CONTROL OF WELL PIPE ROTATION AND ADVANCEMENT

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ATTORNEYS.
This invention relates generally to manipulation of well pipe to produce pipe displacement in the well. More particularly, it concerns the control of torque and weight application to a rotating pipe string to cause the pipe in the well to move in a preferred manner, as in freeing of pipe stuck in a well, restoring circulation that has been lost, and in drilling control particularly as to direction and as a warning of cave-ins.

In well drilling, it frequently happens that the drill string may become stuck at locations that may range from depths near the bit to intermediate depths many pipe stand lengths above the bit, depending upon conditions encountered in a particular well being drilled and the particular reason for the pipe becoming lodged. To illustrate, the pipe may become stuck as a result of a case-in well, or by key seating of pipe in crooked holes. Also, well casing may become stuck in the hole.

In keeping with presently prevailing practices in the determination of the stuck point location, the pipe is manipulated at the well head as by slowly rotating, lifting and lowering of the Kelly. These practices produce rather slow pipe displacement in the well, which is a disadvantage when detection of pipe movement in the well is dependent upon acceleration undergone by the pipe deep in the hole. The present invention has for one of its major objects the provision of apparatus and method for rapidly and automatically displacing the pipe at different depths in the well to produce more rapidly detectable pipe acceleration.

Referring first to freeing pipe stuck in a well, the method broadly contemplates the steps that include applying torque for rotating and twisting the string above the stuck point, displacing the string vertically at the well head to exert variable loading on the string proximate the stuck point, and suddenly releasing the torque application to allow the string to rapidly untwist and oscillate, these operations being repeatable. Also, well fluid may be circulated downwardly in the string and to the formation proximate the stuck point, particularly at successively different elevations, as will be brought out.

By carrying out these steps at the well head, it is ensured that the string will be placed in torsion and will accelerate and become displaced as for example by whipping in the hole above the stuck point no matter where the latter exists in the well. Also, the energy stored in the pipe during torsional twisting will, upon sudden release, tend to cause transmission of shock torsional loading and oscillation to the pipe at the stuck point for freeing the stuck pipe. Such movement will facilitate crushing of the formation about the pipe. In the case where drilling mud has caked due to operating conditions and has caused the pipe to become stuck, the re-dissolving of the cake will be aided by facilitating access of fluid mud to the cake through the loosened formation.

It should be noted that by rotating, twisting, oscillating and pulling of the pipe up and down, the well fluid above the stuck formation will be better able to flow down along the pipe, lubricating and softening the formation of the mud cake, so as to allow the pipe to be removed. In this regard, pipe may be rotated far below the point from which it may be removed. Also, the pipe in a well may be considered as subject to being wound up or twisted as a rope, and then released for unwinding and reaction winding in the opposite direction due to its rotary inertia.

The apparatus which I provide for carrying out this method includes means by which and through which rotation is transmissible for forwardly rotating the pipe at the well head to twist the string placing it in torsion within the well without restricting vertical movement thereof, said means including a coupling releasable to allow counter rotation of the pipe at the well head substantially faster than forward rotation whereby the pipe string may be caused to untwist rapidly at different depths in the well. Also, the said means includes actuator apparatus free of the string for exerting controllable loading opposing release of the coupling. The actuator apparatus, as will be seen, includes a force adjusting device for varying the loading to be applied for opposing said coupling release.

In the method of drilling a well wherein directional control of bit downward movement is dependent upon rotary speed of the bit and string weight loading application, the invention contemplates the steps that include transmitting such loading through a rotary slip coupling and transmitting torque through the coupling to effect string rotation while the coupling and string loading are controlled to govern bit advancement direction. In this regard, the coupling may be controlled as well as string loading application and within a selectable driving torque range above which the coupling is subject to slippage.

As the pipe advances downwardly through the coupling driving, drilling, the resistance encountered by the bit or string in the hole may become altered, as for example, as may result from a change in the resistance of the formation being cut or the start of a cave-in. The invention contemplates that such a change in resistance will affect the degree of slippage of a slip coupling at the well head and further that apparatus is provided to be responsive to such slippage for controlling application of force to the string by at least one of the string elevator mechanism or the rotary drive for the string, or both of these all in a desired manner to achieve desired manipulation of the string in the well as will be seen.

These and other objects and advantages of the present invention as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is a general view showing the pipe string stuck in the well and in the manipulation thereof to free the string;

FIG. 2 is an enlarged plan view of the string rotating apparatus;

FIG. 3 is a vertical section taken on line 3-3 of FIG. 2;

FIG. 4 is a view like FIG. 1, but showing the string during a directional drilling operation;

FIG. 5 is a linear extension showing the rotary parts as they are engaged during rotation of the Kelly by the rotary table; and

FIG. 6 is a schematic showing of a system for controlling weight and rotary drive application to a string.
Referring first to FIG. 1, the drill string is shown generally at 10 suspended in a well open hole 11 by elevator mechanism 12. The surface equipment also includes a rotary table 13 which is used in rotating and torsionally winding or twisting the drill string as and for the purposes later described. Typically, a cave-in such as is shown at 14 causes the pipe to become stuck in the well, the pipe extent above the stuck point being subject to varying degrees of movement as by manipulation at the well head, but the pipe extent below the stuck point is not movable until the pipe is freed, so that the location of the stuck point may be determined by traveling an acceleration detector vertically within the pipe while the latter is accelerated. As will be brought out, the pipe is twisted forwardly and then allowed to untwist rapidly, these steps being repeated, and the string is subjected to lifting and lowering for the purpose of transmitting such displacement to the stuck portion of the pipe. Also, well fluid is pumped downwardly through the pipe and into and below the top of the cave-in formation 14 to soften the latter. A mud pump is shown at 15 as having an inlet 16 and an outlet 17 for flowing drilling mud at 18 to the pipe and downwardly therethrough.

Preliminarily, the pipe may be perforated at several vertical locations, two of which are shown at 19 and 20 at the general location of the cave-in. Well fluid pumped downwardly as shown by the arrows 21 flows outwardly through the upper perforation 19 to soften the upper portion of the cave-in formation and thereby re-establish circulation of drilling fluid. Thereafter, a ball or other plug 22 may be dropped in the pipe to plug the upper perforation 19, and continued well fluid flow passes to and through the lower perforation 20 for loosening a lower portion of the cave-in formation to re-establish circulation. Alternatively, the pipe string may be unscrewed at joint 200 in the cave-in formation 14 to an extent permitting release of downwardly pumped well fluid into the formation to re-establish circulation, and thereafter the joint may be made up and a lower joint unscrewed for establishing circulation at a lower level. This step by step procedure, in combination with rotary twisting and rapid untwisting and oscillation of the pipe extent at the cave-in, and vertical lifting and lowering of the pipe, may be considered very effective for loosening the stuck pipe.

Coming now to a description of the apparatus by means of which the pipe string may be rapidly displaced or automatically untwisted, reference to FIGS. 2 and 3 will show that means to be indicated generally as at 23 for rotating the Kelly 24 by operation of the rotary table 13 to twist the string and place it in torsion within the well, without restricting vertical movement of the string. The said means includes a slip-coupling 26 having interengaged upper and lower rotary parts 27 and 28. Referring first to the part 28, it typically comprises a split master bushing, the respective halves 29 of which are sized at their periphery 30 for fitted reception within the square opening 31 in the rotary table. As a result, the latter part 28 is connected in driven relation with the table.

The upper part 27 of the coupling typically comprises a plate having a central square opening 32 sized for fitted reception on the kelly 24 for driving the latter while allowing relative vertical movement of the kelly through the plate. The lower part 29 has an enlarged opening 34 into which seats the Kelly 24, and which seats on the top surface of the table for limiting downward displacement of said part relative to the table.

Downwardly loading is exerted on the upper part 27 by an actuator apparatus which is free of the string, said loading typically being controllable to oppose slip-release of the coupling. Typically, and in the form of the invention shown, the actuator includes a series of compression springs 35 circularly spaced about the axis 36 of the kelly, and retained between upper and lower plate members 37 and 38, the latter having a thrust bearing relation to the coupling upper part 27 as through the rings 39a. The latter allow relative rotary displacement as between the part 27 and the plate member 38, while transmitting vertical thrust to the part 27. Both of the members 37 and 38 are rotated with the lower coupling part 28, as by means of a series of circularly spaced arms 39 which are fastened to the flanges 43 as shown at 40. The arms project upwardly to a level above the upper member 37, then laterally inwardly at 41 and then downwardly at 42 into notches formed in the inner flanges 43 and 44 of the members 37 and 38 for driving the latter. Members 37 and 38 may also have notched outer flanges 43a and 44a to loosely fit the arms 39. Force adjustment means, as for example, the screws 45 projecting downwardly through the arm portions 41 to bear against the upper plate member 37, may be adjusted to control the loading imposed on the coupling 26 to oppose release of the coupling. Alternatively, liquid or gas actuated devices may be used as shown in FIG. 6 at 46 to variably control the force exerted against the upper plate member 37 and part 27 to oppose release of the coupling. The pressure in device 46 may be changed when rotation of table 13 is interrupted, or during such rotation as from a source of pressure which rotates with the table.

The rotary parts 27 and 28 have formed thereon cam shoulders 47 and 48 which are respectively downwardly and upwardly presented for frictional engagement. These shoulders are formed on undulating lugs or teeth 49 and 50 which are respectively downwardly and upwardly presented on the parts 27 and 28 and are also circularly arranged around the axis of the kelly, which is common to the axes of parts 27 and 28.

Referring to FIG. 5, as part 28 is driven in the direction of arrow 51 it tends to drive part 27 in the direction of arrow 51 for rotating the kelly with the rotary table. However, such rotation twists the drill string in the well and places it in torsion acting through part 27 to resist rotation by part 28. As a result, during such rotation by the rotary table the torsion forces build up and tend to cause slippage at the interengaged cam shoulders 47 and 48, FIG. 5 showing that some slippage has occurred, by virtue of the gaps 52 between the reverse shoulders 53 and 54 on lugs 49 and 50. Such slippage is resisted by friction forces exerted at the interengaging shoulders 47 and 48 and arising from downwardly through plates 37 and 38, springs 35 and rotary part 27, the degree of imposed loading being of course under the control of the adjustable screws 45.

Assuming that the imposed loading remains constant, the torsion forces in the drill string will build up during rotation of the kelly until they overcome the loading acting at the interengaged shoulders 47 and 48, at which time the rotary part 27 will have lifted relative to part 28 to the extent that the parts will release and slippage will occur, part 27 counter-rotating in the direction of arrow 55 as shown in FIG. 5. This counter-rotation will occur at a rate substantially faster than rotation of the rotary table in the direction of arrow 51 and will, accordingly, rapidly untwist the pipe string in the hole imparting a sharp or high degree of torsional acceleration to the pipe.

Furthermore, the automatic counter-rotation of the rotary part 27 will be suddenly and automatically interrupted, depending upon the amount of loading imposed downwardly through the kelly, and which seats on the top surface of the table for limiting downward displacement of said part relative to the table. Thus, when the counter-rotation of part 27 has carried that part sufficiently in reverse that the torsion loading of the string is diminished below the point at which imposed loading causes frictional interlocking of parts 27 and 28 and shoulders 47 and 48, counter-rotation of part 27 will cease. At this time, shoulders 47 and 48 will engage vertically and vertical shock loading on the pipe will produce a wave traveling vertically along the pipe and de-
tachable as pipe acceleration above the stuck point. The amount of counter-rotation in the direction of arrow 55 may be controlled by increasing or decreasing the activator imposed loading. After frictional engagement at shoulders 47 and 48 is re-established the rotary table effects rotation of the Kelly to build up increased string torsion, with resultant deceleration of the Kelly and the string followed by sudden interruption of such counter-rotation as previously described. Moreover, this torsional and vertical shock loading may be caused to occur as rapidly and repeatedly as is desirable so as to vibrate the pipe accelerating in the hole above the stuck point, both laterally and longitudinally.

While such torsional and vertical shock loading is transmitted to the pipe extent at the stuck point as a result of operation of the slip coupling 26 as described the elevator 12 may be lifted and lowered as desired to superimpose additional displacement of the pipe transmitted to the extent thereof at the stick point. Also, as previously described, fluid may be pumped into the pipe and into the formation to soften it at vertically successive elevations, all for the purpose of co-action to free the pipe.

Reference to FIG. 2 will show that the arms 39 are carried on separate hubs of the coupling 28 integral with the bushing halves 29, the split therebetween being indicated at 129. Also, the coupling upper part 27, bearing rings 39a and the plates 37 and 38 may each be formed as halfs divided at the line of the split 129, and assembled during assembly of the apparatus 23 about a Kelly 24. The halves of the upper part 27 may be interfitted about the Kelly and with tongue and groove connection at 150, and then dropped in position and retained by an annular flange 130 upstanding from the part 28. Thereafter, the split bearing rings 39a may be dropped in position and the arms 39 bolted at 40, with split plates 37 and 38 retained by the rings 39 by the arms 39a and 41.

Referring again to FIG. 5, the lugs 49 and 50 may be formed or staggered as to permit complete engagement at only one relative position about the vertical axis of rotation, or at a lesser number of rotary positions than the number of lugs would seem to indicate. This will allow slippage in corresponding angular increments, while in any engagement position all the lugs will afford bearing surface.

Reference to FIG. 4 will show the use of the coupling as previously described in the method of drilling a well wherein directional control of drill bit downward advance ment is essential, especially where the bit is subject to loading application. The bit is indicated at 60 with its axis 61 extending at a substantial angle to the vertical and having a lateral component desirable directionally oriented. Since the coupling freely passes the Kelly 24, string weight loading is controllable independently of operation of the coupling. Also, torque is transmitted through the coupling to effect string rotation while the coupling and string loading are controlled to govern bit advancement direction, either vertical or non-vertical and typically within a selectable torque range above which the coupling is subject to slippage. Thus, adjustment of the means establishes a torque level above which the coupling will slip. In accordance with the invention, it may be desired to maintain the rotary speed of the bit at a particular level correspondent to desired directional control of bit advancement. Should the bit, for any reason, encounter greater resistance, as for example in the formation, the loading to be overcome by the rotary drive increases and this would tend to slow down the drive. Such increased resistance to drilling may be noted by the operator as reflected in relative vertical displacement of the coupling parts 27 and 28, a suitable indicator 62 in FIG. 5 projecting radially from the part 38 to indicate such axial movement. The indicator is movable vertically with the part 38 and relative to the arm vertical extent 63. Upon noting such movement, the operator may adjust the vertical loading exerted on the bit by the string, as through relative vertical movement of the elevator 12, thereby to re-establish the desired rotary drilling speed for directional control of bit advancement.

FIG. 3 also shows a sensor 64 carried by the arm extent 63 and operable to provide a slippage signal usable to control either the rotary drive of the table 25, or the vertical drive of the elevator. FIGS. 1 and 4 show the sensor 64 as being switch connectible with a control 65 which is in turn connected with the rotary drive 66 and the elevator drive 67, and it will be understood that the control may be such as to establish or maintain a relationship between the rotary drive and the elevator position such as to effect desired directional control of the bit advancement. In this regard, the control may be such as to govern the rotary drive or the elevator in response to changes in the relative slip or positions of the parts 27 and 28, adjusted as affected by torque transmission thereto. Thus, the rotary drive speed or r.p.m. may be fixed, and the control signal used to govern the elevator drive independently and automatically. Also, the slip coupling allows for release in the event of jamming of the bit in the formation.

The switches seen in FIGS. 1 and 4 and by which sensor 64 is connectible with control 65 may be such as to allow relative rotation of switch components, inasmuch as the sensor 64 rotates with table 13. 1 claim:

1. For use in the method of rapidly accelerating a pipe string stuck in a well, means by and through which rotation is transmissible for forwardly rotating the pipe at the well head to twist and place the string in torsion within the well without restricting vertical movement of the string, said means including a coupling releasable to allow counter rotation of the pipe at the well head substantially faster than forward rotation whereby the pipe string may be caused to untwist rapidly at different depths in the well, and actuator apparatus free of the string for exerting loading yieldably opposed said releasing of the coupling, said actuator apparatus including a force adjusting device for varying said loading to be applied for opposing said coupling release, said coupling comprising split sections sized for assembly about the pipe at the well head and in torque transmitting relation therewith.

2. The invention as defined in claim 1 including a rotary table for rotating the pipe string, and a fastener for integrally attaching said means to said table.

3. The invention as defined in claim 1 in which said actuator apparatus includes a spring variably tensioned by said device.

4. The invention as defined in claim 1 in which said device includes a fluid pressure responsive element operable to exert said controllable loading.

5. The invention as defined in claim 1 in which said means includes interengaged rotary parts releasable in response to build-up of string torsion acting through the coupling in opposition to said actuator applied loading to allow counter-rotation of the string, the actuator includes springs acting to urge the interengagement of said parts and said means includes spring retainer and drive structure extending at the outside and inside of said springs and forming a central opening to pass the string.

6. The invention as defined in claim 5 in which said actuator device includes adjustable elements for controlling the tension of said springs.

7. The invention as defined in claim 1 including a signal producing means responsive to relative displacement of interengaged coupling parts for indicating varying of torque transmission through said coupling.

8. The combination of claim 1 including other apparatus for controlling the string weight applied downwardly in the well and for transmitting a signal to said means, and other means to control said other apparatus in response to relative displacement of coupling parts.

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