Control of drilling courses in the drilling of bore holes.

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Description

Field of the invention

This invention relates to the control of drilling courses in the directional drilling of bore holes, for example in the fields of oil extraction, oil exploration, mineral exploration and geothermal energy extraction. The invention is concerned with apparatus for use in rotary drilling, rather than turbine drilling which uses down hole motors.

Background to the invention

Currently, course control with conventional rotary drilling is particularly difficult and time consuming, other than for purely vertical bore holes. However, rotary drilling has the potential to be very attractive in directional drilling since it is economical. In fact, many drillers revert to conventional rotary drilling when drilling the inclined tangent section of directionally drilled bore holes, despite the associated difficulties. A typical assembly of drill string components near the bottom of a bore hole may consist of a drill bit, drill collars and stabilisers, this being known as a bottom hole assembly. A drill collar is a heavy drill pipe whose function it is to transmit the drilling torque and axial thrust to the drill bit as well as to provide weight and to provide a connection to the other drill string components above. A stabiliser is a device which is approximately the same diameter as the bore hole wall and acts to centralise the drill collar and also to the maximum desired curvature of the bore hole during the transition from the initial bore hole course to the desired bore hole course. Information can be supplied to the information storage means either when the latter is on the surface prior to drilling or when in situ during the drilling operation when a course change may be required. When on the surface, an electrical contact will be made with the information storage means and the required data transmitted in digital form. When in situ, information can be transmitted to the information storage means in the following way. Rotation of the drill collar in the vicinity of the control stabiliser can readily be detected since certain parts of the control stabiliser are normally stationary. In its simplest form this could be counting pressure pulses from the reciprocating hydraulic pump. Thus, when it is required to supply information, a timed, coded sequence of drill string rotations and stop rotations, or reverse rotations, is initiated from the surface. This code can be recognised and the information storage means can be triggered into a receive information mode. A following timed sequence of drill string rotations, stop rotations, or reverse rotations, provides the required information of direction, inclination and curvature which is recognised and stored by the information storage means. Alternatively, the coded rotation of the drill collar could be sensed from the voltage produced by an electrical generator driven by rotation of the drill collar.

Disclosure of the invention

According to the invention drilling apparatus comprises a rotatable drill collar, a drill bit carried by the end of the drill collar, control means for controlling the drilling course, the control means comprising sensing means for sensing the actual drilling course, information storage means for storing a predetermined required drilling course and comparison means for comparing the sensed course with the required course and for delivering an error signal in dependence upon the comparison, characterised by two spaced stabilisers which act to locate the drill collar within a bore hole being drilled and actuating means which do not rotate with the collar and which apply a controlled lateral force or displacement to the drill collar at a location between the two stabilisers in order to deflect the drill collar between the spaced stabilisers to vary the drilling course in dependence upon said error signal, the control means being located down the hole being drilled.

The sensing means preferably sense direction and inclination of the bore hole course relative to the earth's magnetic and gravitational fields respectively.

The actuating means preferably include a specially adapted control stabiliser which may be located between said spaced stabilisers which may be conventional stabilisers. One of the spaced stabilisers will be located close to the drilling bit (the "near bit stabiliser") and the other typically 9.15—30.50 m behind. The control stabiliser controls the drilling direction by deflecting the drill collar through controlled magnitudes in controlled radial directions, using the two spaced stabilisers as support points. Thus when a change in drilling direction is required, the deflection of the drill collar results in a change in the angle of the drilling bit relative to the current direction of the bore hole. This change in angle results in a change in drilling direction.

The information storage means may be provided with information which relates to the desired direction and inclination of the bore hole course, and also to the maximum desired curvature of the bore hole during the transition from the initial bore hole course to the desired bore hole course. Information can be supplied to the information storage means either when the latter is on the surface prior to drilling or when in situ during the drilling operation when a course change may be required.

US—A—3993127 discloses drilling apparatus which uses a feedback technique to generate an enter signal representative of a correction to be applied to the drilling course, but there is no disclosure of how the drill bit is deflected to alter the drilling course.

GB—A—2077811 discloses drilling apparatus in which the drill bit is deflected in order to follow a required drilling direction. This deflection is applied to the drill string by slave pistons which respond to fluid pressure in respective master pistons, the master and slave pistons rotating with the drill string and being housed in respective spacer stabilisers.

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An alternative method of supplying information
is to lower down the inside of the drill string a programmer unit by means of an electrically conductive line. The information storage means may be magnetically or acoustically coupled to the programmer unit and the required information transmitted by a timed sequence of electrical and magnetic or acoustic pulses.

The comparison means and the subsequent generation of signals to drive the actuating means are generated by an algorithm which is stored and processed electronically.

The actuating means deflects the drill collar, in the vicinity of the control stabiliser, in two orthogonal directions by amounts giving the desired magnitude and direction of deflection. The forces to produce these deflections may be provided by flexible tubes or bags which when supplied with hydraulic fluid expand until the required deflections are obtained. A measure of the required deflections are the forces which are applied by the actuators since the essence of the control is to deflect the drill collar between, and relative to, the two conventional stabilisers in the bottom hole assembly. These forces are functions of the hydraulic fluid pressures which are applied to the actuators. Signals resulting from the measurement of these pressures are utilised by the control means, as feedback signals, indicating the attained magnitude and direction of deflection of the drill collar.

The required hydraulic fluid flow and pressures may be generated by a suitable reciprocating pump or pumps which are driven from the rotating drill collar. Control of the hydraulic fluid is exercised by suitable valves which divert the fluid flow in accordance with control signals generated by the comparison means.

The actuating means may include devices other than tubes or bags to apply the controlled lateral force to the drill string. For example, it may be possible to use piston and cylinder devices but the confined space available makes fluid tubes or bags the preferred construction.

Drilling apparatus according to the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic view of the bottom hole assembly of drilling apparatus according to the invention,

Figure 2 is a detailed view, on an enlarged scale, of part of Figure 1,

Figure 3 is a sectional view on the line III—III of Figure 2, and

Figure 4 is a block diagram of a feedback loop of the drilling apparatus.

Detailed description of the drawings

Referring to Figure 1, the drilling means comprises a drill collar 10 carrying an extender and a drill bit 12. The collar 10 is supported and centred in the bore hole 14 by two spaced stabilisers, namely a near bit stabiliser 16 and a far bit stabiliser 18. Between the stabilisers 16 and 18 is located a control stabiliser 20 which applies to the drill collar 10 a controlled lateral force or displacement (indicated by arrow 22) in order to deflect the latter between the spaced supports constituted by the stabilisers 16, 18. The lateral forces applied to the drill collar 10 by the bore 14 are indicated at 21 in Figure 1. Figure 1 illustrates the undeflected drill collar at 24 and the deflected drill collar at 26, the change in drilling direction being indicated by the angle 28.

Figure 2 shows a half section through the control stabiliser 20, on an enlarged scale. Referring to Figure 2, the control stabiliser 20 has a housing 31 which contains the sensing means, information storage means and comparison means, together with batteries, hydraulic pump, valves and other equipment necessary for the operation of the actuating means. The batteries are for powering the electronic and other equipment associated with the control means. The hydraulic pump is driven from the rotating drill collar by virtue of the relative rotation between the rotating drill collar and the normally stationary housing.

The wall contact assembly 33, which is externally similar to a conventional stabiliser, provides the reaction to the radial force applied to the drill collar by means of the actuator assembly 34. The wall contact assembly may rotate with the drill collar, in which case the forward joint 35, which is connected to the wall contact assembly by a nose casing 36, is arranged to allow angulation about axes normal to and passing through the axis of the drill collar, while preventing rotation about the axis of the drill collar and minimising radial and axial movement. Bearings 37 connect the rotating wall contact assembly with the non-rotating assembly consisting of an angulation coupling 38, an actuator casing 39 and an anti-rotation device 40. The angulation coupling 38 is similar in performance to the forward joint and allows angulation about axes normal to and passing through the axis of the drill collar but prevents relative rotation about the axis of the drill collar and prevents all relative translational movements. The anti-rotation device 40 is designed to apply radial force to the bore hole wall 14 and provide torsional resistance preventing rotation, while having minimal resistance to axial movement.

The housing 31 is connected rigidly to an actuator bridge member 41. This assembly is located onto the drill collar by means of spaced bearings 42. This assembly is also connected to the actuator casing by means of a rear joint 43 which has the same properties as the forward joint and similar properties to the angulation coupling.

The actuator assembly 34 consists of four individual actuators 44. These actuators 44 lie within the annular space 46 between the actuator casing 39 and the actuator bridge member 41 and each actuator is disposed at equal intervals around the periphery, as best shown in Figure 3. The movement of the drill collar relative to the wall contact assembly is achieved by applying...
different pressures, in a controlled manner, to each of the four actuators 44.

The form of the actuators could be a flexible hose or tube 44 or a variation thereof, with one end blanked off and the other end connected to a hydraulic supply and return pipe. The flexible material could be woven polyester or nylon coated with a suitable elastomer such as Viton.

Four of these tubes 44 are fitted into the annular space 46 reserved for the actuators, as shown in Figure 3. In the neutral position the cross section of each tube 44 would be partially flattened. As hydraulic fluid is supplied to any one actuator it has the tendency to return to its circular cross section and hence a radial force is applied at the actuator location which is dependent on the hydraulic fluid pressure and the cross sectional geometry of the actuator. Provided the actuator diametrically opposite to the actuator being filled is allowed to vent, the actuator bridge member 41 and hence the drill collar 10 will be moved radially with respect to the actuator housing. The use of four actuators allows the actuator bridge member 41 to be positioned at any location relative to the actuator housing only within the limits of maximum radial movement.

An alternative mode of operation of this form of the invention is with the wall contact assembly not rotating with the drill collar. In this case the forward joint 35 is located on the drill collar by means of a bearing assembly 45 and the bearings 37 are locked to provide a rigid connection. It may be useful to configure this form of the invention so that the modes of operation can be interchanged by means of simple adjustments. With the wall contact assembly not rotating it may be that the anti-rotation device is not required, this function being provided by the wall contact assembly itself.

Referring to Figure 4, the sensing means 50 sense the actual drilling course which is compared with the predetermined required drilling course stored in the information storage means 52. This comparison is carried over in the comparison means 54 which produce an error signal in dependence upon the comparison. The error signal is fed back by a feedback loop 56 to the actuating means 58 (constituted by the control stabiliser 20) which applies the controlled lateral force to the drill collar.

Claims

1. Drilling apparatus comprising a rotatable drill collar (10), a drill bit (12) carried by the end of the drill collar, control means for controlling the drilling course, the control means comprising sensing means (50) for sensing the actual drilling course, information storage means (52) for storing a predetermined required drilling course and comparison means (54) for comparing the sensed course with the required course and for delivering an error signal in dependence upon the comparison, characterised by two spaced stabilisers (16, 18) which act to locate the drill collar within a bore hole being drilled, and actuating means (20) which do not rotate with the collar and which apply a controlled lateral force or displacement to the drill collar at a location between the two stabilisers in order to deflect the drill collar between the spaced stabilisers to vary the drilling course in dependence upon said error signal, the control means being located down the hole being drilled.

2. Drilling apparatus according to Claim 1, characterised in that the sensing means sense direction and inclination of the bore hole course relative to the earth's magnetic and gravitational fields respectively.

3. Drilling apparatus according to Claim 1, characterised in that the actuating means include a control stabiliser (20) which applies the controlled lateral force or displacement and which is located between said spaced stabilisers.

4. Drilling apparatus according to any of Claims 1 to 3 characterised in that the information storage means (52) are provided with information which relates to the desired direction and inclination of the bore hole course, and also to the maximum desired curvature of the bore hole during the transition from the initial bore hole course to the desired bore hole course.

5. Drilling apparatus according to any of the preceding claims, wherein the actuating means comprise flexible tubes or bags which when supplied with hydraulic fluid expand until the required deflection of the drill collar is obtained.

6. Drilling apparatus according to Claim 5, wherein the required hydraulic fluid flow and pressures are generated by a reciprocating pump or pumps which are driven from the rotating drill collar.

7. Drilling apparatus according to Claim 6, wherein control of the hydraulic fluid is exercised by valves which divert the fluid flow in accordance with control signals generated by the comparison means.

8. Drilling apparatus according to Claim 1, wherein the actuating means apply controlled forces to the drill collar in each of two orthogonal directions, so that a deflection of any magnitude and in any radial direction can be applied by the actuating means to the drill collar.

Patentansprüche

1. Bohrvorrichtung mit einer drehbaren Bohrstange (10), einer am Ende der Bohrstange gehaltenen Bohrerspitze (12) und Steuereinrichtungen zum Steuern des Verlaufs der Bohrung, wobei die Steuereinrichtungen Meßeinrichtungen (50) zum Messen des tatsächlichen Verlaufs der Bohrung, Informationsspeichereinrichtungen (52) zum Speichern eines vorgegebenen Sollverlaufs der Bohrung und Vergleichseinrichtungen (54) zum Vergleich des gemessenen Verlaufs mit dem Sollverlauf und zum Aussenden eines Fehlersignales nach Maßgabe des Vergleichs aufweisen, gekennzeichnet durch zwei Abstand voneinander aufweisende Stabilisatoren (16, 18), die
zur Lageeinstellung der Bohrstange in dem Bohrloch während des Bohrens dienen, und Betätigungseinrichtungen (20), die sich nicht mit der Bohrstange drehen und auf diese zu ihrer Ablenkung zwischen den beiden auseinanderliegenden Stabilisatoren zum Verändern des Verlaufs der Bohrung nach Maßgabe des Fehlersignales an einer Stelle zwischen den beiden Stabilisatoren eine gesteuerte Seitenkraft oder -verschiebung ausgeübt, wobei die Steuereinrichtungen unten im Bohrloch angeordnet sind.

2. Bohrvorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Meßeintrichtung die Richtung und die Neigung des Bohrlochverlaufs gegenüber dem Magnet- und dem Schwerkraftfeld der Erde mißt.

3. Bohrvorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Betätigungseinrichtung einen Steuerstabilisator (20) enthält, der die gesteuerte Seitenkraft oder -verschiebung ausübt und der zwischen den auseinanderliegenden Stabilisatoren angeordnet ist.

4. Bohrvorrichtung nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Informationsempfängerinrichtungen (52) mit Information versehen sind, die sich auf die Sollrichtung und -neigung des Bohrlochverlaufs und auch auf die maximal erwünschte Krümmung des Bohrloches während des Überganges vom ursprünglichen Bohrlochverlauf zum gewünschten Bohrlochverlauf beziehen.

5. Bohrvorrichtung nach irgendeinem der vorhergehenden Ansprüche, wobei die Betätigungseinrichtungen flexible Rohre oder Säcke sind, die bei Druckschlagung mit einem hydraulischen Medium bis zum Erreichen der erforderlichen Ablenkung der Bohrstange expandieren.


8. Bohrvorrichtung nach Anspruch 1, wobei die Betätigungseinrichtungen Steuerkräfte in jeder von zwei unter 90° zueinander verlaufenden Richtungen auf die Bohrstange ausüben, so daß eine Ablenkung jeder Größe und in jeder Radialrichtung von den Betätigungseinrichtungen auf die Bohrstange ausgeübt werden kann.

Revendications

1. Appareil de forage comprenant une tige lestée (10) rotative, un trépan (12) monté à l'extrémité de la tige lestée, des moyens de commande pour commander l'orientation de forage, les moyens de commande comprenant des moyens de détection (50), destinés à repérer l'orientation de forage réelle, des moyens d'enregistrement d'information (52), destinés à enregistrer une orientation de forage prédéterminée exigée et des moyens de comparaison (54), destinés à comparer l'orientation détectée avec l'orientation exigée et à fournir un signal d'erreur dépendant de la comparaison, caractérisé par deux stabilisateurs espacés (16, 18) qui agissent de façon à positionner la tige lestée à l'intérieur du sondage qui est foré, et par des moyens d'actionnement (20) qui ne tournent pas avec la tige lestée et qui appliquent une force ou un déplacement latéral commandé à la tige lestée, en une position située entre les deux stabilisateurs, dans le but de dévier la tige lestée entre les stabilisateurs espacés, afin de faire varier l'orientation de forage sous la dépendance du signal d'erreur, les moyens de commande étant placés au fond sondage qui est foré.

2. Appareil de forage selon la revendication 1, caractérisé en ce que les moyens de détection détectent la direction et l'inclinaison de l'orientation du sondage, respectivement par rapport aux champs magnétique et de gravitation de la terre.

3. Appareil de forage selon la revendication 1, caractérisé en ce que les moyens d'actionnement comportent un stabilisateur de commande (20) qui applique la force ou le déplacement latéral commandé et qui se trouve entre les stabilisateurs espacés.

4. Appareil de forage selon l'une quelconque des revendications 1 à 3, caractérisé en ce que les moyens d'enregistrement d'information (52) disposent d'une information qui concerne la direction et l'inclinaison désirées de l'orientation du sondage, et également la courbure maximale désirée du sondage pendant la transition de l'orientation initiale du sondage vers l'orientation désirée du sondage.

5. Appareil de forage selon l'une quelconque des revendications précédentes, dans lequel les moyens d'actionnement comprennent des tubes ou des sacs flexibles qui se distendent lorsqu'ils reçoivent un fluide hydraulique, jusqu'à l'obtention de la déviation exigée de la tige lestée.

6. Appareil de forage selon la revendication 5, dans lequel le débit et les pressions désirées de fluide hydraulique sont produits par une ou plusieurs pompes à mouvement alternatif qui sont entraînées à partir de la tige lestée en rotation.

7. Appareil de forage selon la revendication 6, dans lequel la commande du fluide hydraulique est exercée par des vannes qui dévient l'écoulement de fluide conformément à des signaux de commande que produisent les moyens de comparaison.

8. Appareil de forage selon la revendication 1, dans lequel les moyens d'actionnement appliquent des forces commandées à la tige lestée dans chacune de deux directions orthogonales, de façon que les moyens d'actionnement puisent appliquer à la tige lestée une déviation d'une valeur quelconque et dans une direction radiale quelconque.
Fig. 4