WELL DRILLING APPARATUS

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This invention relates to new and useful improvements in well drilling apparatus.

Ordinarily, a well is drilled by imparting rotation to a drill bit through a tubular drill string. In some instances, drilling is effected today with flexible drilling hose instead of the tubular pipe forming the normal drill string. When the flexible hose has been used, the bit has been rotated by a fluid-driven engine, but so far as is known, all prior efforts to rotate the bit with an electric motor have been unsatisfactory.

It is an object of the present invention to provide a new and improved well drilling apparatus wherein the drill bit is rotated with an electric motor disposed in the well.

An important object of this invention is to provide a new and improved drilling apparatus having in combination a shock absorber and a slip clutch connected to a motor to a drill bit so that intermittent shock loads from the bit are decelerated by the shock absorber to reduce the torque change transmitted to the slip clutch, thereby reducing the amount of wear on the parts of the clutch and possible damage to the motor.

Another object of this invention is to provide a well drilling apparatus having a new and improved slip clutch which allows slippage in the drive connection between a motor and a drill bit when the torque acting thereon exceeds a predetermined amount, so that if the drill bit suddenly is caught in the formation being drilled and is thereby prevented from rotating, the clutch functions to prevent damage to the motor.

A further object of this invention is to provide a well drilling apparatus having a new and improved shock absorber which is adapted to transmit rotational power from a motor to a drill bit while absorbing intermittent shocks that may otherwise damage the motor.

Still another object of this invention is to provide a new and improved drilling apparatus having a slip clutch and a shock absorber connected between a motor and a drill bit, with at least the slip clutch operating in an oil bath, and with drilling fluid circulating around the motor, clutch and shock absorber to remove heat generated thereby in use.

An additional object of this invention is to provide a new and improved shock absorber which has a length greater than its diameter so that it is capable of transmitting large torques with a relatively small diameter apparatus without damaging the flexible elements of the shock absorber.

The preferred embodiment of this invention will be described hereinafter, together with other features thereof, and additional objectives will become evident from such description.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein in an example of the invention is shown, and wherein:

FIG. 1 is a view, partly in section and partly in elevation, schematically illustrating the well drilling apparatus of this invention;

FIG. 2 is a vertical sectional view, partly in elevation, illustrating the details of the slip clutch forming a part of the well drilling apparatus of FIG. 1;

FIG. 3 is a cross-sectional view taken on line 3-3 of FIG. 2 to further illustrate the details of the slip clutch;

FIG. 4 is a vertical sectional view, partly in elevation, illustrating in detail the shock absorber forming a part of the well drilling apparatus of this invention;

FIG. 5 is a cross-sectional view taken on line 5-5 of FIG. 4 and illustrating further details thereof;

FIG. 6 is a view, partly in elevation and partly in section, schematically illustrating a modified form of the invention;

FIG. 7 is a cross-sectional view taken on line 7-7 of FIG. 6; and

FIG. 8 is a view, partly in section and partly in elevation, schematically illustrating a portion of another modification of the present invention.

In the drawings, the letter A designates generally the well drilling apparatus of this invention which is adapted to be disposed in a hole for the drilling of an oil well or the like. As schematically illustrated in FIG. 1, the apparatus A includes a housing or drill collar 10 into which a motor M is press-fitted or otherwise secured for driving a drill bit B to drill the well. The motor M is interconnected with the drill bit for imparting rotation thereto, and for accomplishing such drive, a slip clutch C and a shock absorber S are included in the connection between the motor and the bit. By reason of the present invention, the motor M is located in the well in proximity to the drill bit B and is protected against damage during drilling by the interaction of the shock absorber S and the slip clutch C, while at the same time drilling fluid is circulated to dissipate heat generated by the motor M and other apparatus, as will be more evident hereinafter.

In FIG. 1 of the drawings, a housing or drill collar 10 is schematically illustrated. The upper end of the housing 10 is connected to a drill string which preferably is a flexible hose type of drill string. For conducting electrical power to the motor M, an electrical cable 12 extends from the surface of the well to the motor M as seen in FIG. 1. Such electrical cable thus extends inside of the flexible hose or other drill string so that the drilling mud or other drilling fluid which flows through the drill string to the drill bit flows around such cable 12. The cable 12 is of course insulated to prevent any short circuiting. In order to prevent the mud within the drill string from entering the area where the motor M and the clutch C are located, a seal or packing 14 is mounted in the housing 10 above the motor M for providing a fluid-tight seal around the cable 12. Such packing 14 is preferably carried by a disc or plate 16 having the packing as a central opening through which the cable 12 extends. An additional seal 20 is provided below the slip clutch C so that the area between the seal 14 and the packing or seal 20 is sealed off from the drilling mud or fluid.
In order to convey the drilling mud or fluid around such sealed off area and deliver it to the drill bit B for drilling purposes, an annular sleeve 22 or alternatively, longitudinal tubes, are welded or otherwise formed on the housing 10 for bypassing fluid from above the plate 16 to the area below the packing 20 through housing openings 11a and 11b. Preferably the sealed off area between the packing elements or assemblies 14 and 20 is filled with oil or other lubricant which further assists in preventing an intrusion of the drilling mud into the vicinity of the motor M and the slip clutch C. To allow for fluctuations in mud and oil pressures in the system, any suitable compensating means such as indicated by the flexible diaphragm 19a may be employed. A more detailed type of pressure compensating apparatus is illustrated in FIG. 6, which may be used in the FIG. 1 form of the invention if desired.

The drilling mud is discharged from the housing 10 into a bore 23a of a drill bit shank 23 through suitable lateral openings 23b. The drilling mud then flows through the drill bit B for discharge therefrom during the drilling operation in a conventional manner. Bearings such as indicated at 24 may be provided to facilitate the rotation of the drill bit B with respect to the housing 10 and the rest of the drill string connected thereabove.

The motor shaft 25 (FIGS. 1 and 2) is suitably connected to the upper end of a cylindrical shell 26 forming the outer shell of the slip clutch C. Preferably the connection between the outer shell 26 and the motor shaft 25 is with splines 25a which interfit with corresponding splines in the boss 26a at the upper end of the sleeve 26. The inner surface or bore 26b is cylindrical and is ground and polished smooth, preferably being formed of a heat treated alloy steel; such bore 26b is open at the lower end as viewed in FIG. 2 for substantial radial flexing, whereby such shell 26 is expansible.

A plug designed generally with the numeral 30 extends within such bore 26b for frictional engagement therewith. The plug 30 has a lower boss 30a which is internally splined for connecting to a drive shaft 31 having suitable splines 31a or other connecting means therewith.

The boss 30a is preferably cylindrical in construction and has a plurality of expansible plug elements or fingers 32 formed therewith (FIGS. 2 and 3). Each of such expansible elements 32 is adapted to move substantially radially outwardly into frictional engagement with the inner surface or bore 26b so as to lock the elements 32 and the shell 26 together for rotating the shafts 25 and 31 together, as will be more fully explained.

The resilient or flexible elements 32 are preferably three as best seen in FIG. 3, although the number thereof may vary according to circumstances and the size of the entire assembly. In order to expand such elements 32 outwardly so as to engage the inner surface 26b with a predetermined frictional force, a wedge or expander 35 is disposed centrally with respect to such elements 32 and is provided with an external frusto-conical surface 35a which engages with inner tapered surfaces 32a. Thus, as the expander 35 moves downwardly with respect to the elements 32, as viewed in FIG. 2, such elements 32 are expanded radially outwardly. On the other hand, as the expander 35 moves upwardly with respect to the elements 32, the inherent resiliency of the elements 32 returns them to an inward position to reduce the amount of frictional force, or even eliminate such frictional force between the elements 32 and the bore 26b. In addition between the contacting surfaces 32b of the expansible elements 32 and the inner cylindrical surface 26b of the shell 26, the shell and the elements 32 are made of materials which do not gall when in engagement with each other. For example, the external surface of the elements 32 made of a manganese bronze when the inner surface 26b is ground and polished smooth alloy steel.

It will be understood that other materials may be readily used so long as the materials are compatible and do not gall when in engagement and moving with respect to each other.

The expander 35 has an internal end opening with flat surfaces 35b for receiving an Allen wrench or a similar device in order to rotate the expander 35. The lower end of the expander 35 has an external threaded projection 35c with threads 35d formed thereon for engagement with internal threads 30b so that upon a rotation of the expander 35, the position of the expander 35 with respect to the friction elements 32 may be adjusted for thereby adjusting the amount of the frictional engagement between the surfaces 32a and 26b.

For assembly purposes, an annular groove 26c is provided at the lower end of the outer shell 26 for receiving a snap ring 38 formed of metal or the like. Such snap ring is preferably in engagement with a spacer ring 40 disposed below a shoulder 30c of the plug 30.

Referring now to FIGS. 4 and 5, wherein the details of the preferred form of the shock absorber S are illustrated, it can be seen that the upper end of the shock absorber S is preferably connected to the shaft 31 or an extension thereof. The lower end of the shock absorber S is connected to another shaft 41 which may be suitably connected to the hollow shaft 23 therebelow (FIG. 1).

The shock absorber S includes a hollow housing 42 having an open lower end 42a for providing an entrance to the bore 42b. A boss 42c is provided at the upper end for receiving the shaft 31. Preferably, the shaft 31 has external splines 31b formed thereon which interfit with corresponding internal splines within the boss 42c. It will be appreciated that other suitable connecting means may be employed for connecting the shaft 31 to the housing 42. Openings 42d are provided at the upper end of the housing 42 for introducing mud or other drilling fluid into the bore 42b for the purpose of cooling the internal portions of the shock absorber S in use, as will be more evident hereinafter.

In the preferred form of the invention, the housing 42 is formed with longitudinal slots 42e (FIG. 5), each of which is adapted to receive a vane 50 which extends longitudinally within the bore 42b. Each vane 50 is welded as indicated at 50a to secure same to the housing 42 so as to actually become an integral part of such housing 42. If preferred, the vanes 50 may be preformed as an integral part of the housing 42, but the construction illustrated is ordinarily more desirable because it facilitates manufacturing.

A paddle 52 is adapted to extend into the bore 42b of the housing 42. Such paddle 55 is preferably constructed with a central mandrel 55a which has integrally formed therewith, or secured thereto, a pair of paddle elements 56. The number of the paddle elements 56 may vary, but preferably the number of such paddle elements 56 corresponds with the number of the vanes 50. The mandrel 55 is preferably formed integrally with a lower boss 55b which is adapted to be connected to the lower shaft 41 by the interconnection of splines 41a on the shaft 41 with internal splines within the boss 55b. Other suitable connecting means may of course be employed for making such connection between the shaft 41 and the boss 55b.

For transmitting rotational movement from the housing 42 and the vanes 50 to the paddle 55 and thus to the shaft 41, the shock absorber S includes a resilient deformable element 60 in order to prevent 60 being in contact with any of the vanes 50 and the paddle elements 56. Thus, in the form of the invention illustrated in FIGS. 4 and 5, there are four of such resilient rods 60. Each of the resilient rods is formed of a deformable flexible material such as an elastomer of the Buna-N rubber type. By way of example, each may have a durometer of eighty, although the invention is not limited thereto. The prefer-
able shape for such rods 60 is cylindrical as illustrated in the drawings, but the shape may vary so long as there is a suitable space between the rod and each of the vanes 50 and paddle elements 56 to permit a flexing and some distortion of the rods 60 in the transmission of the rotational movement of the shaft 31 to the shaft 41. By reason of the resiliency of the flexible elements or rods 60, shock loads which occur for a relatively short period of time in the drilling with the bit B are absorbed or reduced in intensity, thereby reducing the amount of shock transmitted to the clutch C and the motor M.

Since the bit 42 is driven along the rods 60 becomes heated during the absorption of shock loads, the drilling mud maintains such rods 60 cool by flowing through the openings 42a and discharging through the lower openings 62a. It is also important to note that the shock absorber is greater in length than in diameter, this being to provide an adequate torque distribution to the elastomer rods 60. The torques transmitted by the shock absorber S are relatively high particularly in view of the small diameter of the absorber S, but such loads are adequately handled by the absorber S. The rods 60 are closely spaced so as to distribute the loads to a greater surface area thereof for preventing shearing or other disintegration of the rods 60.

For stabilizing the assembly, a stabilizing ring 62 having openings 62a therethrough is held below the rods 60 by the lower part 55 of the bit 42. The stabilizing ring 62 is closely mounted in an annular groove 42d in the lower open end 42a of the housing 42.

In the use or operation of the drilling apparatus of this invention, the apparatus A is preferably lowered into the well bore or hole on a flexible hose or similar type of drill string. With the drill bit B positioned on the bottom of the hole for drilling, the drilling mud or other fluid, liquid or gas, is circulated through the drill string and down through the bypass tubes or sleeves 22 to the drill bit B. The electrical power is supplied to the motor M through the electrical cable 12 which thereby drives the drill bit B in a rotational direction through the drive connection which includes the clutch C and the shock absorber S.

During the drilling, a large amount of heat is generated by the various parts of the apparatus, particularly the motor M, the slip clutch C and the shock absorber S. The circulating fluid which flows in the sleeve 22 around the oil bath dissipates the heat generated in the oil bath so as to continuously remove heat from the motor M and slip clutch C. Also, the mud or other fluid removes heat from the shock absorber S.

When the bit B hits a hard section or formation during drilling and temporarily is slowed down, the shock of such initial slowing of the drill bit B in its rotation is initially absorbed to some extent, and possibly entirely, by the action of the shock absorber S. By reason of such initial shock absorbing with the shock absorber S, the slip clutch C is prevented from slipping frequently as would normally occur in the absence of the shock absorber S. Therefore, wear on the friction elements 30 and the internal surface of the slip clutch C is reduced by the presence of the shock absorber S in the apparatus.

In the event the drill bit B becomes stuck and cannot rotate further, the load imposed upon the motor M will disconnect the electrical power to the motor M by throwing a circuit breaker (not shown) of conventional construction at the surface of the well. Thus, the electrical power to the motor is cut off so that the motor no longer is being driven by the electrical power. However, even when the motor is no longer being supplied with the electrical power, there is a momentum which remains within the motor and causes it to continue to try to rotate. The torque which is developed in connection with a motor that is suddenly stopped by the stopping of the drill bit B is so high that it would normally ruin the motor by either bending or twisting the shaft thereof, or by otherwise damaging the electrical portions of the motor M itself. However, with the present invention, when the motor M is no longer supplied with the electrical power due to the circuit breaker cutting off such power, the torque load then imposed upon the shaft 25 as it tries to continue to turn is in excess of the capability of the clutch 26 to rotate relative to the friction elements 32 and thereby cause a slipping or relative movement of such parts. The slipping of such clutch parts thereafter relieves the torque load on the motor shaft 25, even though the lower shaft 31 which is connected to the drill bit B indirectly, can no longer turn due to the fact that the drill bit B is stuck in the ground.

In some instances, the motor M may not become loaded sufficiently to throw the circuit breaker and thereby cut off the cable 12, but a temporary load is placed upon the drill bit B by reason of an extremely hard formation or obstruction within the well bore. In such cases, the same action of the slip clutch C takes place, permitting a relieving of the torque load on the motor shaft 25 through the slipping of the outer sleeve 26 with respect to the friction fingers or elements 32.

In FIGS. 6 and 7, a modification of the invention is illustrated wherein the apparatus A-1 corresponds with the apparatus A of FIG. 1, except that a gear train G and a pressure equalizing section E are incorporated in the apparatus A-1. The parts of the apparatus A-1 which are identical or similar to the apparatus A of FIG. 1 are indicated with the same reference letters or numerals.

The gear train G is connected to the slip clutch C through a shaft 131 which corresponds with the shaft 31 of FIGS. 1 and 2. However, the shaft 131 is a pinion shaft which has a pinion gear 131a formed at its lower end for meshing with a plurality of idler gears 70. The idler gears are adapted to engage the internal gear teeth of an internal ring gear 71 which is preferably formed integrally within the housing or tubular body 10.

The idler gears are supported and are connected to a carriage shaft 75 through suitable support rods 76 having bearings 77 of the needle type or any other suitable bearing construction. Thus, as the shaft 131 is rotated, the idler gears 70 are caused to rotate and impart a rotation to the carriage shaft 75. By reason of such planetary gear system G, the speed of the shaft 75 is reduced as compared to the speed of the shaft 131 and the motor shaft 25. In addition, the torque developed at the shaft 75 and therefore at the bit B is increased by reason of the gear train G as compared to the torque developed at the motor shaft 25.

The shaft 75 is suitably connected with any coupling such as indicated at 80 to a shaft extension 81 which joins with the upper end of the shock absorber S. Thus, the shock absorber S is the same as that illustrated in FIGS. 3-5, but the shaft 81 replaces the shaft 31 of FIG. 4.

The pressure equalization apparatus E includes upper and lower heads 82 and 83 and a flexible sleeve 84 formed of rubber or other similar elastic material. A passage 82a in the head 82 communicates the area internally of the sleeve 84 with the area in the vicinity of the motor M and the clutch C, as well as the gear train G. The area 85 externally of the sleeve 84 is in communication with the drilling mud or other fluid which is circulating in the apparatus A-1 by means of a mud port 11c, the number of which may be varied as desired. The lower head 83 preferably carries a flexible packing 83a which seals off the oil in the sleeve 84 from the mud below the head 83. Thus, with the equalizing apparatus E, the variations in the mud and oil pressures may be compensated automatically while maintaining such mud and oil separately from each other.

The operation of the apparatus of FIGS. 6 and 7 is identical and is comparable to the operation of the apparatus A of FIGS. 1-5, except for the function of the gear train G which provides the lower speed and increased torque at the bit B for a given motor speed at the motor M. The gear train G develops a considerable
amount of heat during its operation and such heat is dissipated to the oil and then to the circulating mud which flows downwardly through the sleeve or cylinder 22 surrounding the housing 10, in the same manner as described heretofore in connection with FIG. 1. The other portions of the apparatus A–I are likewise cooled by the circulating drilling mud or fluid, which may be liquid or gas, during the drilling operation.

In FIG. 8, a further modification is illustrated wherein a turbine T is operated by drilling mud and is used in place of the electric motor M. Thus, the turbine T is operated by the drilling mud or fluid which flows downwardly through the drill string and into the housing 10 for imparting rotation to the turbine T in a known manner. The turbine discharge flows into the housing or tubular body 10 below the turbine T in the vicinity of the turbine shaft 125 and is directed through inlet ports 111a to the sleeve or cylinder 22 for conducting the drilling mud or fluid as in the previous forms of the invention. It is to be noted that the shaft 125 is connected to a slip clutch C and that the apparatus below the slip clutch C is identical to that illustrated in FIG. 6. When the turbine T is used as the means for imparting rotation to the drill bit B, the clutch C and the shock absorber S serve primarily to protect the gear train G. In the absence of the slip clutch C and the shock absorber S, the gear train G could be severely damaged in the event the drill bit is intermittently subjected to extreme loads or is suddenly stopped, as explained heretofore in connection with the form of the invention shown in FIG. 1. Thus, the gear train life and dependability are appreciably enhanced by the inclusion of the clutch C and the shock absorber S in the driving connection from the turbine T to the drill bit B. The oil is employed below a head or plate 116 having a fluid-tight seal 116a around the shaft 125 (FIG. 8) so as to operate the turbine T within the drilling mud or fluid while still separating such mud or fluid from the oil bath or chamber provided within the housing 10.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A well drilling apparatus, comprising:
   (a) a tubular body adapted to be supported in a well bore,
   (b) a drill bit mounted on the lower end of said body for rotation relative thereto,
   (c) a motor mounted in said tubular body,
   (d) drive means connecting said motor to said drill bit,
   (e) said drive means including,
      (1) a slip clutch which is normally engaged for driving the drill bit with the motor but which is temporarily released for permitting rotation of the motor independently of the drill bit when the load on the bit exceeds a predetermined amount, and
      (2) a shock absorber for transmitting rotational power from the motor to the bit and for absorbing intermittent shock loads imposed thereon,
   (f) means for circulating drilling fluid relative to said motor, slip clutch and shock absorber for removing heat generated thereby during drilling operations with the drill bit.

2. A well drilling apparatus, comprising:
   (a) a tubular body adapted to be supported in a well bore,
   (b) a drill bit mounted on the lower end of said body for rotation relative thereto,
   (c) a motor mounted in said tubular body,
9. A well drilling apparatus, comprising:
(a) a tubular body adapted to be supported in a well bore,
(b) a drill bit mounted on the lower end of said body for rotation relative thereto,
(c) a motor mounted in said tubular body,
(d) drive means connecting said motor to said drill bit,
(e) said drive means including,
(1) a slip clutch which is normally engaged for driving the drill bit with the motor but which is temporarily released for permitting rotation of the motor independently of the drill bit when the load on the bit exceeds a predetermined amount,
(2) a shock absorber for transmitting rotational power from the motor to the bit and for absorbing intermittent shock loads imposed thereon,
(g) seal means for sealing off the tubular body from above said motor to below said slip clutch to provide an oil bath therein, and
(b) fluid passage means on said body for conducting drilling fluid from the tubular body externally of the area thereof sealed off by said seal means and then back to the tubular body for supplying the drill bit with such fluid.

10. A well drilling apparatus, comprising:
(a) a tubular body adapted to be supported in a well bore,
(b) a drill bit mounted on the lower end of said body for rotation relative thereto,
(c) a motor mounted in said tubular body,
(d) drive means connecting said motor to said drill bit,
(e) said drive means including,
(1) a slip clutch which is normally engaged for driving the drill bit with the motor but which is temporarily released for permitting rotation of the motor independently of the drill bit when the load on the bit exceeds a predetermined amount,
(2) means for transmitting rotational power from the motor to the bit and for absorbing intermittent shock loads imposed thereon, and
(f) means for circulating drilling fluid relative to said motor, slip clutch and said last-mentioned means for removing heat generated thereby during drilling operations with the drill bit.

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