said sleeve is positioned such that the internal face of said lower shoulder of said sleeve is opposite said balls and is disengageable from said groove when said sleeve is receded to its retracted position, said collet being of a character to engage said groove of said shaft when said sleeve is positioned such that the internal face of said lower shoulder of said sleeve is opposite said balls and is disengageable from said groove when said sleeve is receded to its retracted position; and a friction ring member between said shaft and said hollow extension member.

2. An apparatus as defined in claim 1 including means to close said split orifice when the upper end of said
orifice is in said first bore portion in said housing and to open said orifice when the upper end of said orifice is in said second bore portion of said housing.

3. An apparatus as defined in claim 1 in which said means to close said orifice is a ball which is of a size to close said orifice when the orifice is in said first bore portion but to pass through when said orifice is in said second bore portion.

4. A bit for the rotary drilling of boreholes in the earth comprising in combination: a cylindrical member adapted to be attached to a drill string; a bit body member provided with means for connecting said body member to said cylindrical member and having a longitudinal slot therein; a blade-like cutter element having drilling and reaming edges and adaptable to be supported within the slot of said body member; a traveling sleeve mounted in said cylindrical member and having longitudinal movement therein between a lower position and an upper position; a shaft provided with means for connecting said shaft to said blade and mounted within said sleeve; releasable holding means supported from said bit body member and operable to hold said shaft rigid with respect to said bit body member when said sleeve is in one position and operable to release said shaft from rigid relationship with said bit body member when said sleeve is in all other positions of its longitudinal movement; first means to longitudinally move said sleeve downwardly with respect to said cylindrical member to its lower position; second means to longitudinally move said sleeve upwardly from its lower position with respect to said cylindrical member; releasable engaging means supported between said shaft and said sleeve to connect said shaft with said sleeve upon downward relative movement of said sleeve and to disconnect said shaft from said sleeve upon upward relative movement of said sleeve.

5. An apparatus as defined in claim 4 in which said body member has a face which on one side of said slot is recessed with respect to the face of the opposite side of the slot at a given point a distance h which is equal to tangent μ times w in which μ is the face clearance angle of the base of the cutting face at each given point and w is the thickness of said cutter element at each such point, μ being an infinitesimal amount greater than the helix angle at each such point, such angle being arc tangent A/B in which A is the axial advance of the bit during one revolution and B is the circumferential travel of such point during one revolution.

6. An apparatus as defined in claim 5 in which the raised side of the face has hard cutting elements therein.

7. An apparatus as defined in claim 6 in which the edge of said cutter element adjacent said raised side of said face is of harder material than the trailing edge of said blade.

8. A bit assembly for the rotary drilling of boreholes in the earth using a drill string suspended from the surface of the earth and comprising in combination: a cylindrical member adapted to be attached to said drill string; a body member provided with means for connecting said body member to said cylindrical member and having a longitudinal slot therein; a blade-like cutter element of a character to be supported within the slot of said body member; a traveling sleeve mounted in said cylindrical member and having longitudinal movement therein between a first position and a second position; a shaft attachable to said blade-like cutter element and mounted within said sleeve; releasable holding means to hold said shaft rigid with respect to said body member when said sleeve is in one position and to release said shaft from rigid relationship with said body member when said sleeve is in all other relative longitudinal positions with respect to said cylindrical member; means to drive said sleeve downwardly with respect to said cylindrical member to its second position; releasable engaging means of a character to connect said shaft with said sleeve upon downward movement of said sleeve and operable to disconnect said shaft from said sleeve upon upward movement of said sleeve; and resilient means urging said sleeve upwardly with respect to said cylindrical member.

9. An apparatus as defined in claim 8 in which said body member has a face in which each increment on one side of said slot is higher than the corresponding increment on the opposite side of the slot a distance h which is equal to tangent μ times w in which μ is the face clearance angle of the base at such increment of the cutting face and w is the thickness of said cutter element at such increment, μ at each such increment being an infinitesimal amount greater than the helix angle at each corresponding increment, such helix angle being defined as arc tangent A/B in which A is the axial advance of the bit during one revolution and B is the circumferential travel of such increment during one revolution.

10. A bit assembly attachable at the lower end of a string of drill pipe for the rotary drilling of boreholes in the earth, said bit assembly having a helix angle at each radial point, comprising in combination: a bit body member having a longitudinal slot therein; a blade-like cutter element; means supporting said cutter element within the slot of said bit body member; means for connecting the bit body member to the lower end of a string of drill pipe; means operable to advance said cutter element downwardly through said slot a selected distance; said bit body member having a face in which each increment on one side of said slot is recessed with respect to the corresponding increment on the opposite side of the slot a distance h which is equal to tangent μ times w in which μ is the face clearance angle of the base at such increment of the cutting face at each such given increment along the length of the cutter element, w is the thickness of said cutter element adjacent such increment, the angle μ at each increment being greater than the helix angle at such increment, such helix angle being arc tangent A/B in which A is the axial advance of the bit during one revolution and B is the circumferential travel of such increment during one revolution.

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