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DIRECTIONAL DRILLING DEVICE

Abstract

Directional drilling device for installing underground cables or tubes, comprising a housing having a drill space extending between two openings in sides of the housing for accommodating a drill string through the two openings, and defining a longitudinal drill axis; and a drive mechanism arranged in the housing for engagement with the drill string configured to move the drill string in a drilling direction along the longitudinal drill axis and configured to selectively rotate the drill string about the longitudinal drill axis to perform directional drilling; wherein the drive mechanism comprises a first clamping device for clamping the drill string; wherein the drive mechanism further comprises a second clamping device for clamping the drill string; wherein the first clamping device and the second clamping device are each configured to be arranged in a clamping state, in which the drill string is clamped by the respective clamping device, and in a release state, in which the drill string is movable with respect to the respective clamping device, wherein the drive mechanism is configured to move the clamping devices back and forth along the longitudinal drill axis, and wherein the directional drilling device comprises a control device operatively connected to the drive mechanism and the clamping devices for alternating movement of the clamping devices and for switching the clamping devices between the clamping state and the release state to perform directional drilling.

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Background/Summary

FIELD OF THE INVENTION

[0001] The invention relates to a directional drilling device for installing underground cables or tubes, a directional drilling assembly, an attachment for a mini excavator, a mini excavator, and a method for directional drilling in the ground.

BACKGROUND OF THE INVENTION

[0002] Horizontal directional drilling systems are known for making a directional drilling in the ground for installing pipes and pipelines when no trenches are possible or desired. Such systems usually include a drill string having a steerable drill head and a drilling device placed at an entry hole for pushing the drill string into the ground.

[0003] Known systems for horizontal directional drilling (HDD) usually require specialised equipment that is relatively large, heavy, difficult to move and has a limited working speed. As a result, known horizontally steered drilling devices (HDD) are relatively expensive and are often only used for larger pipe diameters and lengths.

[0004] An example can be found in US2020/0392798A1, which discloses a drilling machine having a hybrid thrust/pull back system, which includes a track with two drive mechanisms, a main carriage and a sub-carriage. The first drive mechanism is coupled to the main carriage and the track, and the second drive mechanism is coupled to the main carriage and the sub-carriage. The drilling machine is operable in a state in which the first drive mechanism drives the main carriage along the track, and the second drive mechanism drives the main carriage relative to the sub-carriage.

[0005] For rapid installation of pipes or cables, particularly for smaller diameters or shorter lengths, a more compact, unguided rocket moved by the pressure of a pulsating fluid, such as air, is therefore often used. The rocket is manually positioned horizontally at a desired depth in a starting pit in the ground, travels in a straight line and then, hopefully, emerges at good fortune near a desired exit pit.

[0006] However, it has been found that maps of underground cables and pipelines, when present, are not always accurate and that unguided rockets can deflect due to objects in the ground. This causes deviations from the expected drilling path and quickly causing problems such as damage to existing cables, pipelines, foliage or foundations. In the case of, for example, existing electricity, water or gas lines, this can lead to dangerous or environmentally unwanted situations that should not be avoided by good fortune only.

[0007] It would therefore be beneficial to apply directional drilling in situations where unguided rockets are now commonly used and where existing directional systems would be unapplicable due to their size, weight or slow working and movement speed. Especially when multiple, relatively shorter boreholes are desired, it is desirable to do steered drilling without using a large, heavy and slow existing system.

[0008] U.S. Pat. No. 6,279,667B1 discloses a rotating push rod boring system comprising a push rod rotator and push rod boring rig having a carriage to push a drill string into the ground. The rotator comprises a non-rotating conduit having helical slots and a rotating part having a pin following the slots for inducing rotation while being pushed by hydraulic cylinders. The rotating push movement is transferred to the drill string by a unidirectional slipping grip.
[0009] However, this device, inter alia due to the required placement in the starting pit, is still relatively slow and not suitable for varying soil types.
[0010] In view of the current sustainability and modernization challenges, for example in existing residential areas, such as in areas having older gas-heated houses, it is desirable to provide a relatively large number of houses with a hot water network connection, an updated electricity connection providing higher power and/or a fibre optic connection within a short period of time.

OBJECT OF THE INVENTION

[0011] It is therefore an object of the invention to provide a directional drilling device for installing underground cables or tubes that at least partially overcomes the disadvantages of the prior art, or at least to provide an alternative directional drilling device, such as a directional drilling device suitable for drilling house connections of utility lines, for example a directional drilling device that is relatively compact and/or lightweight and that can be used relatively efficiently, reliably and/or fast.

DESCRIPTION OF THE INVENTION

[0012] According to the present invention, this object is achieved by a directional drilling device according to claim **1**. The directional drilling device may be configured to install underground cables or tubes, such as house connection utility lines.
[0013] The drilling device comprises a housing having a drill space extending between two openings in sides of the housing for accommodating a drill string through the two openings. The drill space defines a longitudinal drill axis. In use, a longitudinal axis of a drill arranged in the drill space would coincide with the longitudinal drill axis.
[0014] A drive mechanism is arranged in the housing for engagement with the drill string and is configured to move the drill string in a drilling direction along the longitudinal drill axis. The drive mechanism is configured to selectively rotate the drill string about the longitudinal drill axis to perform directional drilling. The drilling direction may be determined by a fixed angle of the longitudinal drill axis with respect to the housing, i.e. by rotating the housing, the drilling direction may be determined with respect to the earth, and by rotating the drill string about the longitudinal drill axis.
[0015] The drive mechanism comprises a first clamping device for clamping the drill string. The drive mechanism further comprises a second clamping device for clamping the drill string. The first clamping device and the second clamping device may be arranged at a distance from each other along the longitudinal drill axis.
[0016] The first clamping device and the second clamping device are each configured to be arranged in a clamping state, in which the drill string is clamped by the respective clamping device, and in a release state, in which the drill string is movable with respect to the respective clamping device, for example movable in the drilling direction and in rotation about the longitudinal drill axis. The drive mechanism is configured to move the clamping devices back and forth along the longitudinal drill axis.
[0017] The directional drilling device comprises a control device operatively connected to the drive mechanism and the clamping devices for alternating movement of the clamping devices and for switching the clamping devices between the clamping state and the release state.
[0018] The directional drilling device may offer multiple benefits:
[0019] First of all, drilling may be performed relatively fast as the drilling device comprises two clamping devices that are moved alternatingly. For example, drilling may be performed by the first clamping device the drilling direction in the clamping state, while moving the second clamping

device against the drilling direction in the release state. Subsequently, the second clamping device may be moved in the drilling direction in the clamped state, and the first clamping device may be moved against the drilling direction in the release state. This way, a relatively continuous movement of the drill string may be obtained.
[0020] Furthermore, the operation mode of the clamping devices may be varied to provide flexibility, as will be explained herein. Also, owing to the selective rotation of the drill string about the longitudinal drill axis, the longitudinal movement of the drill string along the longitudinal drill axis may be controlled independently of the rotation movement.
[0021] Secondly, the clamping devices and two openings allow the drilling device to be relatively compact. In particular, as the drill string is clamped by the clamping devices, the drill string may protrude through the two openings in the housing, such that the housing may be shorter than a single drill string section. Therewith, weight of the device may be saved.
[0022] In particular, the drill string may be made relatively long beforehand, such that during drilling, relatively little or no time is required for elongating the drill string, as in the prior art. This way, drilling may be performed substantially continuously and will thus be very fast. In contrast with prior art, the length of a single drill string segment may be longer than the length of the drilling device. The drill string having one or multiple drill string segments may for example have the full expected length of the borehole to be drilled in the ground prior to drilling, such that the borehole may be drilled in one go.
[0023] Thirdly, as the longitudinal drill axis is defined by the openings in sides of the housing, the drilling direction may be adjusted by turning the housing and/or selecting a position of the openings.
[0024] As such, the drilling device may be made suitable for usage on smaller locations, such as sidewalks or front yards with relatively little nuisance compared to known directional drilling devices and other techniques, such as digging trenches in gardens and streets. In contrast with the prior art, the drilling device may now advantageously be sufficiently small to be transported in within a minivan or on a relatively small trailer.
[0025] Due to the relatively small size, relatively high speed and relatively low weight, the drilling device may be used in applications and on locations unseen in the prior art as it combines speed with directional drilling. By having the drive mechanism, the physical effort required from operators operating the drilling device is relatively low.
[0026] The directional drilling device is capable of drilling or boring non-vertical bores, that is, bores that are not entirely vertical, for example bores that are substantially horizontal. The directional drilling device is suitable for installing underground cables or tubes, for example from a starting pit. Such a pit is a location where utility lines, such as cables or tubes, are planned to enter or exit the borehole in the soil, and may e.g. be dug before drilling. However, drilling may potentially also be performed from the soil surface without prior digging. The directional drilling device may for example be configured to perform directional drilling after being positioned near a pit or soil surface without requiring further preparations to the pit or soil surface. The directional drilling device may be configured to perform directional drilling without being supported by the pit or soil surface in the pit.
[0027] In contrast with injecting a string in a pre-drilled bore, the directional drilling device is capable of directional drilling in the soil to create the bore by pushing and/or rotating the drill string.
[0028] The openings may be arranged on opposing sides of the housing. The openings may be arranged in sides that are parallel to each other, such that the drill space determines a straight longitudinal drill axis that determines the drilling direction. Alternatively, the openings may be arranged in sides that are at an angle with respect to each other, for example in a top side and front side of the housing. This way, the drill space may be curved. The longitudinal drill axis be curved when the drill string is arranged in the drill space. The drill string may extend from the drill space

at an angle with respect to the housing when advanced along the drill axis, such that the drilling direction is at an angle with respect to the housing.
[0029] Guide elements may be provided in the drill space and/or in the openings for guiding the drill string through the openings. The position of the guide elements and/or of the openings may be adjustable to adjust the longitudinal drill axis.
[0030] The housing may comprise support elements configured to provide support to the housing during drilling. The support unit may comprise outriggers or stabilizers configured to support the housing against the earth surface. The outriggers or stabilizers may be telescopic. Additionally or alternatively, the support elements may comprise other means to temporarily fix the housing to the earth. For example, the support elements be provided with openings through which stabilisation pins may be inserted into the earth. By having support elements, the housing may be held stationary during drilling with relatively little or no effort.
[0031] The clamping devices comprising the first clamping device and the second clamping device may have any desirable shape. Each clamping device may for example be shaped from pivotally connected segments, such as two segments. The segments may be partially circular. A segment shape that corresponds to an outer contour of the drill string may be advantageous to obtain a relatively large contact area and relatively high clamping force.
[0032] The clamping devices may be configured to, in the clamping state, at the position of the respective clamping device, surround the drill string circumferentially. This way, a relatively large contact surface between the drill string and the clamping device may be obtained compared to a width of the clamping device in direction of the longitudinal drill axis, which may be advantageous as a large width may limit the back-and-forth movement of the clamping devices.
[0033] The clamping devices may be configured to, in the clamping state, have a circular inner shape that corresponds to an outer shape of the drill string. Alternatively, the clamping devices may be provided with an inner shape, for example non-circular, which is different from the drill string. Therewith, the drill string may locally be elastically deformed to comply with the inner shape of the clamping device. Deformation of the drill string towards a non-circular shape may contribute to a high clamping force, as it allows, on the one hand, a higher torque to be transmitted from the clamping device to the drill string. On the other hand, a normal force increases as a result of elastic forces of the drill string material. The inner shape may for example be oval. At least one clamping device may be, partially or completely, have an inner shape that differs from the drill string, e.g., the shape of at least one of the clamping devices may be such that an inner clamping contour is at least partially flat, oval, polygonal, provided with indents and/or other contours.
[0034] The clamping devices may be shaped to, in the release state, have an inner diameter that is larger than an outer diameter of the drill string, for example larger than or equal to a minimum diameter of the openings.
[0035] The clamping devices may be shaped to, in the clamping state, have an inner diameter that is smaller than or equal to an outer diameter of the drill string, for example smaller than or equal to the smallest diameter of the openings.
[0036] The clamping devices may comprise at least two segments that are each connected to a pivot and an actuator. In an embodiment, the at least two segments are connected to the same actuator. This way, an efficient clamping device may be obtained that is controllable by a single actuator. The actuator may for example be a hydraulic, pneumatic or electric piston or gear mechanism.
[0037] The actuator may be operatively connected to the control device and the control device may be configured to control a clamping force exerted by the actuator. This way, the clamping force may be adjusted to ground type and drill string type.
[0038] The directional drilling device may comprise a rotation sensor configured to provide a rotation signal representative for a rotational position of the drill string. The rotation sensor may be arranged in the housing and may for example measure rotation of the drill string or of the clamping

devices, e.g. optically or magnetically. The control device may be configured receive operator input regarding desired drilling direction.
[0039] The control device may be configured to move the clamping devices on the basis of the rotation signal and/or the received operator input.
[0040] The control device may be any control device, such as a hydraulic, pneumatic or electric control device. The control device may comprise a computer or remote control for inputting operator input.
[0041] The clamping devices may be configured to rotate the drill string continuously in the clamped state. For example, the drive mechanism may comprise a rotational motor and the clamping devices may be rotatable by means of the rotatable motor.
[0042] The control device may be configured to control the rotational motor to rotate the clamping devices continuously during drilling.
[0043] The control device may be configured to switch the clamping devices between the clamping state and the release state within 2 seconds, for example within 0.5 second.
[0044] In an embodiment, the directional drilling device comprises a support configured to support the housing, wherein the support positioned with respect to the drill space such that, when the housing is supported by the support, a drill string arranged in the drill space points towards the earth surface at an angle (α) of −45° to 45°, such as −30° to 30° with respect to the horizontal. The support may be formed by the support elements, a mounting bracket for attaching the directional drilling device to a tool, e.g. an excavator, or another type of support.
[0045] The drill space may be shaped such that a drill string exists the drill space perpendicular to an exit opening of the two openings, and the exit opening faces the earth surface at an angle of −45° to 45°, such as −30° to 30° with respect to the horizontal.
[0046] Alternatively, the drill space may be shaped such that the drill string exits the drill space at a non-perpendicular angle, wherein the drill space is shaped such that the drill string is bend in a curve upon leaving the drill space, causing the drill string to point towards the earth surface at an angle of −45° to 45°, such as −30° to 30° with respect to the horizontal. The drill space may for example be curved.
[0047] In an embodiment, the control device is configured to alternatingly move the first clamping device and the second clamping device in the drilling direction in the clamping state.
[0048] This way, the first clamping device is moved in the clamping state in the drilling direction to advance the drill string, for example from an initial position to a final position. Then, the first clamping device is moved in the release state back to the initial position and the second clamping device is moved in the clamping state in the drilling direction to further advance the drill string. As such, directional drilling may be performed relatively fast.
[0049] The first clamping device and the second clamping device may be moved at similar or different speeds. The second clamping device may be arranged in the clamping state before arranging the first clamping device in the release state, and vice versa. This way, the chances of movement of the drill string when the clamping device are simultaneously in the release state may be further reduced.
[0050] In an embodiment, the control device is configured to selectively move the first clamping device and the second clamping simultaneously in the drilling direction in the clamping state. By moving the clamping device simultaneously, longitudinal movement of each of the clamps contributes to advancing the drill string, such that a force exerted on the drill string may be relatively large.
[0051] The control device may for example be provided with multiple operation mode, such as a first mode in which the first clamping device and the second clamping device are moved alternatingly, a second mode in which the first clamping device and the second clamping device are moved simultaneously, and/or a third mode in which one of the clamping devices is not moved along the longitudinal drill axis only switches between the clamping and release state. By having

multiple operation modes, the drilling device may be adapted to the environment to provide additional speed, longitudinal force, or energy efficiency, respectively.
[0052] The operation mode may be selectable by an operator, for example via a remote control.
[0053] A longitudinal pressure exerted on the clamping device in direction of the longitudinal drill axis may be adjustable. The control device may be configured to receive a desired pressure from an operator, for example via a remote control, or be configured to control the longitudinal pressure automatically depending on process parameters.
[0054] This way, the longitudinal pressure may be adapted to working conditions, such as process parameters and soil conditions. For example, for pulling a pipe, cable or reamer backwards in the negative drilling direction, a different pressure may be required than is required for drilling in the drilling direction.
[0055] In an embodiment, a rotation speed with which the drive mechanism rotates the drill string about the longitudinal drill axis is adjustable. By increasing or decreasing the rotation speed, drilling may be adapted to working conditions. For example, a higher rotation speed may lead to faster removal of relatively dense material. The control device may be configured to receive a desired rotation speed from an operator, for example via a remote control, or be configured to control the rotation speed automatically depending on process parameters.
[0056] The drive mechanism may for example comprise a motor operatively connected to the control device, such as an electric motor or a hydraulic motor having a variable rotation speed.
[0057] The rotation speed and/or the longitudinal pressure may be adjustable in discrete steps or in a continuous range.
[0058] In an embodiment, wherein the drive mechanism comprises a rotational motor, the rotational motor is configured to rotate the first clamping device in the clamped state about the drill axis while simultaneously rotating the second clamping device and vice versa.
[0059] By simultaneously rotating the clamping devices, a relatively compact and durable mechanism may be provided. Further, a fixed rotational difference between the clamping device may be adapted, for example 90°, such that different sides of the drilling string are clamped during drilling. This way, wear or deformation of the drill string may be reduced. As such, both clamping devices are rotatable in their respective clamped state by the rotational motor and both clamping devices are rotatable in the same direction.
[0060] In an embodiment, wherein the drive mechanism comprises a rotational motor, the rotational motor is configured to rotate the first clamping device in the clamped state about the drill axis without rotating the second clamping device and vice versa. As such, both clamping devices are rotatable in their respective clamped state by the rotational motor. Preferably, the clamping devices are rotatable in the same direction to continue directional horizontal drilling in the drilling direction after switching the first clamping device from the clamping state to the release state and the second clamping device from the release state to the clamping state, and vice versa.
[0061] Instead of a single rotational motor, multiple rotational motors may be provided that are each connected to one of the clamping devices. However, by having a single rotational motor, the drilling device may be more compact.
[0062] In an embodiment, the drive mechanism comprises a longitudinal actuator attached to the clamping devices and configured to move the clamping devices along the longitudinal drill axis, wherein the rotational motor is configured to rotate the longitudinal actuator with the clamping devices. In the past, stationary longitudinal actuators have been used to achieve a relatively simple construction. It has however been found that having longitudinal actuators attached to the clamping devices and rotating therewith allows to omit relatively complex couplings between rotating and non-rotating parts of the drilling device further contributes to the compactness of the drilling device.
[0063] Multiple longitudinal actuators may be provided. For example, the longitudinal actuators may be attached to each other to form a rotatable subframe that is rotatable about the longitudinal

drill axis. The rotatable subframe may be supported by bearings, such as ball bearings. The bearings may provide the only support for the subframe. The bearings may be provided on outer ends of the sub frame along the longitudinal drill axis in the housing to provide advantageous stability and reduce complexity of the subframe.
[0064] In an embodiment, the longitudinal actuator comprises a pin, a track or a rod extending parallel to the drill axis and arranged to rotate about the longitudinal drill axis with the clamping devices, wherein the clamping devices are movably attached to the pins, tracks or rods.
[0065] The rods may for example each be a piston rod of a hydraulic, pneumatic or electric cylinder. Each piston rod may be provided with a cylinder attached to a clamping device. The cylinder may be configured to move a clamping device parallel to the longitudinal drill axis. The piston rod may be a continuous rod that protrudes from two sides of the cylinder. A cylinder may be advantageous as it may be kept in a stationary position relatively simple, for example by closing a valve, in the event of a structural or power failure.
[0066] Additionally or alternatively, the rod may be part of a linear drive that is configured to move a clamping device parallel to the longitudinal drill axis.
[0067] The outer ends of the pins, tracks or rods, for example both outer ends of the continuous piston rod, may be connected to each other to form a rotatable subframe. The piston rods may be connected by a connection piece provided with a drill space opening.
[0068] A separate pin or rod may be provided for each clamping device, or multiple clamping devices may be moved by a single pin or rod.
[0069] In an embodiment, each clamping device is provided with a set of pins, tracks or rods that are circumferentially spaced around the drill axis. This way, forces may be distributed evenly. The set of longitudinal actuators may be evenly spaced around the longitudinal drill axis, for example two opposing each other or three arranged at 120° with respect to each other.
[0070] Each clamping device may be provided with throughgoing openings to provide space for longitudinal actuators, such as piston rods, which are connected to other clamping devices.
[0071] This way, the pins, tracks or rods of different clamping devices may be arranged between each other, for example evenly spaced around the longitudinal drill axis.
[0072] The longitudinal actuator may be configured to provide a force of at least 1000N, for example 2500 N for each clamping device.
[0073] In an embodiment, the drilling device further comprises a bearing configured to align the drill string with the drill axis, wherein the bearing is provided with fluid channels for distributing fluid to the drive mechanism, wherein the fluid channels comprise a stationary port and a rotating port that is rotating with the drill string.
[0074] This way, actuation fluid, such as oil, for actuating the clamping devices and/or the longitudinal actuator may be provided relatively easily from a single bearing. The bearing may be provided with a separate stationary port and a rotating port for each clamping device.
[0075] The invention provides a horizontal drilling assembly, comprising a directional drilling device according to any of the embodiments disclosed herein, and a drill string to be accommodated in the drill space of the directional drilling device, wherein a length of the drill string is larger than a length of the drill space.
[0076] The drill string may comprise a head. A length of the drill string without head may be larger than a length of the drill space.
[0077] The drill string may comprise multiple segments interconnected by couplings. A length of a drill string segment may be larger than the length of the drill space. The couplings may comprise screw threads, shape lock couplings or other types of couplings.
[0078] The drill string may have a cylindrical shape. The head may be asymmetric, such that when the drill string is rotated and moved along the longitudinal drill axis, the drill head moves forward along a relatively straight line, but when the drill string is moved along the longitudinal drill axis without rotation, the drill head moves in a drilling direction determined by the asymmetry of the

head. This way, directional drilling may be performed.
[0079] The drill string may comprise a relatively elastic material, such as a plastic or composite. The elasticity may allow the drill string to have a relatively small bend radius, for example a bend radius of less than 10 meter, such as less than 5 meter, for example a bend radius of approximately 1 or 2 meter. This way, relatively precise directional drilling may be performed. Also, elasticity may allow the drill string to bend past unexpected obstacles in the ground and/or further reduces the chances of damaging structures in the ground.
[0080] The drill string may comprise a metal, such as aluminium or steel. Metal may provide additional strength to allow for relatively high drilling forces and reduce wear. The drill string may comprise metal reinforcements that are attached to another drill string material.
[0081] The drill string may comprise multiple drill string segments that are releasably couplable to each other. The drill string segments may be couplable via coupling pieces, such as screw threads or bayonet couplings. The drill string segments may have length of, for example, 1.5 meter.
[0082] The drill string may have a length larger than a length of the drilling device. This way, a very high working speed may be possible as it is no longer required to frequently couple a new drill string segment. The use of a relatively long drill string in combination with not having to place the drilling device in a starting pit that would limit the drill length contributes to the advantageous speed of the drilling device.
[0083] In particular, in contrast with the prior art, a drill string segment may have a length larger than a length of the drilling device.
[0084] The drilling device may have a length smaller than 2.5 meter, for example less than 1.5 meter. The drill string may have a length larger than 2.5 meter, for example 6 meter.
[0085] A diameter of the drill string may be smaller than 15 cm, such as smaller than 10 cm, for example 2-5 cm.
[0086] The drill string may comprise a drill fluid channel extending from the drill head towards a fluid inlet port to provide drilling fluid at the drill head. The fluid inlet port may be provided at a rear end of the drill string. The fluid inlet port may be connected to a drilling fluid source, for example a water or bentonite source.
[0087] The drilling fluid pressure at the drill head may be adjustable. For example, the control device may be configured to adjust a valve or pump fluidly connected to the drilling fluid source.
[0088] In an embodiment, each clamping device delimits an inner clamping diameter, wherein, in the clamping state, the inner clamping diameter is smaller than a diameter of drill string, such that the drill string is locally deformed to improve gripping between clamping device and the drill string. It has been found that elastic deformation of the drill string may contribute to a high clamping force.
[0089] The clamping devices may be shaped differently from the drill string, such that the drill string is deformed to another shape. At least one clamping device may be, partially or completely, have an inner shape that differs from the drill string, e.g., the shape of at least one of the clamping devices may be such that, in the clamping state, an inner clamping contour is at least partially flat, oval, polygonal, provided with indents and/or other contours. In case of a drill string having a substantially circular cross section, the drill string may, in the clamping state of the respective clamping device, be deformed to a non-circular shape.
[0090] In an embodiment, the directional drilling device comprises an interface, such as a display, wherein the drill string comprises a fluid channel a tracking device configured to emit a tracking signal, wherein the interface is configured to receive the tracking signal and to display position data representative for a position of the tracking device on the basis of the tracking signal, wherein the tracking device is provided in a tracking device compartment in the drill string, separate from the fluid channel.
[0091] The interface may be used as the remote control.
[0092] The tracking device may emit a signal, such as a magnetic signal, which is detected by a

monitoring device on the earth surface, or vice versa. The tracking device may comprise sensors, such as an accelerometer, magnetometer, gyroscope. The interface may be configured to display an estimated position of the drill string based on position data comprising, for example, actual drill head angles, input from the operator or control device, and/or an initial position of the drill string.
[0093] The interface may be a screen, display, a phone or a computer, or be a software interface provided on an external device, for example be a cloud interface.
[0094] The control device may be configured to control the clamping devices on the basis of the tracking signal. This way, the drilling may be performed automatically.
[0095] In an embodiment, the horizontal drilling device comprises an extension piece associated with the housing and configured to be arranged in a guiding position to guide a portion of the drill string that protrudes outside the housing through one of the two openings, to avoid bending of the drill string portion away from the longitudinal axis.
[0096] In certain circumstances, the drill string may bend away from the longitudinal drill axis between a ground entry point and the housing, for example when a relatively elastic drill string is used and/or when the drill string encounters a relatively hard soil.
[0097] By having two clamping devices, the directional drilling device supports the drill string within the housing at least at two support points during drilling, which reduces bending of the drill string compared to having a single clamping device. By having the extension piece, the drill string may be supported between the housing and the soil such that bending of the drill string is advantageously further reduced.
[0098] The extension piece is arrangeable in an guiding position to guide the drill string portion to avoid bending of the drill string away from the longitudinal axis.
[0099] The extension piece may be detachable from the housing to guide the drill string portion in a mounted, guiding position of the extension piece. Additionally or alternatively, the extension piece may be movable between an guiding position, in which the extension piece is configured to guide the drill string portion, and a storage position. The extension piece
[0100] The extension piece may comprise a mounting element for mounting the extension piece to the housing and a guiding element for guiding the drill string portion. The guiding element may be configured to, in the guiding position, support the drill string along the longitudinal axis. The guiding element may comprise an inlet opening and an outlet opening. For example, the guiding element may comprise a hollow shape, e.g. be tubular. The extension piece may comprise a mounting element arranged such that, upon mounting, the inlet opening of the extension piece faces the opening of the housing for accommodating a drill string through the respective opening of the housing and the inlet opening.
[0101] The housing may comprise a second mounting element configured to cooperate with the mounting elements to attach the extension piece to the housing. The mounting element and second mounting element may for example comprise a pin-hole, bolted or latched connection.
[0102] The second mounting element may be formed by at least one of the support elements of the housing. In particular, the support element and the mounting element may each be provided with openings trough which the support element and the second mounting element can be connected. The openings of the second mounting element and the support element may be shaped such that stabilisation pins can be inserted therethrough into the earth. Therewith, the housing and the extension piece may attached to each other and fixed to the earth using a single action, e.g. insertion the stabilisation pins.
[0103] The extension piece may also be beneficial and provide advantages in directional drilling devices not according to the invention.
[0104] According to another aspect, the invention provides an attachment for an excavator, such as a mini excavator, comprising a directional drilling device according to any of the embodiments disclosed herein, or a horizontal drilling assembly according to any of the embodiments disclosed herein, and an excavator mount for attaching the directional drilling device to the excavator.

[0105] Several advantages may be obtained with the attachment, as explained for the directional drilling device hereinabove. By using the directional drilling device as an attachment, the excavator may be used for multiple purposes, the directional drilling device may be supported by the excavator during drilling and/or power may be provided by the excavator during drilling.
[0106] The excavator mount may comprise a mounting bracket for mounting the drilling device to the mini excavator, such as a quick-release mounting bracket.
[0107] The mounting bracket may be rotatable around a substantially vertical axis, such that a horizontal orientation of the longitudinal drill axis with respect to the excavator may be adapted.
[0108] The mounting bracket may be rotatable around a substantially horizontal axis, such that the vertical orientation of the longitudinal drill axis with respect to the excavator may be adapted.
[0109] The excavator may provide support to the housing during drilling. The mounting bracket may function as support elements configured to provide support to the housing during drilling. In particular, the excavator may be relatively heavy such that the housing, by being attached to the excavator is fixed with respect to the earth.
[0110] When attached to the excavator, the attachment may be supported by the excavator, such that the weight of the attachment is carried by the excavator, instead of, e.g. by the soil directly underneath the attachment. As such, less or no load may be carried by the soil in the starting put, which may be beneficial as soil in the starting pit may be weakened due to drilling activities, e.g. due to drilling fluid.
[0111] The attachment may be configured to be transportable in a mini van or on a conventional two-axle trailer, i.e. be dimensioned to fit therein.
[0112] The invention provides an excavator, comprising the attachment according to any of the embodiments disclosed herein, wherein the attachment is provided with a power connection, to the power system, of the mini excavator for powering the drive mechanism. The power system may be an electrical, pneumatic, hydraulic or another system capable of providing power to the directional drilling device. For example, the attachment is provided with a fluid connection to the fluid system of the mini excavator for powering the drive mechanism hydraulically. The excavator may advantageously be a relatively small excavator having a weight less than 6000 kg, for example less than 3000 kg, such as 1000-2000 kg. The excavator may be a mini excavator.
[0113] The excavator may provide power, e.g. electricity and/or hydraulic pressure, and may therewith function as power source. Additionally or alternatively, the excavator may provide support to the directional drilling device. Further, by having a directional drilling device as attachment for an excavator, only the attachment may be required in addition to an excavator, which is usually already present at cable laying sites. Therewith, no additional separate power source or support device for the horizontal drilling may be necessary for conducting both digging and drilling operations.
[0114] However, the directional drilling device may additionally or alternatively be operable stand-alone or on another tool. For example, a stand may be provided that is configured to provide support to the housing during drilling.
[0115] The invention also relates to the use of the drilling device, the attachment or the excavator for directional drilling in the ground.
[0116] The invention provides a method for horizontal directional drilling, comprising the steps of providing a drill string in a directional drilling device, wherein a length of the drill string, for example a length of the drill string without its drill head, is larger than a length of the directional drilling device; [0117] positioning the device such that the drill string enters the earth surface at a desired angle, for example at an angle of −45° to 45°, such as −30° to 30°, with respect to the horizontal; [0118] clamping the drill string with a first clamping device and moving the first clamping device parallel to a longitudinal drill axis away from an initial position to advance the drill string into the earth; [0119] releasing the first clamping device and clamping the drill string with a second clamping device and moving the second clamp parallel to the drill axis to further

advance the drill string into the earth; [0120] while advancing the drill string, with the first and/or second clamping device, rotating the drill string about the drill axis to advance the drill string along a straight path, and holding the drill string in a fixed rotational position to advance the drill string in a path curved corresponding to the fixed rotational position; and [0121] while advancing the drill string with the second clamp, moving the first clamp back to the initial position, e.g. for continuous drilling, or moving the first clamp together with the second clamp in the clamping state, e.g. for drilling using higher force.

[0122] The drill string may comprise multiple drill string segments. The length of a drill string segment may be larger than the length of the directional drilling device. The drilled passage may have a diameter less than 15 cm, such as less than 10 cm, for example 2-5 cm.

[0123] In an embodiment, the method further comprises the steps of, upon drilling, attaching a reamer and/or a utility line, such as a pipe or a cable, to the drill string, and subsequently retracting the drill string by clamping the drill string while moving the clamping devices in reverse direction. The utility line may be coupled to the drill head and/or to the reamer via a rotatable coupling.

[0124] According to the invention, relatively high clamping forces may be obtained, while the drill string may be moved at a relatively high speed. In the prior art, the clamping forces were limited, such that usually one or more separate reaming steps are required before the utility line can be drawn through the soil. As a result of the relatively high clamping forces that can be obtained according to the invention, a reamer and a utility line may be attached to the drill string upon drilling, and reaming and pulling of the drill string through the drilled canal may be performed during a single reverse movement of the drill string up to a relatively high diameter, for example for drawing a utility line, such as a cable or pipeline, potentially up to 20 mm in diameter, in particular up to 10 mm in diameter.

[0125] In an embodiment, the method further comprises the steps of, before drilling, digging a starting pit and/or an exit pit with a tool, such as a mini excavator; [0126] optionally, removing a digging device, such as an excavator bucket, from the tool; attaching a directional drilling device to the tool; [0127] and performing the steps of advancing the drill string with the directional drilling device from the starting pit and/or towards the exit pit. The steps of advancing the drill string are performed using the directional drilling device attached to the tool. As such, both digging pits, such as starting and exit pits, and the drilling itself may be performed using a single tool. In particular, only one tool, such as a mini excavator, may now be necessary to perform the steps of digging pits and drilling. The mini excavator may function as power source and provide support to the directional drilling device.

[0128] The use and the method may for example be performed in sand, peat or clay soils, such as common in the Netherlands.

[0129] The use and the method may provide advantages similarly as explained herein for the drilling device, the attachment and the excavator. Especially for connecting houses to utility lines in existing neighbourhoods, the invention may provide a combination of speed, safety and precision unseen in the prior art and can therefore significantly contribute to connecting homes to faster internet and sustainable heating sources.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0130] Further characteristics of the invention will be explained below, with reference to embodiments, which are displayed in the appended drawings, in which:

[0131] FIG. **1** schematically depicts a top view of an attachment for an excavator according to an embodiment of the present invention;

[0132] FIG. **2** schematically depicts a side view of a cross section along line A-A of the attachment

of FIG. **1**;
[0133] FIG. **3**A schematically depicts an enlarged side view of the clamping devices and the longitudinal actuator of the embodiment of FIG. **2**, wherein the clamping devices are in an initial position according to a first mode of operation;
[0134] FIG. **3**B schematically depicts an enlarged side view according to FIG. **3**A, wherein the camping devices are moved along the longitudinal axis towards a second position according to a first mode of operation;
[0135] FIG. **4**A schematically depicts an enlarged side view of the clamping devices and the longitudinal actuator of the embodiment of FIG. **2**, wherein the clamping devices are in an initial position according to a second mode of operation;
[0136] FIG. **4**B schematically depicts an enlarged side view according to FIG. **4**A, wherein the camping devices are moved along the longitudinal axis towards a second position according to a second mode of operation;
[0137] FIG. **5**A schematically depicts a clamping device with attached cylinders and pistons according to an embodiment of the invention;
[0138] FIG. **5**B schematically depicts a rear view of the clamping device of FIG. **5**A;
[0139] FIG. **5**C schematically depicts a front view of the clamping device of FIG. **5**A;
[0140] FIG. **6**A schematically depicts an embodiment of a directional drilling device provided with an extension piece; and
[0141] FIG. **6**B schematically depicts the step of advancing the drill string from a starting pit with the directional drilling device according to the embodiment of FIG. **6**A.
[0142] Throughout the figures, the same reference numerals are used to refer to corresponding components or to components that have a corresponding function.

DETAILED DESCRIPTION OF EMBODIMENTS

[0143] FIG. **1** schematically depicts a top view of an attachment **10** for an excavator comprising a drilling device **1**, having a housing **2** with a drill space **20** extending between two openings **21**, **22** in sides of the housing for accommodating a drill string **90** through the two openings **21**, **22** arranged on opposing sides of the housing **2** that are parallel to each other. The drill space **20** defines a longitudinal drill axis A of the drill string **90**. Bearings **6**, **6**′ are provided next to the openings **21**, **22** and guide the drill string **90**. Support elements **24** provided with openings **23** are provided to provide support to the housing during when deemed necessary, either by pushing the support element **24** towards the earth surface, or by inserting stabilisation pins through the openings **23** into the earth to temporarily fix the housing **2** to the earth.
[0144] A drive mechanism **3** is arranged in the housing for engagement with the drill string **90** and is configured to move the drill string in a drilling direction d along the longitudinal drill axis A. Due to the arrangement of openings **21**, **22** in a straight line, the longitudinal axis A enters the housing **2** perpendicularly to the drilling device **2**, such that the initial drilling direction of the drill string is perpendicular to the housing **2**.
[0145] The drive mechanism comprises a first clamping device **31** and a second clamping device **32** for clamping the drill string **90**, which are arranged at a distance from each other along the longitudinal drill axis A.
[0146] The first clamping device **31** and the second clamping device **32** are each configured to be arranged in a clamping state, as shown in FIGS. **5**B and **5**C, in which the drill string **90** is clamped by the respective clamping device, and in a release state, in which the drill string **90** is movable with respect to the respective clamping device in the drilling direction d and in rotation about the longitudinal drill axis A. The drive mechanism **3** is configured to selectively rotate the drill string about the longitudinal drill axis A to perform directional drilling by moving the clamping devices **31**, **32** back in negative drilling direction and forth in drilling direction d along the longitudinal drill axis A.
[0147] The clamping devices **31**, **32** are shaped similar to FIGS. **5**B and **5**C and comprise two

partially circular segments **56** that are pivotally connected via a pivot hinge **57** and, in the clamping state, have a circular inner shape that corresponds to an outer contour of the circular drill string **90** to, in the clamping state, surround the drill string **90** circumferentially. In the clamping state, the inner diameter D**1** of the clamping devices D**1** is smaller than or equal to an outer diameter of the drill string **90**.

[0148] The inner clamping shape in this embodiment is circular, but the inner shape of the clamping devices may alternatively differ from the outer shape of the drill string, such that the drill string is deformed into another, e.g. non-circular shape, such as a slightly oval shape.

[0149] The clamping devices **31**, **32**, are provided with an actuator **58**, in this embodiment a hydraulic cylinder with a piston, which is pivotally connected to both segments **56** via hinges **57**′. In the release state, the piston extends from the cylinder such that the hinges **57**′ are pushed away from each other. In the release state, the clamping devices **31**, **32** have an inner diameter D**1** that is larger than an outer diameter of the drill string **90**, and larger than or equal to the smallest diameter of the openings **21**, **22**.

[0150] The clamping devices may be provided with a friction surface **59** for increasing clamping force, for example a structured surface or padding of a high-friction material.

[0151] The directional drilling device comprises a control device **4** operatively connected to the drive mechanism **3** and the actuator **58** of the clamping devices **31**, **32** via hydraulic connectors **43**, **44**, bearing **6** via hydraulic lines (not shown). The control device **4** may additionally or alternatively be connected via electric lines **42**, for example to sensor **45**. The control device comprises a computer and hydraulic regulation means in this embodiment. The remote control **7** is a touch interface configured to receive inputted operator input and functions as a remote control by wirelessly communicating with the control device, for example via a wireless internet connection.

[0152] The control device **4** is configured to control a clamping force exerted by the actuator by regulating hydraulic fluid flow via a valve or pump. The directional drilling device **1** comprises a rotation sensor **45**, which is an optical sensor in this embodiment. The rotation sensor **45** is arranged in the housing **2** and is configured to provide a rotation signal representative for a rotational position of the drill string **90**.

[0153] The control device **4** is configured to wirelessly communicate with the remote control **7** and to receive operator input regarding desired drilling direction. The control device **4** is configured to move the clamping devices **31**, **32** on the basis of the rotation signal and/or the received operator input. The control device **34** is configured to switch the clamping devices between the clamping state and the release state within 2 seconds, for example within 0.5 second.

[0154] The control device **4** is configured to operate in multiple operation modes and receives a desired operation mode from the remote control **7**. A first mode of operation is depicted in FIGS. **3**A-**3**B, and a second mode of operation is depicted in FIG. **4**A-**4**B.

[0155] In the first mode, the first clamping device **31** and the second clamping device **32** are moved alternatingly in the drilling direction in the clamping state by the controller. The first clamping device **31** is moved in the clamping state in the drilling direction d to advance the drill string **90**, from an initial position of the first clamping device **31** as depicted in FIG. **3**A to a final position of the first clamping device **31** as depicted in FIG. **3**B. At the same time, the second clamping device **32** is moved in the release state from the position of FIG. **3**A to the position of FIG. **3**B to achieve the positions as depicted in FIG. **3**B.

[0156] Then, the first clamping device **31** is moved in the release state back to the initial position of FIG. **3**A and the second clamping device **32** is moved in the clamping state in the drilling direction d to further advance the drill string **90** to achieve the positions as depicted in FIG. **3**A. This alternating movement may be repeated until the drill string **90** is advanced sufficiently, from example when the drill head **91** reaches an exit location and protrudes out of the earth.

[0157] In the second mode, the control device **4** positions the clamping devices **31**, **32** in the positions of FIG. **4**A and simultaneously switches the clamping devices **31**, **32** into the clamping

state. Then, the first clamping device **31** and the second clamping device **32** are moved simultaneously in the drilling direction d to arrive at the positions of FIG. **4**B.

[0158] In this mode, the control device **4** selectively moves the clamping devices simultaneously in the drilling direction D in the clamping state.

[0159] Both clamping devices may then be switched simultaneously into the release state and moved back to the position of FIG. **4**A such that this movement may be repeated. If simultaneous movement of the clamping devices **31**, **32** in the release state would lead to unexpected movement of the drill string **90**, one of the clamping devices **31**, **32**, may be moved from the position of FIG. **4**B into the release state to the position of FIG. **4**A first, be arranged in the clamping state to clamp the drill string **90**, after which another one of the clamping devices is subsequently moved back to the position of FIG. **4**A.

[0160] The second mode of operation is slower than the first mode of operation but provides additional force in direction of the longitudinal drill axis, for example in dense soil. A third operation mode in which one of the clamping devices is not moved along the longitudinal drill axis only switches between the clamping and release state may also be provided.

[0161] The drive mechanism **3** comprises a motor **33** operatively connected to the control device **4**, such as an electric motor or a hydraulic motor. The rotation speed and/or the longitudinal pressure are adjustable a continuous range by varying voltage or hydraulic fluid flow with the controller **4**. The rotational motor **33** is configured to rotate the first clamping device **31** in the clamped state about the longitudinal drill axis A while simultaneously rotating the second clamping device **32** and vice versa.

[0162] The drive mechanism **3** comprises a longitudinal actuator **5** attached to the clamping devices **31**, **32** and configured to move the clamping devices along the longitudinal drill axis A. The rotational motor **33** is configured to rotate the longitudinal actuator **5** with the clamping devices **31**, **32** via a chain **35** or belt attached to rotor **34** of the motor **33**.

[0163] The longitudinal actuators **5** are attached to each other by circular plates **36** to form a rotatable subframe that is rotatable about the longitudinal drill axis A and that is supported by ball bearings **6**, **6′** on the outer ends of the rotatable subframe that form the only support for the subframe. One of the circular plates **36** is provided with a chain wheel **36′** for rotation via chain **35**. Between the circular plates **36**, reinforcement beams **37** that extend parallel to the longitudinal drill axis are provided for extra rigidity of the rotatable subframe.

[0164] Each longitudinal actuator **5** comprises a hydraulic cylinder **52** attached to the respective clamping device **31**, **32**, with a continuous piston rod **51** that protrudes from two sides of the cylinder **52** and extends parallel to the longitudinal drill axis A and arranged to rotate about the longitudinal drill axis A with the clamping devices **31**, **32**. The clamping devices are movably attached to the piston rods **51** as the cylinder **52** is movable on the piston rods **51** and is fixed to the clamping device by a mounting plate **54**. The cylinder **52** is configured to move the respective clamping device **31**, **32** parallel to the longitudinal drill axis.

[0165] The outer ends of the continuous piston rods **51** are be connected to each other on both outer ends **53** by a connection piece, e.g. plate **36** provided with a drill space opening, to form a rotatable subframe.

[0166] Each clamping device **31**, **32** is provided with a set of two cylinders **52** with piston rods **51** that are evenly spaced at opposing sides of the axis A, i.e. at 180° with respect to each other. The mounting plate **54** of each clamping device is provided with throughgoing openings **55** to provide space for longitudinal actuators **52′**, such as piston rods, which are connected to other clamping devices. The cylinders **52** each provide a force of at least 1000N, such as 1250 N, thus for example 2500 N for each clamping device **31**, **32**.

[0167] A longitudinal pressure exerted on the clamping devices **31**, **32** in direction of the longitudinal drill axis A is adjustable and a rotation speed of the motor **33** is adjustable. The control device **4** is configured to receive a desired pressure and rotation speed from an operator, for

example via remote control **7**, or to control the longitudinal pressure and rotation speed automatically depending on process parameter such as a measured torque or force.

[0168] The bearings **6**, **6**′ are configured to align the drill string **90** with the drill axis A. One of the bearings **6** is provided with fluid channels **61** for distributing fluid to the drive mechanism, wherein the fluid channels **61** comprise a stationary port and a rotating port for each clamping device, and for each longitudinal actuator. The rotating ports are rotating with the subframe and the drill string **90**.

[0169] The drill string **90** has a cylindrical shape and comprises an asymmetric drill head **91**, such that when the drill string is rotated and moved along the longitudinal drill axis, the drill head moves forward along a relatively straight line, but when the drill string is moved along the longitudinal drill axis without rotation, the drill head moves in a drilling direction determined by the asymmetry of the head. This way, directional drilling may be performed.

[0170] The drill string comprises relatively elastic plastic resulting in a bend radius of less than 10 meter, such as less than 5 meter, for example a bend radius of approximately 1 or 2 meter. The drill string also comprises coupling pieces **94** to releasably couple multiple drill string segments to each other, in this case via bayonet couplings. The coupling pieces **94** and the drill head **91** are made of steel.

[0171] The drill string segments may, for example, have length L**1** of 1.5 meter or more, larger than a length of the drilling device **1**. The drilling device has a length smaller than 2.5 meter, in particular less than 1.5 meter. This way, the attachment **11** is configured to be transportable in a minivan or on a conventional two-axle trailer. The drill string, in this embodiment, has a length of a single segment but multiple segments may be coupled to a length larger than 2.5 meter, for example 6 meter. A diameter of the drill string is smaller than 15 cm, such as smaller than 10 cm, for example 2-5 cm.

[0172] The drill string comprises drill fluid channel extending from openings **92** in the drill head **91** towards a fluid inlet port **95** at a rear end of the drill string **90** to be connected to a drilling fluid source, for example a water or bentonite source. The drilling fluid pressure at the drill head **91** is adjustable. The control device **4** is configured wirelessly communicate with the drilling fluid source to adjust a valve or pump fluidly connected to the drilling fluid source on the basis of operator input or process parameters.

[0173] The drill string **90** comprises a tracking device compartment 93 separate from the drill fluid channel, for housing a tracking device configured to emit a magnetic tracking signal. The remote control **7** comprises a display and is configured to receive the tracking signal and to display position data representative for a position of the tracking device on the basis of the tracking signal.

[0174] The remote control **7** may receive data from the tracking device directly or via a monitoring device on the earth surface. The tracking device comprises sensors, such as an accelerometer, magnetometer and a gyroscope. The remote control **7** is configured to show an estimated position of the drill string **90** based on the position data comprising, for example, actual drill head angles, input from the operator and an initial position of the drill string.

[0175] The attachment **10** comprises an excavator mount, in this embodiment a quick-release mounting bracket **11** for mounting the drilling device **1** to a mini excavator. Other mounts for mounting the attachment to other tools may additionally or alternatively be provided.

[0176] The mounting bracket **11** is rotatable around a substantially vertical axis V and around a substantially horizontal axis H, such that the vertical and horizontal orientation of the longitudinal drill axis A with respect to the excavator may be adapted. The attachment **10** is provided with a fluid connection **41** to the fluid system of a 1000-2000 kg mini excavator for powering the drive mechanism **3**.

[0177] As shown in FIGS. **6**A and **6**B, the directional drilling device **1** can optionally be provided with an extension piece **70** configured to guide a portion of the drill string **90** protruding outside the housing **2** through the opening **21**. The extension piece **70** is detachable from the housing **2** as

shown in FIG. **6**A, to guide the drill string portion in an attached, guiding position as shown in FIG. **6**B. Additionally or alternatively, the extension piece **70** may be hingedly connected to the housing **2** to be movable between an guiding position, in which the extension piece is configured to guide the drill string portion, and a storage position. The extension piece **70** comprises a mounting element **73** for mounting the extension piece **70** to the housing **2** and a hollow tubular guiding element that is configured to, in the guiding position, support the drill string along the longitudinal axis A. The guiding element comprises an inlet opening **71** and an outlet opening **72**.

[0178] The support elements **24** on the housing **2** form second mounting elements configured to cooperate with mounting elements **74** to attach the extension piece **70** to the housing **2**. Upon mounting, the inlet opening **71** of the extension piece faces the opening **21** of the housing **2**.

[0179] The support elements **24** and mounting elements **74** are each provided with respective openings shaped such that stabilisation pins **25** can be inserted therethrough into the earth **97**.

[0180] In use, a drill string **90** is provided in the directional drilling device **1**. A length of the drill string, for example without its drill head, is larger than a length of the directional drilling device **1** in the present embodiment. The device **1** is then positioned near the starting pit by the mini excavator via attachment **11**, which provides support to the housing and is arranged such that the drill string **90** points towards the earth surface at a desired angle α, for example at an angle α of −45° to 45°, such as −30° to 30°, with respect to the horizontal.

[0181] Optionally, an extension piece **70** may be provided to provide additional support to the drill string **90** to avoid bending of the drill string **90** portion between the housing **2** and the earth **97**. The extension piece **70** may be attached to the housing **2** and the housing **2** may be fixed to the earth **97** by inserting at least one, e.g. **2**, of the stabilisation pins **25** through respective openings in the support elements **24** and the mounting elements **74**.

[0182] The drill string **90** is clamped with a first clamping device **31**, and the first clamping device **31** is moved parallel to the longitudinal drill axis A away from an initial position to advance the drill string into the earth. The drill string **90**, in particular, a single drill string segment, may have a length (L**1**) longer than a length (L**2**) of the drill space. The first clamping device **31** is then released and the drill string **32** is clamped with a second clamping device **32** and moved further parallel to the drill axis A to advance the drill string **90**. Simultaneously, drill string **90** is rotated about the drill axis A to advance the drill string **90** along a straight path, and, when a change of direction is desired, the drill string **90** is held in a fixed rotational position to advance the drill string in a path curved corresponding to the fixed rotational position due to the asymmetric drill head **91**.

[0183] While advancing the drill string **90** with the second clamp **32**, the first clamp **31** is moved back to the initial position for continuous drilling in a first operation mode. Alternatively, the first clamping device **31** is moved together with the second clamp **32** for drilling using higher force.

[0184] Upon reaching a desired position with the drill head **91**, a reamer **96** and/or a utility line, such as a pipe or a cable is attached to the drill string **90**, and subsequently the drill string **90** is moved in backward direction, i.e. opposite to the drilling direction, by clamping the drill string while moving the clamping devices **31**, **32** reverse to the drilling direction. The utility line may be coupled to the drill head and/or to the reamer via a rotatable coupling.

[0185] As relatively high clamping forces may be obtained, and the drill string may be moved at a relatively high speed. a reamer and a utility line may be attached to the drill string simultaneously upon drilling, and reaming and pulling of the drill string through the drilled canal may be performed during a single reverse movement of the drill string up to a relatively high diameter. The utility line may for example have a diameter up to 10 mm.

Claims

1. A directional drilling device for installing underground cables or tubes, comprising: a housing having a drill space extending between two openings (**21**, **22**) in sides of the housing for accommodating a drill string through the two openings, and defining a longitudinal drill axis; and a drive mechanism arranged in the housing for engagement with the drill string configured to move the drill string in a drilling direction along the longitudinal drill axis and configured to selectively rotate the drill string about the longitudinal drill axis to perform directional drilling; wherein the drive mechanism comprises a first clamping device for clamping the drill string; wherein the drive mechanism further comprises a second clamping device for clamping the drill string; wherein the first clamping device and the second clamping device are each configured to be arranged in a clamping state, in which the drill string is clamped by the respective clamping device, and in a release state, in which the drill string is movable with respect to the respective clamping device, wherein the drive mechanism is configured to move the clamping devices back and forth along the longitudinal drill axis, and wherein the directional drilling device comprises a control device operatively connected to the drive mechanism and the clamping devices for alternating movement of the clamping devices and for switching the clamping devices between the clamping state and the release state to perform directional drilling.

2. The directional drilling device according to claim 1, wherein the directional drilling device comprises a support configured to support the housing, wherein the support positioned with respect to the drill space such that, when the housing is supported by the support, a drill string arranged in the drill space points towards the earth surface at an angle of −45° to 45°, such as −30° to 30° with respect to the horizontal.

3. The directional drilling device according to claim 1, wherein the control device is configured to alternatingly move the first clamping device and the second clamping device in the drilling direction in the clamping state.

4. The directional drilling device according to claim 1, wherein the control device is configured to selectively move the first clamping device and the second clamping simultaneously in the drilling direction in the clamping state.

5. The directional drilling device according to claim 1, wherein a rotation speed with which the drive mechanism rotates the drill string about the longitudinal drill axis is adjustable.

6. The directional drilling device according to claim 1, wherein the drive mechanism comprises a rotational motor to rotate the first clamping device and the second clamping device, wherein the rotational motor is configured: to rotate the first clamping device in the clamped state about the drill axis while simultaneously rotating the second clamping device and vice versa, or to rotate the first clamping device in the clamped state about the drill axis without rotating the second clamping device and vice versa.

7. The directional drilling device according to claim 6, wherein the drive mechanism comprises a longitudinal actuator attached to the clamping devices and configured to move the clamping devices along the longitudinal drill axis, wherein the rotational motor is configured to rotate the longitudinal actuator with the clamping devices.

8. The directional drilling device according to claim 7, wherein the longitudinal actuator comprises a pin, a track or a rod extending parallel to the drill axis and arranged to rotate about the longitudinal drill axis with the clamping devices, wherein the clamping devices are movably attached to the pins, tracks or rods.

9. The directional drilling device according to claim 1, further comprising a bearing configured to align the drill string with the drill axis, wherein the bearing is provided with fluid channels for distributing fluid to the drive mechanism, wherein the fluid channels comprise a stationary port and a rotating port that is rotating with the drill string.

10. The directional drilling device according to claim 1, further comprising an extension piece associated with the housing and configured to be arranged in a guiding position to guide a portion

of the drill string that protrudes outside the housing through one of the two openings, to avoid bending of the drill string portion away from the longitudinal drill axis.

11. A directional drilling assembly, comprising: a directional drilling device according to claim 1, and a drill string to be accommodated in the drill space of the directional drilling device, wherein a length of the drill string, for example without drill head, is larger than a length of the drill space, for example wherein the length of a drill string segment is larger than a length of the drill space.

12. The directional drilling assembly according to claim 11, wherein each clamping device delimits an inner clamping diameter, wherein, in the clamping state, the inner clamping diameter is smaller than a diameter of drill string, such that the drill string is locally deformed to improve gripping between clamping device and the drill string.

13. The directional drilling assembly according to claim 12, wherein at least one of the clamping devices is provided with an inner clamping shape that differs from an outer shape of the drill string, such that the drill string is deformed into another, e.g. non-circular shape.

14. The directional drilling assembly according to claim 11, wherein the directional drilling device comprises an interface, such as a remote control, wherein the drill string comprises a drill fluid channel and a tracking device configured to emit a tracking signal, wherein the interface is configured to receive the tracking signal and to display position data representative for a position of the tracking device on the basis of the tracking signal, wherein the tracking device is provided in a tracking device compartment in the drill string, separate from the drill fluid channel.

15. An attachment for an excavator, such as a mini excavator, comprising a directional drilling device according to claim 1 or a horizontal drilling assembly according to claim 11, and an excavator mount for attaching the directional drilling device to the excavator.

16. An excavator, comprising the attachment according to claim 15, wherein the attachment is provided with a power connection, for example a fluid connection, to the power system, e.g. fluid system, of the mini excavator for powering the drive mechanism.

17. A method for directional drilling in the ground, comprising the steps of: providing a drill string in a directional drilling device, for example wherein a length of the drill string is larger than a length of the directional drilling device; positioning the device such that the drilling direction reaches the earth surface at a desired angle, for example at an angle of −45° to 45°, such as −30° to 30°, with respect to the horizontal; clamping the drill string with a first clamping device and moving the first clamping device parallel to a longitudinal drill axis away from an initial position to advance the drill string into the earth; releasing the first clamping device and clamping the drill string with a second clamping device; moving the second clamp parallel to the drill axis to further advance the drill string into the earth; while advancing the drill string, with the first and/or second clamping device, rotating the drill string about the drill axis to advance the drill string along a straight path, and holding the drill string in a fixed rotational position to advance the drill string in a path curved corresponding to the fixed rotational position; and while advancing the drill string with the second clamp, moving the first clamp back to the initial position, or vice versa, or moving the first clamp and the second clamp together in the clamping state in the drilling direction.

18. The method according to claim 17, wherein a length of the drill string prior to drilling is larger than a length of the directional drilling device.

19. The method according to claim 18, wherein a length of the drill string prior to drilling is the full expected length of the borehole to be drilled in the ground.

20. The method according to claim 17, further comprising the steps of: before drilling, digging a starting pit and/or an exit pit with a tool, such as a mini excavator; optionally, removing a digging device, such as an excavator bucket, from the tool; attaching a directional drilling device to the tool; performing the steps of advancing the drill string with the directional drilling device from the starting pit and/or towards the exit pit using the directional drilling device attached to the tool.