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PRESSURE LUBRICATED DRILL BIT BEARING

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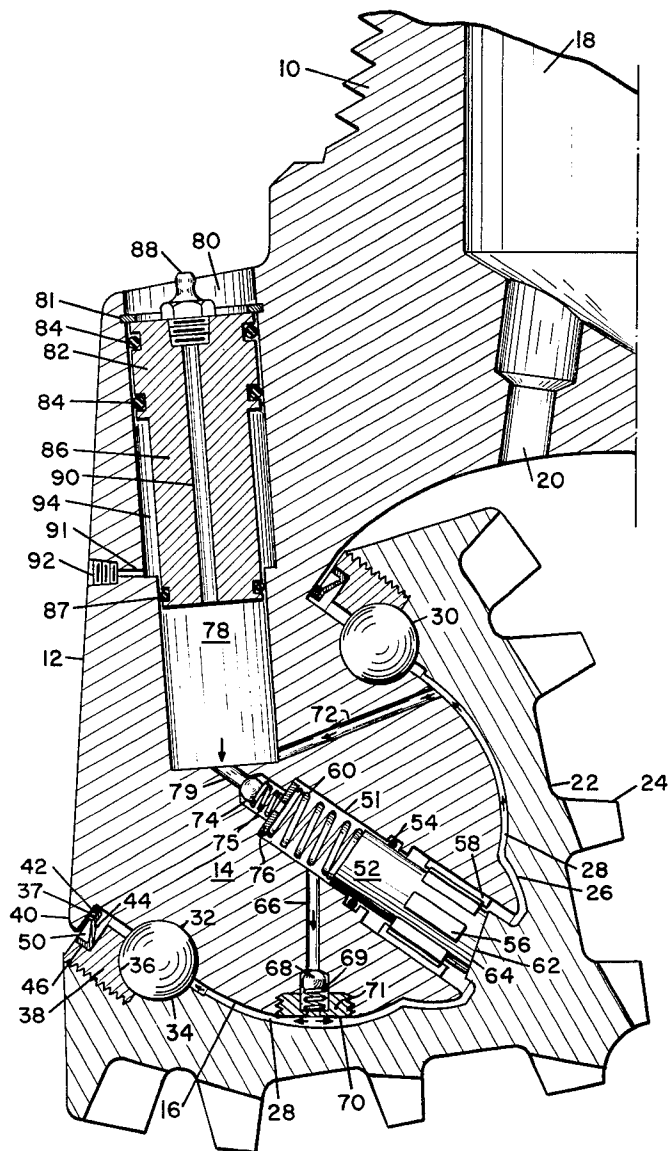


FIG. 1

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PRESSURE LUBRICATED DRILL BIT BEARING

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5 Claims. (Cl. 308-8.2)

This invention relates to the drilling of boreholes in the earth. It relates particularly to roller cone type bits for use in the drilling of such boreholes. It relates especially to a system for providing lubrication to such roller cone bits.

In the art of drilling wells for the production of oil and gas, the most commonly used method is the so-called rotary drilling method. In the rotary drilling method, a drill bit is suspended at the lower end of a string of drill pipe which is supported from the surface of the earth. The drill string is conveniently formed of many joints of drill pipe, each joint usually being about 30 feet long. As the hole is deepened, additional joints of drill pipe as needed are connected into the string. A drilling fluid under high pressure is forced down through the drill string, through the drill bit, and back up to the surface through the annulus between the drill pipe and the wall of the borehole. While the drilling fluid serves primarily to carry the rock cuttings from the drill bit to the surface, it also serves to cool the bit. The drill bit obtains its rotary motion from the drill pipe which is rotated from the surface. It is known that the rate of penetration of a drill bit can be increased by increasing the force (commonly called bit weight) of the drill bit on the bottom of the borehole. The penetration of the drill bit is also influenced by the rate at which the drilling fluid is forced through the pipe and by the rate of rotation of the bit.

One of the most widely used types of bit at the lower end of a string of drill pipe is the so-called rock bit or roller cone bit. A rock bit is normally composed of a shank member which threadedly connects into the lower end of a string of drill pipe. Usually three leg members extend downwardly from the shank. The lower end of each leg member is sometimes called a shaft or pin which extends inwardly and downwardly toward the axis of the bit. On the exterior of the shaft are inner bearing races. Roller cone cutting elements or members are rotatably supported by roller and ball bearings from the shaft of each such leg. The interior of the roller cone element contains the outer bearing races. As the drill pipe is rotated, the bit is likewise rotated. As the bit is rotated, each individual cone rotates about the shaft of the leg member from which it is supported. The cone also rotates about the bottom of the hole. Normally only the rolling cutting surfaces of the cone are exposed to the bottom of the hole. The action of the rolling cutting surface on the bottom of the hole is a twisting, tearing or gouging action for softer formations, and an approximate chipping, crushing action on the harder formations.

To perform ideally, a rock bit should be so designed that the teeth, that is, the roller cutting portions of the cone, and the bearings which support the roller cone from the leg members, should wear out at the same time. Due to recent developments in the manufacturing of the roller teeth, such as use of tungsten carbide "compact" bits, the cutting surface consistently outlasts the bearings by a large factor in hard formation drilling. The same is true in the case of soft formation bits where only light bit weights are required. One of the major problems in the failure of the bit bearings, and thus in effect the bit, is the mixing of mud and lubricating greases in the bearings. Mud thus displaces the lubricating fluid. The drilling mud is a poor lubricant and frequently carries into the

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bearings particles of the rock or earth formation that has been drilled. These two factors cause a rapid deterioration or wearing away of the bearings and failure of the bit.

This invention relates to a lubricating system for extending the life of the bearings of a roller cone type bit. Sealing means are provided to effectively separate or close off the clearance between the journal of the leg and the bearing of the roller cone from the exterior of the bit. A special pump means is provided to circulate lubricating fluid under high pressure through this sealed off clearance space. The pumping means is actuated by the rotation of the roller cone element about the shaft. This system provides high lubricating characteristics. (a) It provides a hydrostatic bearing by the pumping of lubricating fluid between the journal and the bearing; (b) a hydrostatic squeeze film is available as lubricating fluid is always present between the two surfaces; and (c) a third component of the film pressure is developed by the relative rotation of the bearing components and can be called hydrodynamic effect.

The objects and a complete understanding of the invention can be had from the following description taken in conjunction with the drawing in which:

FIG. 1 is a section view illustrating the best mode contemplated for practicing the invention.

Shown in the drawing is shank 10 from which extends leg member 12. In most cases there will be three such leg members; however, for the purposes of illustrating this invention, only one leg will be shown. Leg member 12 has an integral shaft 14 forming a journal 16. The shaft 14 extends inwardly and downwardly toward the axis of the bit. Shank 10 has an internal chamber 18 through which drilling fluid is conducted downwardly to passageway 20 and about the cutters. Roller cutter element 22 having teeth or cutting elements 24 is rotatably supported about shaft 14. The internal surface of roller cone element 22 forms a bearing 26 which mates with journal 16. A clearance 28 is provided between journal 16 and bearing 26. Clearance 28 is preferably about .0005 to .002 inch.

Roller cone 22 is rotatably supported from shaft 14 of the bit leg 12 by ball bearings 30. The inner race for ball bearings 30 is provided at 32 in shaft 14. One-half of the outer race is provided at 34 in the inner portion of roller cone 22. The other half of the outer race is provided at 36 in annular bearing retainer 38. Sufficient clearance is provided between face 37 of shirt tail 40 of leg 12 and retainer 38 to permit placing ball bearings 30 in their races after retainer 38 has been placed over shaft 14 and adjacent to face 37.

Seal means are provided between bearing retainer 38 and shirt tail 40 of bit leg 12. Retaining ring 38 has an annular groove or cell 50 which is positioned just above outer race 36. The seal means includes a seal element 42 which can be phenolic resin, impregnated hard carbon or bronze for example. The seal element 42 is held against face 37 of shirt tail 40 by a conical disc spring 44. One end of conical disc spring 44 is sealingly secured to bearing retainer 38 at 46.

As shown above, roller cone element 22 is rotatably supported from shaft 14 of leg 12 by ball bearing means 30 and its associated races. A sealing contact is made between the roller cone and the leg. Thus space or clearance 28 is effectively sealed and isolated from the exterior of roller cone 22.

Attention is next directed toward that part of the system for circulating lubricating fluid under high pressure through the clearance between the journal 16 and bearing 26. A chamber 51 which is cylindrical and axially aligned with the axis of shaft 14 is provided. A piston 52 is mounted in cylinder 51 and seals 54 provide the sealing

contact between piston 52 and cylinder 51. External splines 56 of piston 52 engage internal splines 58 of the cylinder; thus, piston 52 has longitudinal movement within cylinder 51 but does not have rotational movement therein. Mounted between the upper end of cylinder 51 and piston 52 is a spring 60 which urges piston 52 outwardly in the direction of the splines or toward the apex of the shaft or cutting element. The outermost end of piston 52 is cut to form a diagonal face 62. A second diagonal face 64 is provided in roller cone 22. Thus, as roller cone 22 rotates about shaft 14 of leg 12 during drilling operations, piston 52 reciprocates within cylinder 51. The upper or power end of cylinder 51 is connected through conduit 66 through check valve 68 to clearance 28 between the journal and the bearing. Check valve 68, which includes spring member 69 held in place by screw-threaded plug 71, permits the flow of fluid only from the cylinder toward the clearance. Shaft 14 has a flat surface 70 to aid in getting fluid into clearance 28. A second conduit 72 connects a second portion of the clearance 28 with reservoir 78 which is in leg 12 and is connected by conduit 79 with the inlet to cylinder 51. A check valve 74, which includes spring member 75 held in place by washer 76, is provided in the inlet permitting fluid to flow only inwardly toward the cylinder.

In drilling the greatest force between journal 16 and bearing 26 is at the bottom. Thus high pressure lubricant is directed to flat surface 70 at the bottom of the shaft at this point or area of greatest force. In operation the lubricating fluid is pumped between the bearing and the journal and a hydrostatic bearing effect is obtained. By having a fluid between the bearing and the journal and a hydrostatic squeeze film lubrication is also effected. Thirdly by having a fluid contained in clearance 28, a hydrodynamic lubrication effect is developed when relative motion between the bearing components are achieved as in drilling. The outlet of the pumping means is connected through conduit 66, check valve 68 and flat surface 70 to a first portion of clearance 28 at the point of highest force. Inlet conduit 72 of the pumping means is connected to one portion of clearance 28 which is on the upper side of shaft 14 at the point of smallest force. Thus a circulating path of lubricating fluid is obtained.

It is very important to prevent drilling fluid from entering clearance 28. Seal 42 prevents this as long as it is working properly. To aid its proper functioning, the minimum pressure within the cone 22 is maintained slightly above that of the pressure of the mud in the borehole surrounding the bit. Then if the seal should develop a slight leak, lubricating fluid would escape due to the pressure being in excess of that of the drilling fluid. Conversely, the higher pressure inside the roller cone 22 would prevent drilling fluid from entering. Means are provided so that when this does occur, make-up lubricating fluid is supplied to the pumping means. Lubricating fluid reservoir 78, in bit leg 12, is in communication through conduit 79 with the inlet to cylinder 51 of the pump. Fluid reservoir 78 is preferably cylindrical in shape and has a diameter d_1 . Axially aligned with fluid reservoir 78 is a second cylinder 80 having a diameter d_2 which is larger than d_1 . Cylinder 80 extends or opens into the exterior of leg 12. Mounted in cylinder 80 is a piston member having an upper portion 82 of diameter d_2 which is essentially the diameter of cylinder 80. Sealing rings 84 are provided to give it a sliding and sealing contact with the inner wall of cylinder 80. A retaining ring 81 is provided in cylinder 80 to prevent the piston from being forced out the upper end of cylinder 80.

Extending downwardly from element 82 is a piston extension 86 which has a diameter d_1 substantially the same as the diameter of fluid reservoir 78. A seal ring 87 is provided about extension 86. A passage 90 is provided through piston elements 82 and 86. At the top of

passage 90 is a fitting 88 such as a Zerk. Fitting 88 can be a valve which can be opened when it is desired to pump fluid downwardly through passage 90 and can be closed at other times. A conduit 91 extends from annular space 94 beneath piston element 82 to the exterior of the bit. A valve such as a removable plug 92 is provided at the outer end of conduit 91. When it is desired to load fluid reservoir 78, valve 92 is opened and piston 82 is pushed or forced to its lowermost position in cylinder 80. This exhausts all the air or other fluid which is below piston element 82 in annular space 94. Plug 92 is then inserted, thus closing conduit 91. Thereafter a lubricating fluid is injected through fitting 88 and passageway 90 to fill reservoir 78 and the space between cone 22 and journal 16. As fluid is injected, it forces piston element 82 upwardly. As the piston goes up, a partial vacuum is created or occurs in annular space 94.

After the reservoir 78 and the space between cone 22 and journal 16 has been filled with lubricating fluid as described in the immediately above paragraph, the bit is ready for attachment to a drill string and use in drilling a borehole. It is believed that the operation of the tool is now apparent. However, a few comments will be made thereon. When drilling operations are commenced, roller cutting elements rotate about the axis of shaft 14 of leg 12. When this occurs, diagonal face 64 on the cone and diagonal face 62 on the lower end of piston 52 are changing their relative position. This change, coupled with the energy thus stored in the spring 60, produces a reciprocating motion of piston 52. The movement of piston 52 causes the fluid in cylinder 51 to pass downwardly through conduit 66 and check valve 68 into clearance 28 under very high pressure. The pressure is primarily dependent upon the design of diagonal faces 62 and 64 (which determines the stroke of piston 52) and the volume within cylinder 51 above piston 52. Thus a lubricating fluid under high pressure is forced into clearance 28 at the point of greatest force between the journal and the bearing. This causes a hydrostatic bearing and prevents contact between the journal 16 and bearing 26. The fluid then flows through clearance 28 through conduit 72 and back to the inlet to the pump cylinder 51.

Any make-up fluid needed for the system is provided from reservoir 78. The fluid in reservoir 78 is maintained under relatively high pressure by the piston differential arrangement of piston elements 82 and 86. The pressure of the drilling fluid in the well bore acts on the upper surface of piston element 82, which is of greater area than the area of the lower end of piston element 86. Thus the pressure of the make-up fluid in the fluid reservoir 78 is in excess of that of the drilling fluid exterior of the bit. The pumping means is selected to have an output pressure substantially greater than that developed in the reservoir 78. As the clearance is very small between journal 16 and bearing 26, very high pressure from the pump output is required to force the fluid through clearance 28 (which is at a minimum at the bottom of journal 16) around the journal and back through conduit 72. For example, for a 9 inch diameter bit having a clearance of about .001 inch, this pressure drop can be in the range of from about 10,000 to about 20,000 p.s.i.

A hydrostatic squeeze film effect is also created by the pressure built up between bearing 26 and journal 16. As the bearing rotates with respect to the journal, hydrodynamic pressure is developed in the clearance 28 and contributes to the total load carrying capacity of this bearing. In addition to these improved results of lubricating, the lubricating fluid under pressure prevents any possibility of drilling mud particles entering clearance 28 and causing damage to the bearing or journal surfaces.

It is possible to produce modifications from the embodiment disclosed herein without departing from the inventive concept. For example, cylinder 51 and piston 52 can be positioned in shaft 14 in a non-axial manner. If piston 52 has a reciprocating motion which is at an

angle to the axis of shaft 14, then face 62 of the piston can be perpendicular to the axis of piston 52 and face 64 of the cone member is diagonal, as illustrated in FIG. 1. This is also true if cylinder 51 and piston 52 are arranged such that their axis is parallel to the axis of shaft 14, or in this case the face of the piston can be round for better load distribution. It is thus desired that only such limitation be imposed on the appended claims as are stated therein.

What is claimed is:

1. A bit for drilling boreholes in the earth which comprises:
 - a shank means;
 - a leg member extending from said shank means, the lower portion of said leg member forming a journal;
 - a roller cone member, a portion of said roller cone member shaped to define a bearing means mating with the journal of said leg member, said bearing means and said journal having a sufficient clearance therebetween to permit the circulation of a lubricating fluid;
 - means to rotatably support said roller cone member from said leg member;
 - sealing means for preventing the escape of lubricating fluid from between said journal and said bearing;
 - pump means within said leg member having an input and an output;
 - means to connect the output of said pump means with one portion of the clearance between the journal and the bearing;
 - means to connect the input to said pump means to another portion of such clearance;
 - means for driving said pump means from the relative movement between said leg member and said roller cone member.
2. An apparatus as defined in claim 1 including a reservoir means for supplying lubricating fluid to the input to said pump means.
3. A bit which comprises:
 - a shank means;
 - a leg member extended from said shank means, a portion of said leg member forming a journal, such journal of said leg member having an axis, said leg member having a flat surface on its lower side;
 - a roller cone member, a portion of said roller cone member shaped to define a bearing means mating with the journal of said leg member and forming a

- clearance therebetween and also surrounding said flat surface; said leg member having a cylinder whose longitudinal axis coincides with the axis of the journal of said leg member;
- a piston having a pressure end, said piston sealably, slidably, and nonrotatably mounted within said cylinder, said piston also having a face member opposite its pressure end which is nonperpendicular to its axis;
 - means urging said piston outwardly toward said roller cone member;
 - a second face member rigidly supported from said roller cone member opposite the outer end of said piston, such second face being nonperpendicular to the axis of said piston;
 - first conduit means connecting the pressure end of the cylinder to the flat surface of said journal;
 - a check valve in said first conduit means permitting the flow of fluid only from said cylinder toward said flat surface;
 - second conduit means connecting another portion of said clearance remote from said flat surface to the pressure end of said cylinder;
 - check valve means in said second conduit means permitting the flow of fluid only inwardly toward said cylinder; and sealing means between said roller cone member and said leg member to maintain said fluid within the assembly.
 4. An apparatus as defined in claim 3 in which said means urging said piston is a spring.
 5. An apparatus as defined in claim 3 including make-up reservoir means for supplying lubricating fluid to the power end of said cylinder.

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