

Drilling apparatus and method for producing a vertical bore

The invention relates to a drilling apparatus for producing a vertical bore having a basic body, a suspension means arranged on a rear side of the basic body for suspension of the drilling apparatus in the bore, a removal unit supported in a rotatable manner about an eccentric axis, which is arranged on a front face of the basic body in an eccentric manner to a center axis of the basic body and which is supported in a circulating manner around the center axis, and a drive unit for driving the removal unit in a rotating manner about the eccentric axis in accordance with the preamble of claim 1. Furthermore, the invention relates to a method for producing a vertical bore.

A drilling apparatus of such type can be taken from DE 10 2008 028 997 A1 for example. This known drilling apparatus has an approximately cylindrical housing which is sunk vertically into the ground. Located eccentrically to the center axis of the drilling apparatus a conical drilling tool is provided which is driven in a rotating manner by a motor. The single drilling tool circulates in a planetary manner around the center axis of the drilling apparatus, with the distance between the eccentric axis of the drilling tool and the center axis of the drilling apparatus being modifiable so as to be able to cover the entire borehole bottom.

Drilling apparatuses of such type having an eccentrically arranged removal tool are especially advantageous for working in hard ground or rock. As opposed to conventional drilling tools with continuous cutting edges, in the case of the generic drilling apparatuses only a small area of the borehole

bottom is momentarily being worked upon each time. This reduces the load and thus the wear of the removal tool and of the entire drilling apparatus to a considerable degree.

Due to the eccentric arrangement of the drilling tool an asymmetrical load of the drilling apparatus is present during operation. The exertion of such asymmetrical forces can lead to a deflection of the drilling apparatus from the desired vertical drilling direction. In the stated prior art it is proposed to guide the drilling apparatus in a follow-up casing that lines the borehole. The provision and follow-up of a casing of the borehole proves to be work-intensive and time-consuming.

The invention is based on the **o b j e c t** to provide a drilling apparatus and a method for producing a vertical bore, with which bores can be produced in an especially efficient manner even in hard ground material.

The object is achieved in accordance with the invention by a drilling apparatus having the features of claim 1. Preferred embodiments of the invention are stated in the dependent claims.

The drilling apparatus according to the invention is characterized in that the removal unit is of disk-shaped design and in that the eccentric axis of the disk-shaped removal unit is arranged bent at an acute angle to the borehole axis and/or to the center axis of the basic body.

As a result of the arrangement according to the invention a particularly favorable distribution of force and thus favorable wear behavior along with a high removal performance is achieved. For one thing, the removal unit is arranged in a disk-shaped manner, i.e. it is not provided with a defined drill bit lying on the eccentric axis. The eccentric and bent arrangement of the removal unit brings about a kind of tumbling movement around the center axis that normally corresponds to the drilling axis of the drilling apparatus

and thus a borehole axis. During this tumbling movement only a constantly changing partial area of the removal unit is in contact with the ground to be removed. Through this, an overheating of the removal unit and hence excessive wear can be avoided, because during the rotational movement individual circumferential areas of the disk-shaped removal unit are subject to no or only a little load depending on their rotational position.

In addition, by way of an acute angle of the eccentric axis with a distance to the center axis increasing in the downward direction a conical borehole bottom is produced. Such a conical borehole bottom facilitates the centering of the drilling apparatus in the borehole. As a result, the guidance of the drilling apparatus in the borehole is improved. The acute angle ranges between 2° and 30°, preferably 5°.

In accordance with a preferred embodiment of the invention a further improvement of the guidance results from the fact that on the front face of the basic body next to the removal unit at least one bearing element is arranged which is designed for bearing on a bottom of the bore. In a preferred asymmetrical arrangement of the drilling apparatus with a single removal unit, with respect to the center axis, the bearing element is arranged opposite on the front face of the basic body. The bearing element preferably is of bar-shaped design. It is supported in a spring-loaded manner or can be telescoped. This enables counteraction of an undesired tilting of the drilling apparatus in the borehole and alignment to be controlled.

In this connection it is especially preferred in accordance with the invention that a measuring means is provided on the bearing element for determining a bearing force of the drilling apparatus. For this purpose appropriate force sensors can be present, with which the compressive force exerted on the bearing element can be determined. The compressive force acting on the bearing element permits conclusions as to the bearing force of the opposite

lying removal unit. In this way, the pressing force and the rotational speed can be coordinated with each other in a favorable way so that a high degree of progress with a minimum of wear is achieved.

Basically, in a simple embodiment the removal unit can be a disk with removal teeth arranged on the circumference. A particularly preferred embodiment of the invention resides in the fact that the removal unit has a carrier disk, on which several removal tools are each supported in a rotatable manner about a tool axis. The removal tools can be designed as roller bits. Other removal tools, such as multiple hammers (MHD), are possible too. The tool axes can be arranged in a spaced and transverse manner to the eccentric axis of the carrier disk of the removal unit. This enables the rotating removal tools to roll off on the borehole bottom. As a result, the removal and wear behavior is improved further. The removal tools can also be driven in a rotating manner by a transmission located in the carrier disk.

This arrangement is improved in a preferred way in that the removal tools each have several arranged removal teeth. The removal teeth are arranged in a radially projecting manner to the outer circumference. By preference, the removal tools have a removal tip so that a substantially punctiform, chisel-like contact with the ground is present. Compared to linear cutting edges the wear behavior is further improved thereby.

To ensure a high removal performance it is preferred that the rotatable removal tools are driven in a circulating manner with respect to the eccentric axis. Hence, the circulating movement of the removal tools does not result in a rolling movement caused by the rotation of the drilling apparatus in general, but it is specifically brought about by a drive which is preferably arranged in the carrier disk of the removal unit. The removal tools can also be cutting disks that are driven by circulating in a planetary manner around the eccentric axis.

Moreover, according to the invention it is preferred that on the front face of the basic body a suction opening is provided, by way of which removed ground material can be sucked off from a borehole bottom via a suction line. Hence, the drilling apparatus can operate in a bore filled with suspension or liquid. This serves not only for supporting the borehole wall. The liquid also cools the removal tools, which is of advantage when working on hard rock. By way of the suction opening the removed ground material can be sucked off together with surrounding liquid via a suction line. The latter runs through the basic body as far as the rear side of the basic body. As a rule, a connection for a hose line is to be found there so that the ground material can be pumped off from the bottom of the borehole to the surface. A pump can be arranged in the basic body itself and/or a pump means can be arranged above ground.

According to the invention, good guidance and a high drilling progress are achieved in a preferred way in that on the basic body a torque support is arranged, with which the basic body can be supported with respect to a surrounding wall of the bore.

In this connection it is especially preferred that the torque support has several radially extendable support elements. The radial extension can take place by means of hydraulic cylinders or through a corresponding lever mechanism. Through this, at least a part of the basic body is supported with respect to the borehole wall such that reaction forces can be introduced directly into the borehole wall. Consequently, it is no longer absolutely essential to supply a torque via a rigid drill rod to the drilling apparatus exclusively from the surface. This is particularly advantageous if greater drilling depths from 30 to 100 m and more are sunk.

According to the invention it is particularly advantageous that the basic body has a rearward upper part and a front-facing lower part, which can be

displaced axially to each other, that on the upper part the torque support and on the lower part the removal unit are arranged and that a displacement means is provided for axial displacement of the lower part relative to the upper part. Thus, by way of the torque support the rearward upper part of the basic body can be fixed in the radial and/or axial direction with respect to the surrounding ground. In this way, an axial compressive force can be applied from the upper part to the subjacent lower part using a displacement means that comprises hydraulic positioning cylinders in particular. With the displacement means it is thus possible to set and control the pressing force acting on the removal unit in a very precise way.

In addition, according to the invention it is basically possible that the torque is supplied via a rigid drill rod from the surface. In the simplest case, the drive unit can be a transmission which takes up a torque from a central drill rod and transforms this into corresponding output torques for the removal unit, more particularly for the removal tools. In this way, a fixed relation of the torques and rotational speeds between the individual rotatably driven elements of the removal unit can be achieved.

In accordance with the invention it is particularly advantageous for the drive unit to comprise a motor which is supplied with hydraulic and/or electrical energy. Provision of the motor can be made as an alternative for supplying the torque from outside or as a supplement. The energy is supplied from the surface via an electrical line or hydraulic lines. A motor translates the supplied energy into a mechanical rotary movement. According to the invention provision can also be made for the presence of several motors so that, all in all, an individual setting of the rotational speeds and torques of each of the single driven elements is rendered possible.

Finally, as far as the method is concerned, the object stated at the beginning is achieved by a method for producing a vertical bore, in which a drilling

apparatus according to the invention described above is used. With the drilling apparatus bores can thus be produced in a particularly efficient manner in hard ground and rock.

In the following the invention is described further by way of preferred embodiments shown schematically in the accompanying drawings, wherein show:

- Fig. 1 a schematic side view of a drilling apparatus according to the invention with retracted lower part;
- Fig. 2 a schematic side view of the drilling apparatus of Fig. 1 with extended lower part;
- Fig. 3 a partial cross-sectional view of the drilling apparatus according to the invention pursuant to Fig. 2; and
- Fig. 4 a detailed cross-sectional view of the removal unit according to section A-A.

In accordance with Figures 1 and 2 a drilling apparatus 10 according to the invention is shown which has an approximately cylindrical basic body 12 with a center axis 11. In the case of a rotating drive of the drilling apparatus 10 via a square suspension means 18 for a Kelly bar, the center axis 11 corresponds to a drilling axis of the developing borehole.

The basic body 12 comprises a cylindrical upper part 14 and a cylindrical lower part 16, which are supported by being axially displaceable with respect to each other. On an upper side of the box-shaped upper part 14 the suspension means 18 for connection to a drill rod is fixed. From an underside of the upper part 14 a center shank 15 extends coaxially to the center axis 11. The tubular center shank 15 protrudes into a sleeve-shaped receiving part 17. The sleeve-shaped receiving part 17 and the center shank 15 are axially

displaceable with respect to each other and yet connected to each other in a rotationally fixed manner. To limit an axial movement path a ring-shaped stop 13 is arranged on the center shank 15. Below the ring-shaped stop 13 on a lower shank portion 19 of the center shank 15 axial webs, not shown, are provided for forming the axially movable rotary connection. By means of three lifting cylinders 72 of a displacement means 70, which are arranged offset to each other by 120° , the lower part 16 can be extended by a stroke h with respect to the upper part 14 whereby an axial length of the drilling apparatus 10 is increased, as depicted in Fig. 2. The lifting cylinders 72 are fixed with their cylinder housing on an upper side of the lower part 16, while the pistons 74 are mounted via a retaining ring, not shown, on the upper part 14.

On an underside of the lower part 16 a disk-shaped removal unit 20 is arranged eccentrically to the center axis 11. The removal unit 20 is rotatably supported and driven about an eccentric axis 22 that is radially spaced to the center axis 11. On a carrier disk 24 of the removal unit 20, located on the ground-facing underside thereof, roller-shaped removal tools 26 are rotatably supported about tool axes 28. On the external sides of the roller-shaped removal tools 26 removal teeth 30, not shown in detail, are arranged for removing rock or hard ground material.

Lying radially opposite with respect to the center axis 11 a bearing element 50 is arranged on the circular-disk-shaped underside of the lower part 14. The bearing element 50 comprises an axially downward projecting shank 54, on which a circulation roller 52 is arranged, which is rotatably supported about a roller axis directed transversely to the center axis 11. The bearing element 50 serves for supporting and counterbalancing the asymmetrically arranged single removal unit 20 in order to counteract a tilting of the drilling apparatus 10 during operation.

On the bearing element 50 a measuring means can be provided, with which a compressive force of the drilling apparatus 10 exerted on the borehole bottom can be determined. In this way, a suitable pressing force onto the removal unit 20 can be set by way of the displacement means 70.

For this purpose, provision is furthermore made in that on the upper part 14 a torque support 60 is arranged, with which the upper part 14 can be supported and secured with respect to the surrounding borehole wall in the circumferential direction as well as in the axial direction. To this end the torque support 60 has three plate-shaped support elements 62 which are distributed by 120° around the center axis 11 and which are each linked in a radially extendable manner via two positioning levers 64 on the center shank 15. For extension or retraction a positioning cylinder 66 is arranged on each support element 62. The positioning cylinders 66 as well as the pistons 74 are each connected to the center shank 15 by way of suitable retaining rings, not depicted.

The construction and operation of the drilling apparatus 10 according to the invention and of its drive unit 40 in particular is explained further in conjunction with the cross-sectional view of Fig. 3. By way of the suspension means 18 a torque is transmitted via a drill rod, not depicted, to a central sun wheel 41. The sun wheel 41 drives a first pinion 42, which is connected in a rotationally fixed manner to a drive shaft 43 leading to the lower part 16. The drive shaft 43 comprises an upper shaft part 44, which protrudes in an axially displaceable manner into a sleeve-shaped receiving part of a lower shaft part 45 in order to ensure, in accordance with the stroke h , an axial displaceability of the lower part 16 relative to the upper part 14. By way of a spur gear system 46 the lower shaft part 45 drives a drive shank 47 of the removal unit 20. For this purpose the drive shank 47 has a drive pinion 21 with a spiral toothing.

As shown in greater detail in Fig. 4, the axis of rotation of the drive shank 47 is coaxial to the eccentric axis 22 of the removal unit 20, in which case the eccentric axis 22 is arranged at an acute angle to the center axis 11 of the drilling apparatus 10. In the present embodiment the angle amounts to 5°. Due to this inclined position of the removal unit 20, driven in a rotating manner about the eccentric axis 22, an improved ground removal and reduced wear of the removal tools 26 is achieved.

Assisted by a turbine wheel 49 that causes a suction effect, the removed ground material is sucked off upwards via a suction opening 38 on the underside of the lower part 16 along a suction line 39 running through the entire drilling apparatus 10. The turbine wheel 49 is driven via a second pinion 48 by the sun wheel 41. For the suspension means 18 the suction line 39 can be guided upwards in the interior of the drill rod or it can be connected via a line connection to a hose line on the upper side of the upper part 14.

CLAIMS

1. Drilling apparatus for producing a vertical bore having
 - a basic body,
 - a suspension means arranged on a rear side of the basic body for suspension of the drilling apparatus in the bore,
 - a removal unit supported in a rotatable manner about an eccentric axis, which is arranged on a front face of the basic body in an eccentric manner to a center axis of the basic body and which is supported in a circulating manner around the center axis, and
 - a drive unit for driving the removal unit in a rotating manner about the eccentric axis,

wherein

 - the removal unit is of disk-shaped design and
 - the eccentric axis of the disk-shaped removal unit is arranged bent at an acute angle to the borehole axis and/or to the center axis of the basic body.
2. Drilling apparatus according to claim 1,
wherein
on the front face of the basic body next to the removal unit at least one bearing element is arranged which is designed for bearing on a bottom of the bore.
3. Drilling apparatus according to claim 2,
wherein

a measuring means is provided on the bearing element for determining a bearing force of the drilling apparatus.

4. Drilling apparatus according to claim 1,
wherein
the removal unit has a carrier disk, on which several removal tools are
each supported in a rotatable manner about a tool axis.
5. Drilling apparatus according to claim 1,
wherein
the removal tools each have several arranged removal teeth.
6. Drilling apparatus according to claim 4,
wherein
the tool axes of the removal tools are arranged in an offset and/or trans-
verse manner to the eccentric axis.
7. Drilling apparatus according to claim 1,
wherein
the rotatable removal tools are driven by circulating in a planetary maner
with respect to the eccentric axis.
8. Drilling apparatus according to claim 1,
wherein
on the front face of the basic body a suction opening is provided, by way
of which removed ground material can be sucked off from a borehole
bottom via a suction line.
9. Drilling apparatus according to claim 1,
wherein
on the basic body a torque support is arranged, with which the basic
body can be supported with respect to a surrounding wall of the bore.

10. Drilling apparatus according to claim 9,
wherein
the torque support has several radially extendable support elements.
11. Drilling apparatus according to claim 1,
wherein
the basic body has a rearward upper part and a front-facing lower part
which can be displaced axially to each other,
on the upper part the torque support and on the lower part the removal
unit are arranged and
a displacement means for axial displacement of the lower part relative to
the upper part is provided.
12. Drilling apparatus according to claim 11,
wherein
on the upper part of the basic body the drive unit is provided.
13. Drilling apparatus according to claim 1,
wherein
the drive unit comprises a motor which is supplied with hydraulic and/or
electrical energy.
14. Method for producing a vertical bore,
wherein
a drilling apparatus according to claim 1 is used.