ABSTRACT: Directional drilling equipment is disclosed that employs a downhole motor to rotate the bit, while the drill string provides the weight on the bit. The equipment has a sleeve between the bit and the motor that has a bend or inflection point such that the bit makes the desired angle with the axis of the drill string. Torque from the motor is transmitted through the inflection point to the bit by a shaft and a dual universal joint housed in the sleeve. None of the weight on the bit or the end thrust of the motor is transmitted to the shaft.
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DIRECTIONAL DRILLING EQUIPMENT

The present invention relates generally to the art of drilling wells such as oil wells in directional or deviated fashion by means of underground rotating drilling motors.

For acquiring mastery in this art, it is important to be able to give the drilling tool (drilling bit, core drill or the like) an inclination which must not exceed a few sexagesimal degrees with respect to the axis of the drill string. The easiest solution consists in interposing a cranked union or joint between the tool-driving motor and the drill string. However, such a method only gives limited possibilities and it often happens than an inclination of the order of 30° may not be exceeded in this way because the weight of the motor then operates reversely of the sought effect. Moreover, the provision of a cranked union limits the permissible length and consequently the power of the motor.

In view of this, attempts were made to arrange the cranked joint under the motor between the latter and the tool.

Several types of joint or subs of this type have already been developed and tested. However, their duration is very limited and none of them seems to have reached the manufacturing stage. The chief defects of such constructions were that the principles of homokinetics were not respected and that a pushing stress was transmitted simultaneously with the torque. This seems to be detrimental to their behavior in service.

An object of the invention is to remedy the disadvantages of known constructions in this technical field and to provide an equipment for directed drilling wherein the driving force is furnished by an underground rotating motor capable of dissociating axial thrust stresses from torque-transmitting stresses while permitting the use of a homokinetically acting driving device owing to such a novel construction that such device does not transmit axial stresses of any importance.

Another object of the invention is to provide a new or improved equipment for directed drilling comprising in known fashion an inflection point or cranked portion, an underground rotary motor, a motor driven drilling tool, axial thrust bearings and characterized by the fact that the thrust bearing that takes the reaction of the tool and the bearing that supports the axial push of the motor or that part of the motor situated above the inflection point are dissociated or segregated and arranged on the opposite sides of said inflection point, at least one part of the motor being located above the inflection point, a distortable driving device (advantageously of homokinetic nature) being provided opposite the inflection point of the drilling string between the shafts extending through the straight upper and lower parts of the equipment.

Owing to the segregation over and under the inflection point between the bearings and the absorbing means for the axial stresses due to the tool reaction and the pushing stresses due to the motor elements, there is thus created opposite said inflection point in the drive shafting a so-called quiet zone which does not transmit axial stresses, thereby permitting to provide at said point a driving device which substantially transmits angular stresses exclusively.

A further object of the invention is to provide an equipment as aforesaid comprising a particular advantageous construction including a driving device made up of a dual universal joint performing a homokinetic driving action while eliminating axial stresses at this point, thereby making it possible to employ universal joints of conventional structure, for example of the type as commonly used on automotive vehicles.

Yet a further object of the invention is to provide an axially slidable angular driving device interposed in the line of shafting on either the one or the other side of the aforesaid distortable driving device, advantageously on the tool side so as practically to eliminate axial thrust transmission or axial vibrations from said distortable device, elastic means being advantageously provided for attenuating or absorbing angular impacts and vibrations.

A still further object of the invention is to provide an equipment as aforesaid comprising means for advantageously and continuously adjusting the angle defined at the inflection point between 0° and a maximum value without any need to dismangle entirely the equipment.

The underground motor may be arranged entirely over the inflection point or partly over and partly under said point.

With these and such other objects in view as will incidentally appear hereafter, the invention comprises the novel construction and combination of parts that will be now described hereafter with reference to the accompanying diagrammatic drawings exemplifying the same and forming a part of the present disclosure.

In the drawings:

FIG. 1 is a diagrammatic view of this improved ground-drilling equipment including an underground rotating motor connected with the tool by a cranked joint.

FIG. 2 is a view showing the relative positions of the three axes of the motor, deviating sleeve and tool.

FIG. 3 is a graph illustrating the variation law of the several angles defined by the three aforesaid axes.

FIG. 4 is a detailed view of that portion of the equipment capable of defining the varying angle of the cranked portion in the position occupied thereby for performing a straight drilling operation.

FIG. 5 is a partial view corresponding with FIG. 4 but with a position of maximum deviation.

FIG. 6 is a view showing a constructional form of the axially slidable angular coupling, half this figure being in axial section.

FIG. 7 is an under plan view corresponding with FIG. 6, half this figure being in transverse section.

FIG. 8 is a sectional view on the line VIII—VIII in FIG. 6.

FIG. 9 is a view representing a constructional modification of what is shown in FIG. 8.

FIG. 10 shows an embodiment of the equipment having a stationary cranked portion.

In the showing of FIG. 1, the tool 1 which comprises a drilling bit is driven by a shaft 2 fitted in a body member 3 and abutted against it by means of an axial bearing 4 which takes and absorbs the tool reaction. The shaft 2 is angularly connected with a shaft 6 through an axially slidable angular coupling 5. The shaft 6 is driven by a device made up of a pair of universal joints 7, 7' interconnected by a shaft 8. This device is engaged by a shaft 9 accommodated in a body member 10 containing the underground motor which may be of any conventional type. The axial bearing for this motor is shown at 11.

It will be seen from the drawings that the shafts 6 and 9 are mounted in radial bearings 12, 13 and that the axes of the body members 3, 10 define an angle so as to permit deviated drilling to take place. 14 designates in diagrammatic fashion a cranked union. It will be seen that said union is arranged substantially midway of the ends of the shaft 8. This union 14 may be stationary or may have a variable and adjustable angle as described more in detail hereafter.

It will be understood that, during the operation, the reaction of the tool 1 and the axial thrust exerted by the motor are respectively taken and absorbed by the thrust bearings 4, 11 whereby a zone relieved from axial stresses is provided opposite the union or cranked portion 14. In this zone merely prevails a transmission of angular forces for driving the tool from the motor. This permits a dual universal joint device of the illustrated type to be used for performing the driving action thereby ensuring a homokinetic transmission that cannot absorb axial stresses.

In the showing of FIG. 2 is illustrated at x-x' the axis of the drilling string or motor, at y-y' the axis of the tool and tool holder and at z-z' the axis of a deviating sub of the type described hereafter and shown in FIG. 1 as the union or joint 14.

A particularly advantageous feature resides, as described hereafter, in the possibility of varying the deflection angle θ (defined between the axes x-x' and y-y') between zero and a maximum value:
In the graph constituting FIG. 3 is illustrated the variation of the angle $\theta$ in terms of the angle $\alpha$ delineated between the plane defined by the axes of $x$ and $y$ and the plane defined by the axes $x$-$y$ and $z$-$z'$ in the case of a union whose $\alpha$ angle is equal to 1.5.

In said graph are also represented the linear variations of the $\beta$ angle defined between the plane $x-z$-$z'$ and the plane $x-x'$-$y-y'$ the knowledge of which is useful for relative reference of the several elements of an adjustable union.

In the constructional form shown in FIGS. 4 and 5, a turbobulb is also used the body member of which is indicated by 15 while its shaft 16 terminates adjacent the tool in a lower shaft 17 arranged inside a stator union 18. This shaft 17 can resolve in a radial bearing 19 and is rigidly connected with a universal joint 20 housed in a sleeve 21. The universal joint 20 is connected via a shaft 22 with another universal joint 23 which drives the shaft 24, therefore the shafts 24 in the radial bearings 25 and connected through an axially slidable angular coupling 26 with the shaft 27 that imparts rotation to the tool.

It will be easily seen that the motion derived from the shaft 27 is homokinetic with respect to that of the shaft 16 no matter what their relative angular positions may be. The shaft 27 is radially guided by its own set of bearings and bushes 28 and its axial displacements are limited by a double-acting abutment 29 which absorbs the tool reaction. Although this is not shown but as beforehand stated, the axial thrust exerted by the motor is absorbed by an independent thrust bearing.

The universal joint system is housed in the sleeve 21 and in a sleeve 30 connected via a bearing 31 and a union 32 with the body or housing 33 containing the axial bearing 29.

The sleeves 21, 30 are interconnected by a sleeve 34 having a shoulder 35 and a male-threaded portion 36 which can be screwed into a female-threaded portion of the sleeve 30. As it is visible in FIG. 4, the axis of the female-threaded portion defines an angle $\alpha$ with the axis of the sleeve 30. This is also true for the axis of the sleeve 34. Moreover, the axis of the sleeve 21 slants by an angle equal to $\alpha$ which is preferably equal to the angle with respect to the axis of the abutted faces of its lower end on the shoulder 35.

If the shaft 35 is revolved about the sleeve 34, the angle $\theta$ defined between the axes of the sleeves 21, 30 may be varied by $\alpha-\alpha'$ up to the value $\alpha\alpha'$ which, where $\alpha=\theta$, gives the following limit values:

$0<\theta<2\alpha$

Practically speaking, the maximum value used for $\theta$ does not exceed 3° so that $\alpha=15°$. In the graph constituting FIG. 3, the variation of $\theta$ in terms of the angular motion of the sleeve 21 relatively to the sleeve 34 is clearly shown.

The showing of FIG. 4 corresponds with the aligned position, i.e., with $\theta=0°$.

In operation, the sleeve 21 should be axially and angularly rigid with the sleeve 30. In order to achieve this rigid interconnection, there is provided (as shown in FIG. 4) a spacing ring 37 interposed between the abutted faces of the sleeves 21, 30. Such ring is keyed or otherwise made angularly fast at 38 with the sleeve 34. Furthermore, the sleeve 21 is keyed in adjustable fashion by means of pegs 39 engaged into sequentially arranged grooves formed in the end face of the sleeve 21.

However, this angular interconnection might be also obtained by providing the abutment face between the shoulder 35 and the base of the sleeve 21 with crowns of teeth or mutually interlocked ribs and flutes.

When it is desired to vary the relative inclination angle $\theta$, it is only necessary to turn the threaded portion 36 then to rotate the ring 37 with respect to the sleeve 21 by the required angle $\alpha$ and to reestablish the keying effect and to relatch the threaded portion. Advantageously, the connecting elements may be provided with reference marks and/or scale lines permitting the necessary angle $\alpha$ to be determined so as to obtain an angle $\theta$ of desired value.

In FIG. 5 the above-described device is represented in its position of maximum deviation.
thrust stress of said first motor section and combined with said first shaft, a second axial thrust bearing for receiving the resultant force from the axial thrust stress of said second motor section and the tool reaction and combined with said second shaft, and a homokinetic driving device at said inflection point.

5. An equipment for directional ground drilling according to claim 4, wherein the homokinetic driving device comprises a dual universal joint.

6. An equipment for directed ground drilling according to claim 6, wherein the inflection point comprises a one-piece cranked sleeve and the homokinetic driving device comprises a dual universal joint housed in said sleeve.

7. An equipment for directional ground drilling comprising an underground rotating motor, a drilling tool, a homokinetic driving device providing an inflection point between said motor and tool, a first straight shaft extending between said driving device and motor, a second straight shaft extending between said driving device and tool, radial bearings for said shafts, a first axial thrust bearing for receiving the axial thrust stress of the motor and combined with said first shaft, a second axial thrust bearing for receiving the tool reaction and combined with said second shaft, and an axially slidable angular coupling interposed in one of said shafts.

8. An equipment for directional ground drilling according to claim 7 wherein elastic elements are associated with said coupling for absorbing vibrations and angular impacts.

9. An equipment for directional ground drilling according to claim 7 wherein said axially slidable coupling comprises a female joint, a shaft received in said joint, ribs and flutes respectively provided on said female joint and shaft for behaving as guides, and rolling member received in said guides.

10. An equipment for directional ground drilling comprising an underground rotating motor, a drilling tool, an inflection point between said motor and tool, a first straight shaft extending between said inflection point and motor, a second straight shaft extending between said inflection point and tool, radial bearings for said shafts, a first axial thrust bearing for receiving the axial thrust stress of the motor and combined with said first shaft, a second axial thrust bearing for receiving the tool reaction and combined with said second shaft, a homokinetic driving device as said inflection point, and means for adjusting the angle provided by the inflection point.

11. An equipment for directional ground drilling according to claim 10, wherein said adjusting means comprise a first sleeve, a second sleeve screwed upon the first sleeve and having an axis inclined with respect to the first sleeve axis, a revolute ring between said first and second sleeves, and means for angularly keying said ring in a plurality of positions with respect to said first and second sleeves.