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Faulk

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[54] **WELL DRILLING**

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[52] **U.S. Cl.** **175/65,** 175/107

[51] **Int. Cl.** **E21b 3/08,** E21b 7/00

[58] **Field of Search** 175/101, 107, 230, 321, 57, 175/65, 26–38, 6

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[57] **ABSTRACT**

A downhole drilling tool employing a downhole motor which drives a shaft carrying the drill bit, and thrust means both for causing a pressure drop in the drilling fluid in the vicinity of the shaft and for applying the force created by the pressure drop to the shaft thereby increasing the total force applied to the bit. A method for reducing bearing wear while drilling with a downhole motor when bit weight for drilling is applied to the shaft of the downhole motor from a housing, the shaft communicating with the housing through bearings, comprising passing drilling fluids between the shaft and housing, causing a pressure drop of the drilling fluid, and applying the force resulting from the pressure drop to the shaft.

8 Claims, 2 Drawing Figures

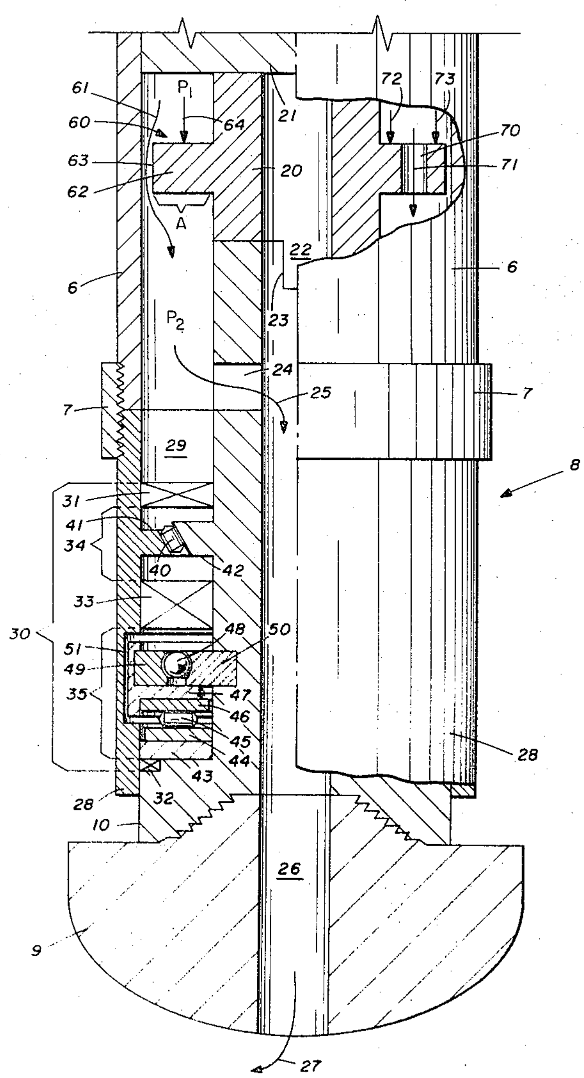
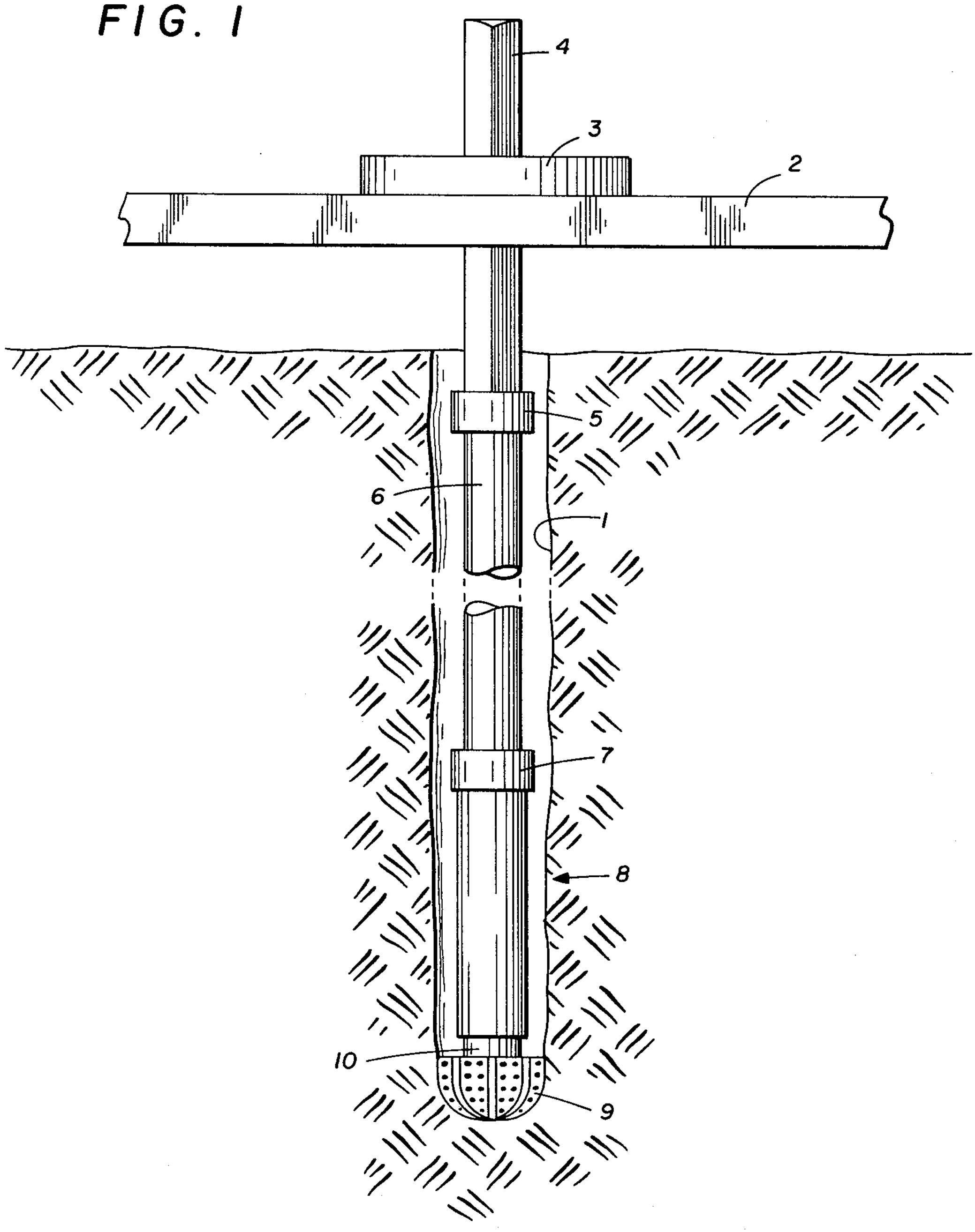


FIG. 1



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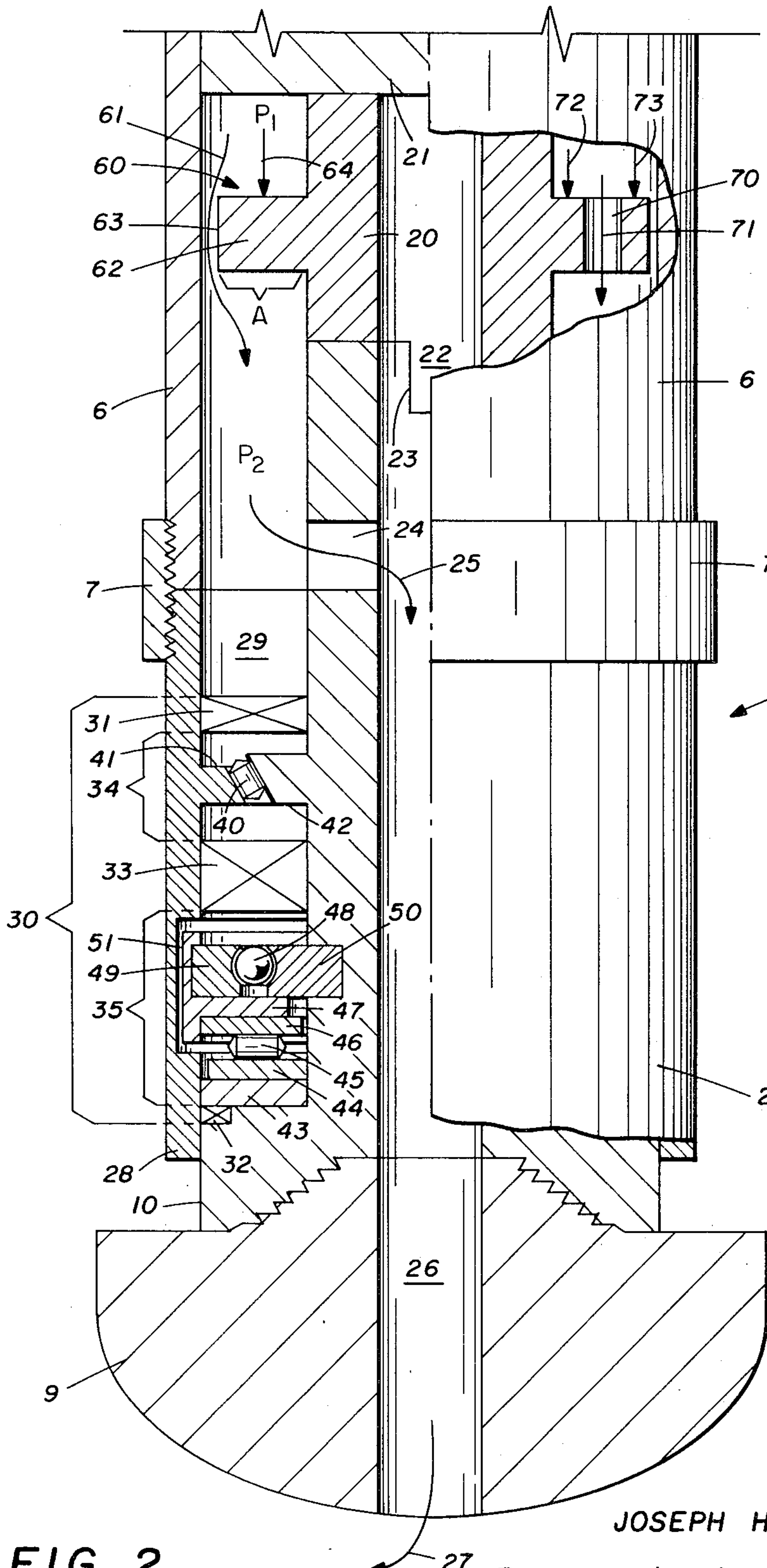

FIG. 2

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WELL DRILLING

BACKGROUND OF THE INVENTION

Heretofore in the use of a downhole motor drilling tool, the downhole motor has been connected to the bit by a shaft and the motor and shaft contained in a housing. The housing was connected to the drill pipe string so that substantially all of the weight applied to the bit for drilling was applied from the drill string to the housing and then transferred from the housing to the shaft of the downhole motor by way of bearing means. Because thousands of pounds are applied to a bit during drilling, the bearing means between the housing and shaft transferred great weight while rotating at various speeds, even very high speeds, such as from about 400 to about 3,000 rpm in the case of "slim hole" drilling.

A problem with such a setup has been that in the process of transferring great weight at high rotation speed the bearing means can wear out before the bit wears out and it is economically wasteful to have to remove the drill string from the wellbore for any reason before the bit itself is completely worn out. To extend the bearing life, elaborate systems have been devised to protect the bearings.

SUMMARY OF THE INVENTION

According to this invention, instead of focusing on the bearing means and making innovations to extend bearing life, focus is made on how the bit weight is applied to the bit. By this invention, instead of transferring substantially all of the bit weight from the housing through the bearing means to the shaft and, consequently, the bit, a substantial portion of the bit weight is generated by creating a force in the vicinity of the shaft and applying this force to the shaft itself so that this force is not transferred through the bearing means between the shaft and housing. By creating at least a portion of the bit weight in a manner such that it is not transferred from the housing to the shaft by the bearing means a substantial reduction in bearing wear is achieved thereby extending the life of the bearing means beyond that of the bit.

According to this invention there is provided a well drilling device or tool wherein a drill bit is rotated to drill a wellbore, the device utilizing a downhole motor which is connected to a shaft that is adapted to carry a drill bit, and thrust means carried in the vicinity of the shaft both for causing a pressure drop in the drilling fluid passing thereby and for applying the force created by the pressure drop to the shaft.

Also, according to this invention there is provided a method for reducing bearing wear while drilling a wellbore by rotating the drill bit with the shaft of a downhole motor, the bit weight for drilling being applied to the shaft from a housing through bearings, the improvement in the method comprising passing drilling fluid between the shaft and housing, causing a pressure drop of the drilling fluid, applying the force resulting from the pressure drop to the shaft so that the weight applied to the shaft and, therefore, the bit by way of the housing is reduced with a resulting saving of bearing wear.

Accordingly, an object of this invention is to provide a new and improved downhole drilling device. Another object is to provide a new and improved downhole drilling tool which will exhibit increased bearing life. It is another object to provide a new and improved downhole drilling device which supplies a substantial portion of the desired bit weight to the bit shaft without transmitting that bit weight through a bearing means. It is another object to provide a new and improved method for reducing bearing wear in a downhole drilling device. It is another object to provide a new and improved method for generating a substantial portion of the desired bit weight in a manner such that this portion of the bit weight is applied to the bit without being transmitted through a bearing.

Other aspects, objects, and advantages of this invention will be apparent to those skilled in the art from this disclosure and the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows well drilling apparatus in which this invention can be employed.

FIG. 2 shows one embodiment within this invention.

More specifically, FIG. 1 shows a wellbore 1 in the earth's surface under the working floor 2 of a conventional rotary drilling rig.

Working floor 2 carries a conventional rotary table 3 which is powered by a conventional earth's surface motor means (not shown) and which, when rotated, rotates square kelly 4. Kelly 4 is coupled by means of coupling 5 to drill pipe 6. Drill pipe 6 is coupled by means of coupling 7 to downhole drill device 8 which in turn is fixed to diamond drill bit 9. Device 8 has its own downhole motor.

In operation, rotary table 3 is rotated by a surface motor means to rotate kelly 4, drill pipe 6, downhole device 8, and bit 9. Downhole device 8 is then operated on its own to speed up the rotation of bit 9 to a rotational speed which, if achieved by the drill pipe 6 alone in a slim hole operation, could cause catastrophic vibration of drill pipe 6 in wellbore 1. However, with this invention, drill pipe 6 is rotated at a lower speed than the net rotating speed of bit 9 when device 8 is in operation.

Accordingly, this invention provides a method of drilling a borehole in the earth by rotating a drilling bit during drilling, the bit being supported from the earth's surface with drill pipe, the rotational speed of the bit being achieved by rotating the bit at a first speed increment using device 8 and further rotating the bit an additional second speed increment using a surface motor means to rotate drill pipe 6. The first and second speed increments additively give the desired net rotating speed for the bit during drilling.

The downhole device 8 can be located substantially any place along the length of drill pipe 6, but is preferably closer to the bit than the earth's surface when the borehole is deeper than the total length of the bit and downhole device 8. A suitable position for the downhole device, but by no means the only position for this invention, is adjacent the bit as shown in the drawing. It should be understood, however, that one or more downhole devices can be employed and can be spaced upwardly from the bit along the length of the drill pipe as desired.

The net rotating speed desired for the bit in slim hole drilling is at least about 400 rpm and has no upper limit other than that dictated by the capability of the equipment being used, the nature of the earth strata being drilled through, and the like. However, generally, the net rotating speed for the bit will be from about 400 to about 3,000 rpm. The second speed increment, i.e., that provided by the surface motor means such as rotary table 3 of the drawing or a conventional power swivel, or the like, will be a finite rate of rotation up to about 400 rpm. The first speed increment, i.e., that supplied by the downhole motor means, comprises the remainder of the desired net rotating speed of the bit. It is preferable that the second speed increment be at least about 100 rpm but less than the desired net rotating speed of the bit. In this manner the second speed increment is a substantial contributing factor to the net rotating speed and, therefore, the drilling rate of the bit. Thus, for example, the second speed increment can be from about 100 to about 400 rpm but will still be substantially less than the net rotating speed, the difference being made up by operation of one or more downhole devices **8**.

The second speed increment can be substantially any desired amount less than the net rotating speed so long as catastrophic vibration of the drill pipe is avoided. Generally, the second speed increment will be no more than about one-half the total desired net rotating speed of the bit.

As with the surface motor means, substantially any conventional downhole motor means can be employed in device **8**. Such motor means are commercially available and well-known in the art. These motor means include downhole electric motors; turbine operated motors such as the "turbo drill" wherein the drilling mud passing downwardly through the interior of the drill pipe runs a turbine in the turbine motor and the turbine turns the drill bit; or motors which are in reality a fluid pump in reverse such as the "dyna-drill." The structure and operation of fluid-pump-in-reverse motors is fully and completely disclosed in U.S. Pat. No. 3,112,801, the disclosure of which is incorporated herein by reference.

FIG. 2 shows the partial cross-sectional interior of tool **8** and shows bit **9** to threadably engage hollow shaft **10** which in turn engages shaft **20**. Shaft **20** is powered by a downhole motor means **21**. Shafts **10** and **20** can be made integral but are preferably separable for ease of replacement of the downhole motor. In any event, shafts **10** and **20**, whether one-piece or in a plurality of pieces comprise a shaft means which is powered by downhole motor means **21** and which, when rotated by motor **21**, rotates bit **9** for drilling purposes. The shaft means has its longitudinal axis extending from motor means **21** to bit **9**. Shaft **10** can engage shaft **20** in any manner such as by a plurality of splines **22** on shaft **20** engaging a plurality of matching slots **23** in shaft **10**.

Shaft **20** has one or more apertures **24** therein which serve as means to pass drilling fluid around the bearing by admitting drilling fluid from outside the shaft into the interior of the shaft as shown by arrow **25**. The drilling fluid then passes down the interior of the shaft through the interior conduit **26** of bit **9** and out around the outer surface of bit **9** as shown by arrow **27** to cool the bit and sweep rock cuttings away from the bit. The rock cuttings are carried upwardly in the annulus by the drilling fluid between the walls of the wellbore and the outer surface of drill string **6** to the surface of the earth where most of the cuttings are removed and the drilling fluid then returned down the interior of drill string **6** for reuse.

Annular housing **28** is concentric with and external to shaft **10**, thereby providing an annular chamber **29** between the exterior of shaft **10** and the interior of housing **28**. The upper end of housing **28**, i.e., the end farthest removed from bit **9**, is threaded so as to be connectible to the lower end of drill string **6** by way of coupling **7**.

The end of housing **28** closest to bit **9** touches or is at least quite close to shaft **10** but is slidable around and along the shaft, i.e., not fixed by welding, bolting, or the like to the shaft, so that the shaft can rotate independently of housing **28**.

Annular chamber **29** has a bearing and seal section **30** which contains upper and lower seal means **31** and **32** and intermediate seal means **33**. Upper seal means **31** prevents drilling fluid in chamber **29** in the vicinity of aperture **24** from penetrating the interior of section **30**. Lower seal means **32** prevents the entry of drilling fluid outside of housing **28** into the interior of section **30**. Conversely, seals **31** and **32** also keep fluid lubricant in the interior of section **30** from leaking out into the upper portion of chamber **29** or to the outside of housing **28**. Intermediate seal **33** effectively seals the upper portion **34** of section **30** from the lower portion **35** of section **30**. Thus, upper section **34** can be at the pressure obtaining in chamber **29** in the vicinity of aperture **24** while lower section **35** can be at the pressure obtaining outside of housing **28**, the two pressures being substantially different because of the pressure drop through the interior channel **26** of bit **9**. Put another way, upper section **34** is at the higher pressure obtaining in chamber **29** in the vicinity of aperture **24**, while lower section **35** is at the lower pressure present on the exterior of housing **28**.

Upper section **34** contains a bearing means which is composed of a plurality of roller bearings **40** which are carried at an angle between the longitudinal axis of shaft **10** and the transverse axis of shaft **10** and between opposed annular races **41** and **42** so that roller bearings **40** transmit both radial and thrust forces. A grease fitting (not shown) can be provided so that lubricant can be injected into the interior of section **34** for lubrication of the bearing device or devices therein.

In lower section **35** above seal **32** there is provided an annular spacer means **43** upon which rests lower annular race **44** of roller bearings **45**. Bearings **45** are disposed horizontally to transmit thrust force acting substantially parallel to the longitudinal axis of shaft **10** in either direction, i.e., toward or away from bit **9**. Upper annular race **46** confines a plurality of roller bearings **45** and completes the thrust bearing device for section **35**. Above race **46** is disposed shoulder **47** which transmits bit weight from roller bearings **45** to housing **28**.

Above shoulder **47** is disposed ball bearings **48** between opposed annular races **49** and **50**. This ball bearing device transmits radial forces which act at an angle to the longitudinal axes of shaft **10** and housing **28**. A grease fitting (not shown) can also be provided for injecting lubricant into the interior section of **35**. To insure that there is an evenness of lubrication for both bearing devices in section **35**, one or more conduit means 51 is provided through housing 28 and is in communication with open areas adjacent roller bearings 45 and ball bearings 48. Since roller bearings 45 force lubricant outwardly toward housing 28 by centrifugal force, lubricant circulates from the vicinity of roller bearings 45 through conduit means 51 and past ball bearings 48 back to roller bearings 45. In this manner, not only the reservoir lubricant provided in the interior section 35, but circulating means is provided so that uniform lubrication of ball bearing devices in section 35 is maintained.

Shaft 10 carries a thrust means 60 which causes a pressure drop in the drilling fluid in chamber 29 as it passes from motor 21 towards aperture 24 as shown by arrow 61 and which applies the force created by this pressure drop to shaft 20. Thrust means 60 increases the total weight applied to bit 9 by way of shafts 20 and 10 without passing the increased weight through the bearing means in section 30. Downthrust means 60 comprises an annular shoulder 62 carried by shaft 20 and extending laterally toward the interior surface of housing 28. Shoulder 62 therefore extends substantially transverse to the longitudinal axis of shaft 20. Shoulder 62 occupies a substantial lateral portion of chamber 29 but not the entire lateral portion in that the outer circumference 63 of shoulder 62 is spaced inwardly from the inner surface of housing 28 to thereby allow for the passage of drilling fluid as shown by arrow 61.

The restricted orifice created by the lateral extension of shoulder 62 into chamber 29 creates a pressure drop in chamber 29 so that the pressure P_1 of the drilling fluid as it passes out of the vicinity of motor 21 is substantially greater than the pressure P_2 of the drilling fluid downstream of shoulder 62. The pressure drop created by shoulder 62 acts over area A on the upper surface of shoulder 62 as shown by arrow 64 so that there is a net, additional downthrust imposed on shaft 20 which is transmitted by way of shaft 10 to bit 9 thereby increasing the weight on bit 9 without transmitting this additional downthrust through any of the bearing means in section 30. By use of thrust means 60 an increase of bit weight can be obtained without passing the increase through the bearing devices in section 30 or the same bit weight can be obtained by passing less weight from drill string 6 and housing 28 through the bearing devices in section 30 to shaft 10, in either of which cases substantial wear on the bearing devices in section 30 is realized with a consequent increase in the life of these bearings.

That portion of shoulder 62 which shows force 64 to be acting thereon is shown to be substantially imperforate and to extend laterally a substantial distance toward housing 28, the outer circumference 63 of the shoulder being spaced from housing 28 sufficiently for the passage of the required volume of drilling fluid. Outer circumference 63 need not be a smooth cylindrical surface; it could as well be scalloped or otherwise uneven or have a plurality of indentations or part circles therein to admit the passage of a greater volume of drilling fluid past shoulder 62 in a given length of time. Conversely, outer circumference 63 can carry one or more spaced apart extensions to decrease the amount of drilling fluid passing shoulder 62 in a given unit of time.

Shoulder 62 need not be imperforate, however. Shoulder 62 can be perforate by having one or more pores, conduits, passageways, and the like passing through its interior. For example, aperture 70 extends through shoulder 62 so that drilling fluid can pass directly through the shoulder as represented by arrow 71. In such a situation the downthrust created by the pressure drop from P_1 to P_2 would act on the remaining upper surface areas of the shoulder as represented by arrows 72 and 73. In this situation it may be desired, but is not necessarily required, that outer circumference 63 be in closer proximity to the interior surface of housing 28 than in the situation when the shoulder is substantially imperforate.

In operation, the downhole motor 21 is energized by electricity, drilling fluid energy, etc., thus rotating shaft 20 and in turn rotating shaft 10 and bit 9. Drill string 6 may be stationary or rotating at the same or lesser rate of rotation as shaft 10. In any of these cases roller bearings 40 and ball bearings 48 transmit some radial forces between shaft 10 and housing 26. Drilling fluid pumped down the interior of drill string 6 passes by or through motor 21 depending upon the type of motor employed and is at a pressure P_1 as it reaches thrust means 60. There is a pressure drop of at least about 200 psig as the drilling fluid passes by thrust means 60. The drilling fluid then passes through aperture 24, into the interior of shaft 10, and through channel 26 in bit 9. There is some pressure drop between the pressure P_2 which generally obtains in the interior of shaft 10 the pressure of the drilling fluid after it leaves channel 26 of bit 9. Intermediate seal 33 can be any rotating or dynamic seal which can hold a pressure differential between that in chamber 29 and that outside housing 28 which will generally be a pressure differential from about 500 to about 1,800 psig at a shaft 10 rotation rate of 1,500 rpm.

Seals 31 through 33 can be any dynamic type seal which when carried by one surface (which can be either stationary or rotating) will bear upon and seal against the rotating surface of another member. Such a seal can be a conventional face seal or a lip seal or the like as would be obvious to one skilled in the art.

EXAMPLE

Water is used as a drilling fluid in apparatus substantially as shown in FIG. 2 in drilling a wellbore in the earth. The thrust means employed is a substantially imperforate shoulder which has its outer circumference spaced from the interior of housing 28 a distance such that the pressure drop from P_1 to P_2 is 300 psig with the additional force resulting from this pressure drop acting downwardly on shoulder 62 thereby increasing the weight on bit 9, all other conditions remaining the same.

Reasonable variations and modifications are possible within the scope of this disclosure without departing from the spirit and scope of this invention.

I claim:

1. In a well drilling device wherein a drill bit is rotated to drill a wellbore, the improvement comprising a downhole motor means, a shaft means operatively connected to said motor, the end of said shaft not connected to said motor being adapted o carry a bit, the longitudinal axis of said shaft extending from said

motor to said bit, a housing carried concentrically with said shaft at least from said motor to the proximity of the bit end of said shaft, said housing being spaced from said shaft to define a chamber, said chamber being a passageway for at least part of the drilling fluid on its way to said bit, and trust means which is separate from said downhole motor means and which is not a downhole motor means, said thrust means being carried in said chamber but physically separate from said housing, said thrust means causing a pressure drop in said drilling fluid in said chamber and applying the force created by said pressure drop to said shaft.

2. A device according to claim 1 wherein sealed bearing means are carried in said chamber for transmitting forces between said shaft and housing, and means for passing drilling fluid around said bearing means.

3. A device according to claim 1 wherein said housing surrounds the outside of said shaft, the end of said housing nearest said motor is adapted to be joined to drill pipe, sealed bearing means is carried in said chamber intermediate said thrust means and said bit end of said shaft, said bearing means being spaced from said thrust means, conduit means carried by said shaft and operatively connected between the bit end of said shaft and said chamber at a point on said chamber which is intermediate said bearing means and said thrust means whereby drilling fluid after passing said thrust means bypasses said bearing means on its way to said bit end of said shaft.

4. A device according to claim 1 wherein said down thrust means comprises an annular shoulder carried by said shaft, said shoulder extending substantially transverse to the longitudinal axis of said shaft, said shoulder occupying a substantial lateral portion of said chamber but not the entire lateral portion so as to allow for the passage of drilling fluid thereby.

5. A device according to claim 4 wherein said shoulder is substantially imperforate and extends laterally a substantial distance toward said housing, the outer circumference of said shoulder being spaced from said housing to allow drilling fluid to pass between said outer circumference in said housing.

6. A device according to claim 4 wherein said shoulder is perforate and extends laterally substantially to said housing.

7. In a method for reducing bearing wear while drilling a wellbore by rotating a drill bit with the shaft of a downhole motor, bit weight for drilling being applied to said shaft from a housing, said shaft communicating with said housing through bearings, the improvement comprising passing drilling fluid between said shaft and housing, causing a pressure drop of said drilling fluid while passing same between said shaft and housing, and applying the force resulting from said pressure drop to said shaft so that the weight applied to said shaft and bit from said housing is reduced thereby saving bearing wear.

8. A method according to claim 7 wherein said pressure drop is at least about 200 psig.

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