United States Patent [19]

Ikeda

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[54] **REACTION MINIMIZED EARTH BORING**

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[52] **U.S. Cl.** **175/95,** 175/103, 175/104, 175/213

[51] **Int. Cl.** **E21b 3/10**

[58] **Field of Search** 175/27, 53, 57, 60, 175/92, 101, 95–97, 103, 104, 106, 215, 227, 228, 333, 371, 213

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Primary Examiner—David H. Brown
Attorney—Richard K. Stevens et al.

[57] **ABSTRACT**

Earth boring using a machine having a high speed motor and a plurality of cutters disposed at mechanically balanced positions, said cutters being rotated about their own axes while revolving about a common axis so that the reaction moment acting on a support for said the motor can be substantially minimized.

4 Claims, 13 Drawing Figures

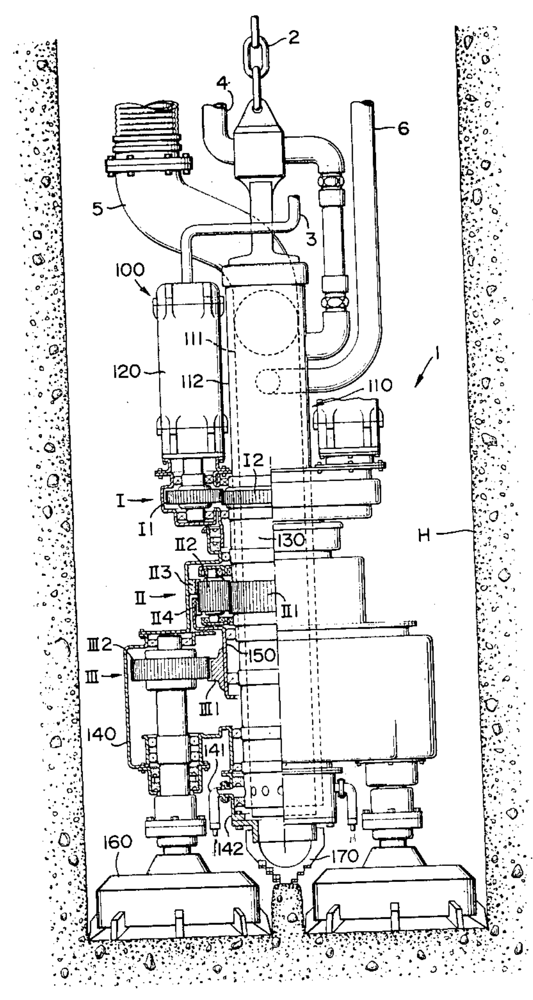


Fig. 1

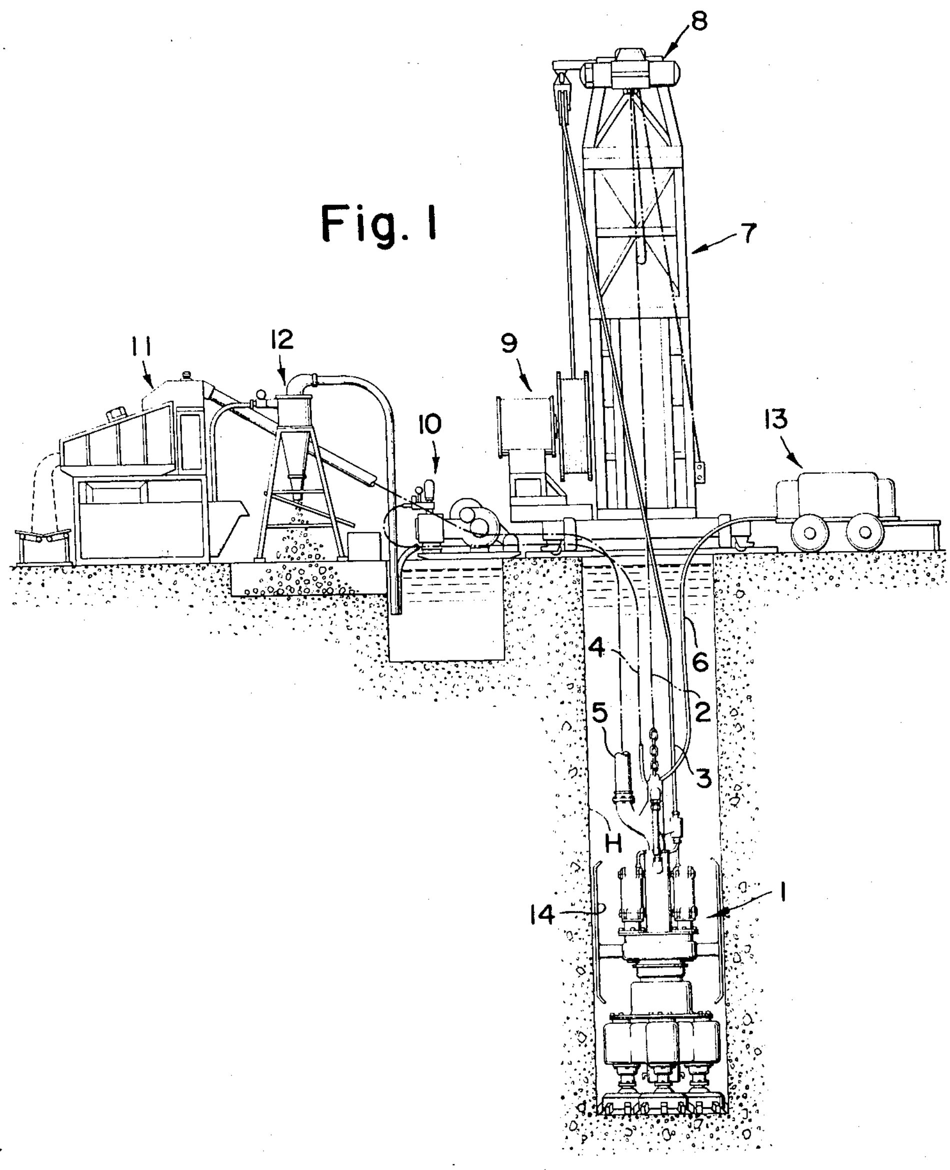
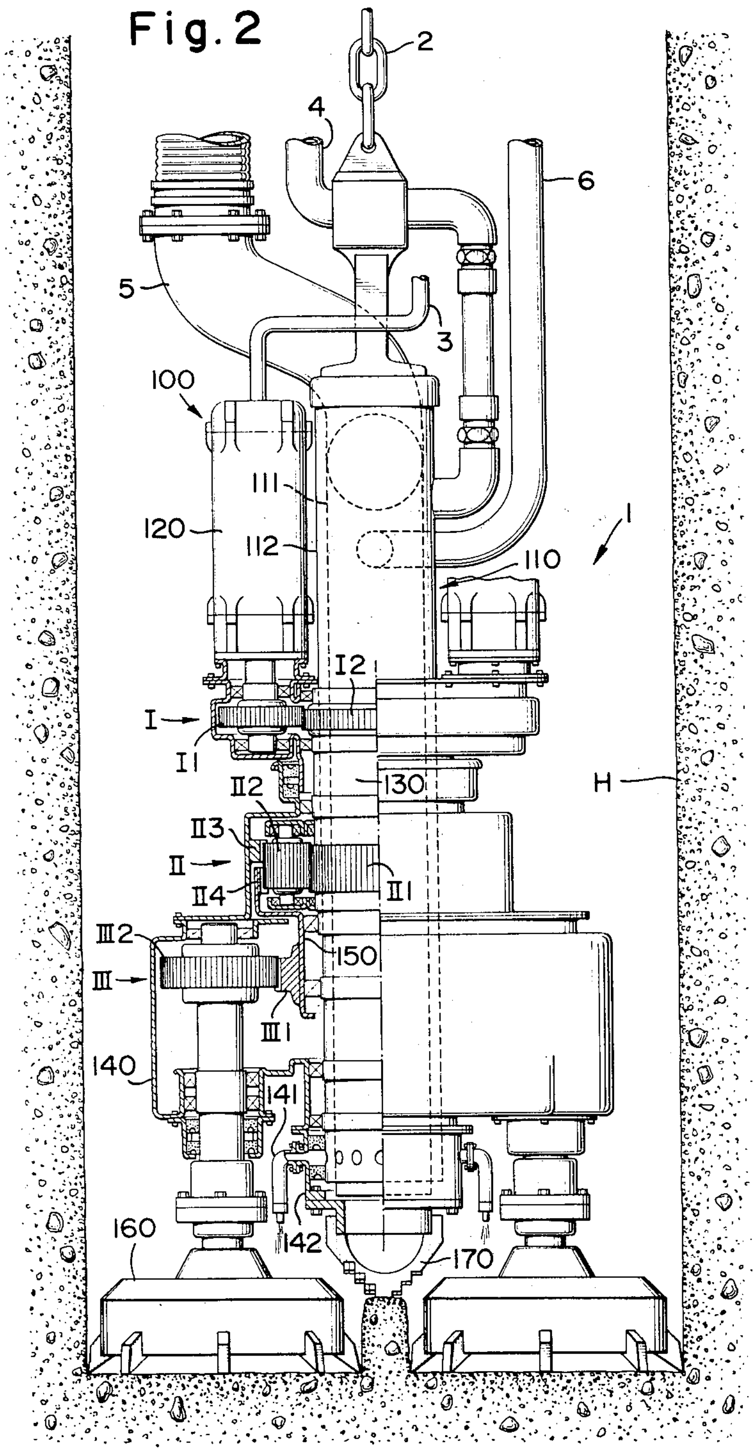


Fig. 2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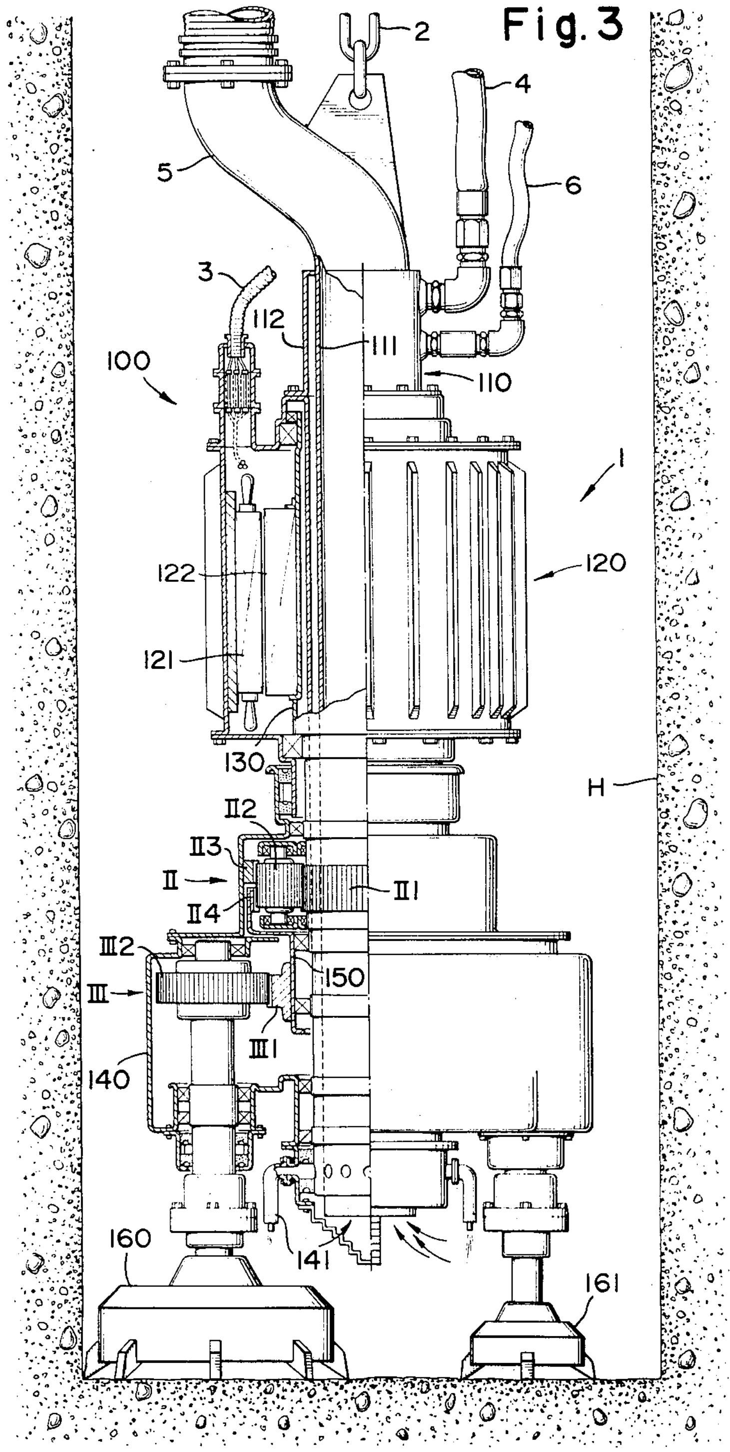
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Fig. 3

Fig. 4

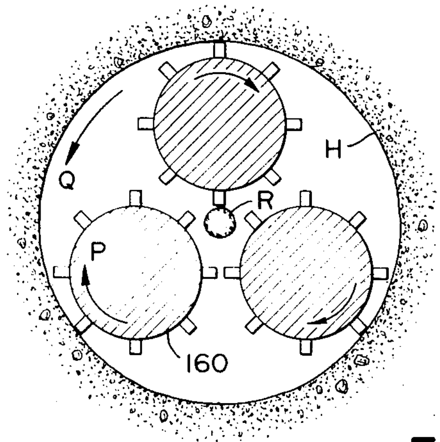


Fig. 5

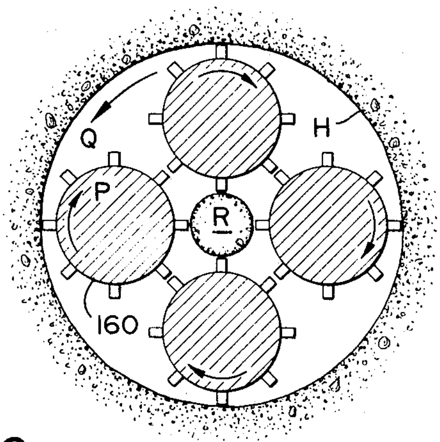


Fig. 6

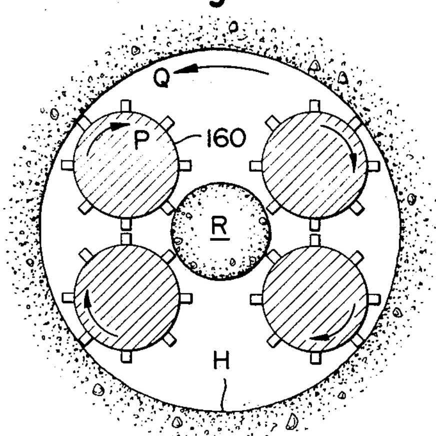


Fig. 7

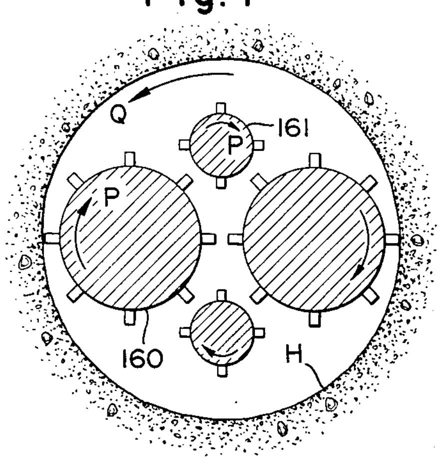


Fig. 8

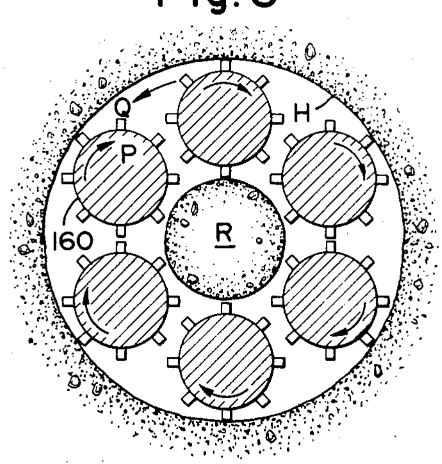


Fig. 9

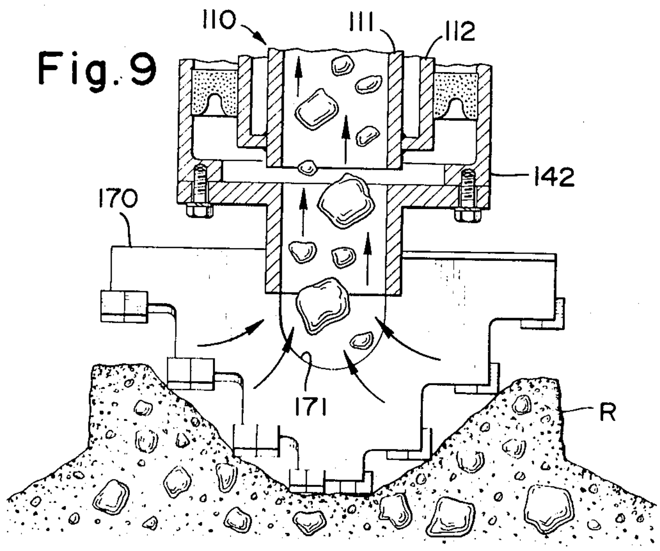


Fig. 11

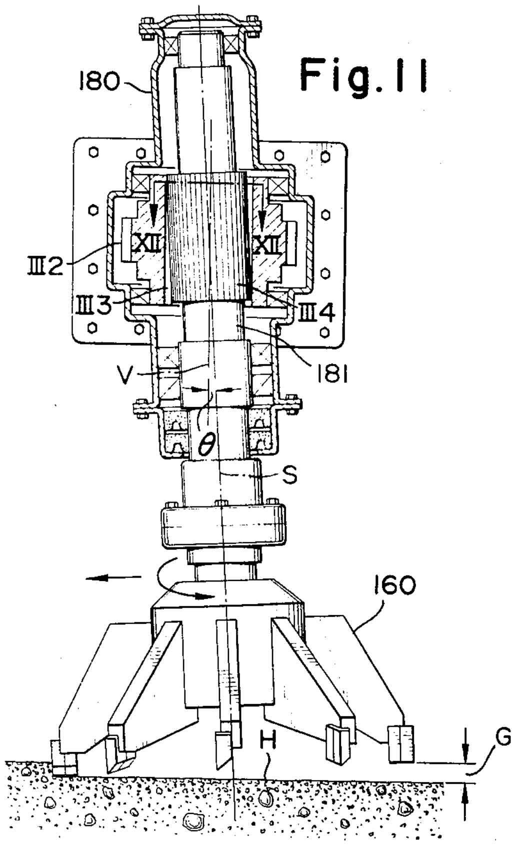


Fig. 12

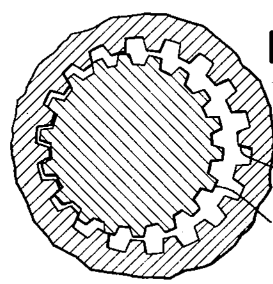


Fig. 13

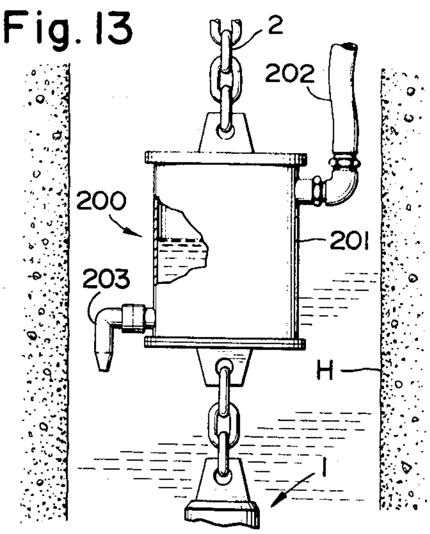
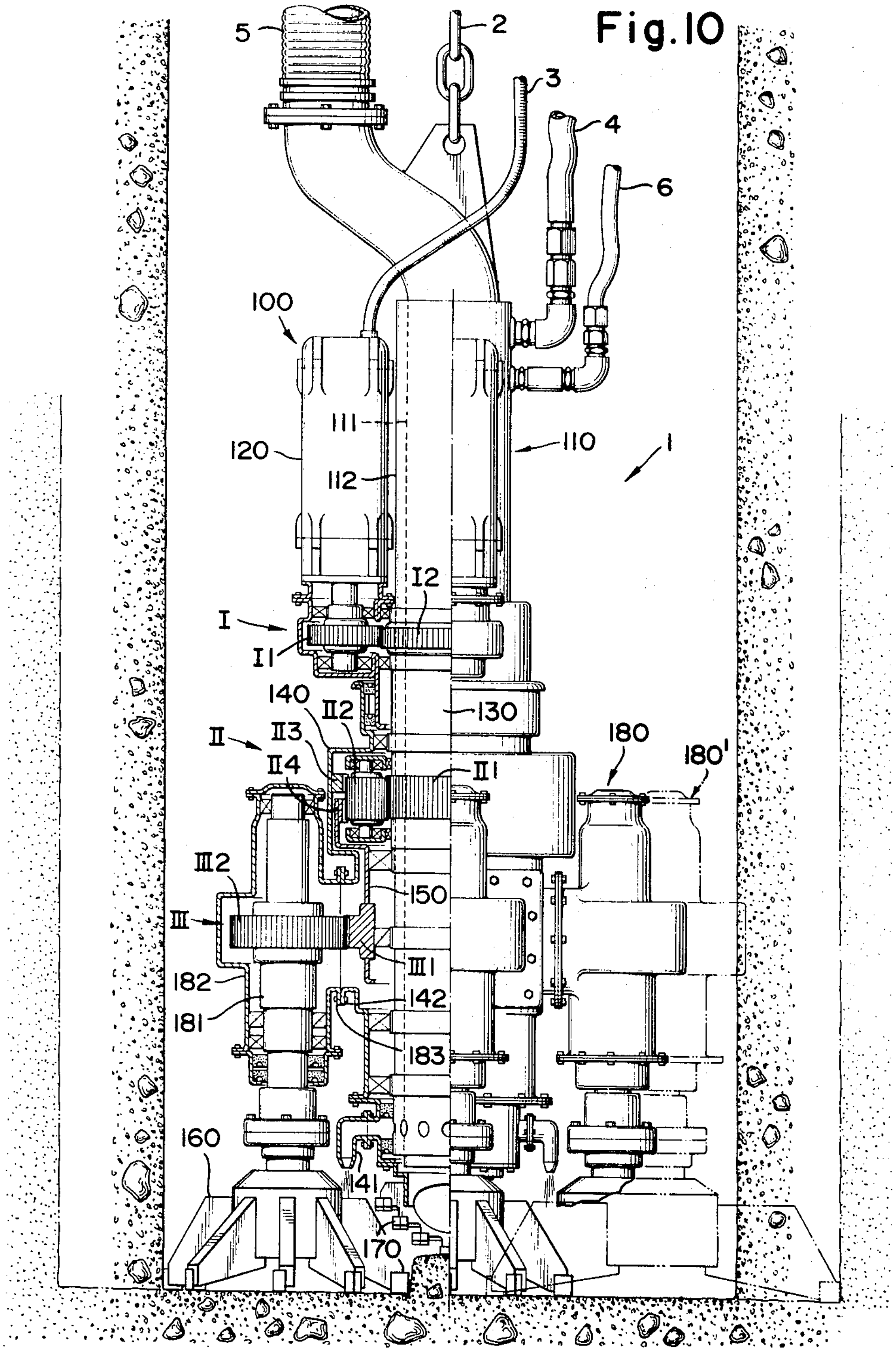


Fig.10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REACTION MINIMIZED EARTH BORING

The present invention relates to an earth boring method and machine and more particularly to such a method and machine in which reaction torque can be minimized.

In a conventional earth boring apparatus in which a drilling pipe is driven to rotate and feed a drill bits provided at the end thereof, the pipe must be provided with a sufficient torsional rigidity. Further, it is also necessary to provide on the ground complicated and bulky mechanisms for journalling and driving the pipe. Moreover, since it is necessary to add another pipe with every few meters of boring, the work made by the conventional apparatus is time-consuming and uneconomical.

In order to overcome these inherent disadvantages of a conventional earth boring method, it has been proposed to provide a so-called "down-the-hole" type apparatus in which the drill bit is connected to motor means through reduction gears to omit intermediate transmission members.

This type of apparatus is advantageous in that the use of a long drilling pipe for transmitting power is not required and complicated ground equipment may be eliminated, however, it is accompanied with a new problem of supporting the motor with reduction gears against reaction torque.

In order to solve this problem, several proposals have been made. For example, it has been proposed to use a drilling pipe for supporting the apparatus against the reaction torque, to provide a solenoid at the inner surface of a casing for blocking the apparatus against rotation, or to provide a linked leg means adapted to be expanded toward the wall surface of a bore which is being drilled. However, none of these proposals have been satisfactory since it requires a complicated operation and increased time and labor.

An object of the present invention is to provide an machine which can effectively perform a novel boring method.

According to the present invention, the above object can be accomplished by transmitting the output torque of at least one high-speed motor with a high reduction ratio to a plurality of cutters disposed at mechanically balanced positions so that the cutters are revolved about the axis of the boring machine while said cutters rotate about their own axes whereby the reaction moment acting on supporting means for the motor means can be substantially reduced.

In the above operation, it is possible to further reduce the reaction moment by means of such an arrangement that the direction of the reaction moment acting on the supporting means for the motor is opposite to that of the revolution of the cutters.

The aforementioned operation of the present invention can well be performed by using an earth boring machine comprising at least one high speed motor secured to a central member, speed reduction means of a high speed reductIon ratio which is rotatable with resepct to said central member and adapted to be driven by said motor, said speed reduction means having a plurality of output ends, a plurality of cutters disposed at mechanically balanced positions, each of said cutters being connected to a respective one of the output ends of said speed reduction means, said cutters being revolvable about the axis of the machine and rotatable about their own axes.

Further, in the aforementioned earth boring machine, a core breaker may be provided beneath said central member and rotated together with said plurality of cutters. With this arrangement, it is possible to remove substantially all of the soil from the bottom of the bore even when said plurality of revolvable cutters are arranged on a circle which is co-axial with said central member. p

The aforementioned boring machine may include one or more submersible motors mounted on the body and the central member may be constituted as a double tube construction which can be used for feeding and scavenging water into and out of the hole being bored. This type of machine can be used in an earth boring operation with boring water in which forced water circulation is performed.

In the above machine that has one or more submersible motors, water discharging nozzle means may be provided on the revolvable casing so that water is discharged under pressure toward each cutter, preferably the leading side thereof as viewed in the direction of the revolution of the cutters. Thus, the cutting edges of each cutter can be always maintained clean preventing mud from adhering thereto. Therefore, the cutting edges can be always sharp and further slime scavenging operations can be facilitated.

In the above earth boring machine, each cutter and its driving means may preferably be constituted as an interchangeable unit so that the dimensional capability of the machine may be readily changed by simply replacing the unit by another unit of a different dimension.

Further, it is preferable to support each cutter by a driving shaft which is forwardly inclined in the direction of the revolution. With this arrangement, the cutting edges on the cutters are spaced apart from the bottom surface of the bore at the trailing side as seen in the direction of the revolution so that the boring performance of the machine can be further improved.

When the machine is used in the water, it is preferable to add a thrust adjusting float disposed above the machine. The buoyancy of the float may be adjusted as desired to maintain the thrust force acting on the cutters at a optimum value even when the property of the earth formations varies during boring operation.

The above and other objects and features of the invention will further become apparent from the following description of preferred embodiments with reference to the accompanying drawings, in which;

FIG. 1 is a diagrammatical elevational view, partly in section, showing the general arrangement of a boring plant employing an earth boring machine in accordance with the present invention;

FIG. 2 is an elevational view of one embodiment of the earth boring machine in accordance with the present invention, the machine being partially cut away in order to show the detail thereof;

FIG. 3 is a view similar to FIG. 2 but showing another embodiment of the present invention;

FIGS. 4 through 8 show in plan view several examples of cutter arrangements;

FIG. 9 is a fragmentary sectional view showing the earth boring operation using the machine of the present invention;

FIG. 10 shows a further embodiment of the machine in accordance with the present invention, in which each cutter and its driving means as an interchangeable unit;

FIG. 11 is a side elevation view of a cutter which is supported on a forwardly inclined shaft;

FIG. 12 is a sectional view taken along the line XII—XII in FIG. 11; and,

FIG. 13 is a side elevational view of a thrust adjucting float which may be used with the machine of the present invention.

Referring to the drawing, particularly FIG. 1, there is diagrammatically shown a machine which is used in a wet-type boring system. In the drawing, the reference numeral (1) generally shows an earth boring machine embodying the present invention. As will become apparent from the following description, the machine (1) of the present invention is subjected to a very little reaction moment so that it is possible to eliminate a drilling pipe of a high torsional rigidity and suspend the whole machine by a thin-walled pipe, a hose or a chain (2) as shown in the drawing.

The machine is provided with driving means such as one or more submersible electrical or hydraulic motors which can be used into water. The drawing shows an example in which a plurality of submersible electrical motors are mounted and supplied with power through an electric cable (3). The cable (3) is continuously fed from a cable reel (9) as the boring operation proceeds.

When hydraulc motors are employed as the driving means, oil supply hoses may be used in lieu of the electric cable (3). A water supply hose (4) is provided for supplying boring water e.g. bentonite mud water which is discharged from the lower end of the machine (1) and scavenged through a discharging hose (5) carryig slime therewith. In such a case, compressed air may be supplied through an air supply hose (6) to form bubbles for facilitating the removal of the slime. The reference numeral (13) shows an air compressor provided for this purpose.

The water carrying the slime is circulated through a mud screen (11) and a cyclone (12) into a water supply pump (10).

Other ground equipment such as a derrick (7) can be simple as compared with a conventional one. As will become apparent later, according to the present invention, the ground equipment is not required to include drive means for rotating and advancing a main drilling pipe, a power transmission mechanism, and bearing means therefor, but only required to include means for lifting the boring machine (1), such as an electrically operated chain block (8) mounted on the derrick (7), for carrrying the chain (2) suspending the machine (1). Further, according to the present invention, since the water is passed through the hoses (4) and (5), it is possible to eliminate water swivels which have been required in a conventional boring apparatus driven by a drilling pipe.

When required, suitable guide means (14) may be provided around the machine (1) for maintaining the straightness of the hole.

The detail of the machine shown in FIG. 1 will now be described taking reference to FIG. 2.

In FIG. 2, there is shown an example of an earth boring machine having submerged type electric motors. As shown in the drawings, the machine which is comprises a body (100) including a central pipe (110) whichis constituted by an inner pipe (111) and an outer pipe (112) respectively connected to the water discharging hose (5) and the water supply hose (4). The water supplied from the hose (4) is passed through the space between the inner and outer pipes (111) and (112), and discharged from nozzles (141). Compressed air is supplied through the air supply hose (6) at an intermediate portion of the inner pipe (111) for producing air bubbles which facilitate the removal of the slime through the water dischage hose (5).

The central pipe (110) of double wall construction comprising the inner and outer pipes (111) and (112) is advantageous in that the pressurized water supplied from th ground can be discharged toward the cutting edges of each cutter to and make the water carry the slime into the double wall central pipe (110).

Submersible type high speed electric motors (120) are supported on the central pipe (110). In the illustrated apparatus, two motors are used, however, it should of course be noted that any number of motors may be used in accordance with the present invention.

Each of the motors (120) includes an output shaft having a gear (I–1) secured thereto and meshing with a second gear (I–2) which is rotatable about the axis of the central pipe (110). The gear (I–2) is secured to a sleeve (130) which is rotatably supported on the pipe (110). The gears (I–1) and (I–2) constitute a first stage of speed reduction means.

Another gear or sun gear (II–1) is secured to the lower portion of the sleeve (130). Around the sun gear (II–1), there are arranged a plurality of planetary gears (II–2) meshing with sun gear (II–1). The planetary gears (II–2) are also in meshing engagement with internal gears (II–3) and (II–4). The internal gear (II–3) has teeth which are slightly less in number than those of the internal gear (II–4). Since the internal gears (II–3) and (II–4) having different number of teeth are simultaneously in meshing engagement with the same planetary gears (II–2), all of the gears (II–1), (II–2), (II–3) and (II–4) have to be profile shifted gears.

The internal gear (II–3) is secured to a casing (140) which is rotatable about the axis of the machine and rotatably supports the cutters. The internal gear (II–4) is secured to a transmission member (150). The planetary gears (II–2) are freely revolvable along the annular spacing between the sun gear (II–1) and the internal gears (II–3) and (II–4) with means for preventing the planetary gears from displacement out of the spacing. The gears (II–1), (II–2), (II–3) and (II–4) provide a second stage speed reduction means of a high speed reduction ratio. Since the number of teeth on the internal gear (II–4) is slightly greater than that of the teeth on the internal gear (II–3), the gear (II–4) is caused to rotate in the same direction as the sun gear (II–1).

The transmission member (150) carrying the internal gear (II–4) also has a gear (III–1) mounted on the lower portion thereof for driving a second gear (III–2) secured to the shaft of each cutter (160). The gears (III–1) and (III–2) may also constitute a third stage speed reduction means, however, in the illustrated arrangement, they constitute a speed increasing means. Thus, the gears may constitute a speed reduction means or a speed increasing means in accordance with the diameter of the hole to be bored.

The casing (140) supporting the cutters (160) and the transmission member (150) supporting the gears (II–4) and (III–1) are rotatable with respect to the body

(100) having the double wall pipe (110) and the motors (120). Suitable sealing means may be provided between the body (100) and casing (140).

The operation of the apparatus constructed as described above will now be described using practical values.

The followings is the description of an example in which a bore of diameter of 1.3 meters is formed in a relatively soft earth formation such as an alluvium or a diluvium for planting a reinforced concrete pile thereinto.

Two induction motors (three-phase, two-pole) having a rate output H of 11 KW (15 ps) with input frequency of 50 Hz under the voltage of 200 V are used as the motors (120). The synchronized speed of each motor (120) is 3,000 r.p.m.

The number of teeth on the gears (I–1) and (I–2) of the first stage speed reduction means are respectively 60 and 100 with the module of 3 mm. Thus, the speed reduction ratio of the first stage is 1.66.

The gears (II–1), (II–2), (II–3) and (II–4) are of a profile-shifted type and module of 5 mm, respectively having 60, 20, 100 and 102 teeth. In this particular arrangement, two gears (II–2) are used. Thus, the speed reduction ratio of the second stage speed reduction means is about 136.

The third stage may be a speed reduction means, however, in this particular case, the gears (III–1) and (III–2) is module of 5 mm and respectively have one hundred, and fifty teeth due to the dimensional relationship. Thus, the third stage provides the speed ratio of 0.5 and serves as a speed increasing means.

Therefore, the total speed reduction ratio throughout the first, second and third stages is as follows:

$$1.66 \times 136 \times 0.5 \approx 114$$

Thus, when the motor (120) is operated at 3,000 r.p.m., the speed of the cutter can be calculated as follows:

$$3{,}000/114 = 26 \text{ r.p.m.}$$

The torque T_B transmitted to the cutter (160) with full load condition can be calculated as follows:

$$T_B = 60 \times 75 \times H/2\pi N$$
$$= 60 \times 75 \times 2 \times 15/2\pi \times 26$$
$$= 820 \text{ m·kg}$$

where:

N represents the rotational speed (r.p.m.).

H represents the output power (ps). This value of torque is considered to be a suitable one for boring a relatively loose earth formation such as an aluvium or a diluvium.

In this instance, the reaction torque (T_R) acting on the body (100) can be represented by the following equation in terms of the reaction torque (T_M) of a motor and the reaction torque (T_L) due to the bearing load on the motor shaft.

$$T_R = 2T_L - 2T_M$$

Further, the torques T_M and T_L can be represented by the following equations:

$$T_M = 60 \times 75 \times 15/2 \times 3{,}000 \approx 3.6 \text{ m} \cdot \text{kg}$$
$$T_L = T_M \times (D_1 + D_2)/D_1$$

where: D_1 and D_2 respectively designate the diameters of the gears (I–1) and (I–2). Therefore,

$$T_R = 2T_L - 2T_M = 2T_m D_2/D_1$$
$$= (2 \times 3.6 \times 100 \times 3)/(60 \times 3) \approx 12 \text{ m·kg}$$

It should be noted that the reaction moment of this order can be borne without using a drilling pipe of high rigidity. Therefore, it is possible to suspend the boring machine (1) by a thin-walled pipe, a strong hose or a chain (2) as shown in the drawing.

In the above calculation, it has been assumed that there is no power transmission loss, but it is apparent that the reaction moment on the body (100) can be sufficiently reduced.

In actual practice, there may be produced a frictional resistance in the sealing means disposed between the body (100) and the casing (140). In an arrangement where the reaction moment (T_R) on the body (100) acts in the direction opposite to the revolution of the cutter (160) as in the illustrated embodiment, the frictional resistance produced between the body (100) and the casing (140) serves to oppose the reaction moment on the body (100) so that it is possible to further decrease the moment required for supporting the body (100).

It should thus be noted that, in accordance with the present invention, the machine (1) can be susepended by a chain (2) or the like without the risk of the cable (3) and the hoses (4), (5) and (6) being undesirably twisted or entangled.

In the example shown in FIG. 2, a plurality of motors are used. FIG. 3 shows an example which includes a single motor. In this example, the machine includes a submersible electric motor (120) which is specially designed so as to include a double wall pipe (110) passing through the center thereof. As in the previous embodiment, a motor casing having a stator (121) is secured to the double wall pipe (110). The rotor (122) of the motor (120) is directly connected to a member (130) corresponding to the sleeve in FIG. 2. In this embodiment, the first stage speed reduction means as provided in the arrangement of FIG. 2 is eliminated, but the whole function of the machine is the same as in FIG. 2.

In FIG. 3, the motor is of a special design in which a double wall pipe is passed therethrough, however, it is of course possible to use a conventional motor.

FIGS. 4 through 8 diagrammatically show examples of arrangements in which a plurality of cutters are disposed in mechanically balanced positions.

FIG. 4 is an example in which three cutters (160) of the same diameter are located at circumferentially equi-distant positions. Each of the cutters (160) rotates about its own axis in the direction shown by the arrow (P) and also revolves about the axis of the machine (1) in the direction shown by the arrow (Q) which is opposite to the arrow (P). Thus, since the cutter (160) rotates about its own axis while revolving about the axis of the machine in the direction opposite to the rotation therof, each of the cutting edges on the cutter (160) moves along a hypotrochoidal path.

FIGS. 5 and 6 show examples in which four cutters (160) are positioned on a circle co-axial to the apparatus. In FIG. 5, the cutters (160) are disposed at circumferentially equi-distant positions, and this arrangement corresponds to the embodiments of FIG. 2. In FIG. 6, the cutters are not at equi-distant positions but, in this arrangement, mechanical balance is also obtained.

The arrangement of FIG. 7 corresponds to the embodiment shown in FIG. 3 and includes two large cutters (160) and two small cutters (161), each of which rotates about its own axis in the direction of the arrow (P) and revolves about the axis of the machine in the direction of the arrow (Q) which is opposite to the arrow (P). With this arrangement, it is possible to dispose the large cutters (160) very closely together so that it is possible to bore a hole without leaving any great amount of soil of the center of the hole.

In FIG. 8, six cutters (160) are arranged at circumferentially equi-distant positions.

From FIGS. 4 through 8, it should be seen that, in the arrangement in which a plurality of cutters (160) are arranged on a circle co-axial to the machine, the portion of the soil at the center of the hole remains without being removed as shown by (R) in the drawings. It should further be seen that the dimension of the core-like remaining portion (R) increases as the number of the cutters increases. In order to eliminate the portion (R), a core breaker (170) may be provided directly beneath the central member (110) as shown in FIG. 9. The core breaker (170) may be secured to a bracket (142) formed on the casing (140). With this arrangement, the core breaker (170) is rotated with the casing (140), so that the portion (R) can be effectively removed. In this case, the core breaker (170) is rotated in the direction of revolution due to the reaction torque. Therefore, it is not preferable to form an excessively large portion (R) since the portion absorbs substantial torque.

It should be noted that the core breaker (170) can be of any form other than that shown in FIG. 9. Asshown in FIG. 2, when an earth boring machine having a double walled central pipe is used to bore through a relatively loose earth formation by a water boring method, it is necessary to take gravel or boulders on the hole bottom into the cebtral pipe and lift them upto the ground together with water containing slime. Therefore, it is preferable that the core breaker (170) has a sufficiently large intake port (171) so that the inner pipe (111) can be of sufficient diameter to prevent the large boulders from clogging in the pipe. Since it is possible that the intake port (171) may be encountered with a boulder which is larger than the port, the machine should preferably be of such a construction that can break by boulder by an impact given by the rotation of the core breaker (170). According to the present invention, however, the machine has a tendency to push gravel and boulders into the wall of the hole, so that it is very unlikely that a large boulder is gathered around the intake port of the central pipe. Thus, even in an arrangement in which a plurality of cutters (160) are arranged along a circle, it is possible to remove all soils without leaving any unbroken core portion (R).

In operation of the machine (1), water may be discharged under pressure from the water discharge nozzle (141) toward the cutters (160), preferably the leading side thereof. Since the position of the nozzle (141) remains unchanged with respect to the corresponding cutter (160), the cutting edges at the leading side of each cutter are continuously cleaned.

FIG. 10 shows another embodiment of the present invention. In this embodiment, the machine (1) has a plurality of cutter driving units (180), each comprising a cutter drive shaft (181), a gear (III–2) secured thereto and a casing (182) which is removably mounted to the casing (140) and enclosing the drive shaft and the gear. Thus, the cutter drive units (180) are removable from the casing (140). In the illustrated embodiment, the casing (182) of each drive unit (180) has a flange (183) which is adapted to be secured to the co-operating flange (142) formed on the casing (140).

The machine (1) of FIG. 10 is intended to make the cutter (160) replaceable with another cutter of different size. According to the above arrangement, a wide variety of cutter drive units (180) can be used in a single earth boring machine. In FIG. 10, the phantom line (180′) shows a cutter of larger dimension.

Further, in the arrangement of FIG. 10, it is also possible to replace the gear (III–1) by another gear of different diameter. FIG. 10 illustrates an arrangement in which four units (180) are disposed at circumferentially equi-distant positions as in the arrangement of FIG. 5, however, it should be noted that various changes may be made in the arrangement of the units.

Referring now to FIG. 11, there is shown an earth boring machine in which cutters (160) are mounted on forwardly inclined shafts. In the drawing, each of the cutters (160) has cutting edges on the outer periphery thereof and the axis (S) of the shaft (181) is forwardly inclined by an angle (θ) with respect to a vertical line (V). With this arrangement, the cutting edges at the leading side of the cutter come in engagement with the bottom of the hole (H) but are apart therefrom at the trailing side of the cutter as shown by a gap (G). Thus, the cutting edges on the cutter (160) intermittently come in contact with the hole bottom.

It is apparent from therawing that the cutting edges do more work at the leading side than at the trailing side. Therefore, in a conventional arrangement in which each drill bit is mounted on a vertical shaft, the cutting edges merely slide along the surface of the hole bottom, so that power is wasted and the cutting edges are undesirably worn. This disadvantage can be eliminated by the arrangement of FIG. 11.

It has been known in a face milling machine that the cutting performance can be improved by arranging a milling cutter on a forwardly inclined shaft. The problem that arises in such an arrangement is that the milled surface is undesirably concave. Thus, the arrangement could be used only in a rough finishing. However, in an earth boring operation, no problem will arise even when smooth finishing the bottom surface of the hole, so that the arrangement provides only an advantageous feature.

It should be noted, however, that another problem is encountered in this arrangement of the present invention in transmitting a substantial torque between a pair of non-parallel shafts.

Screw gears have already beem known as a means for transmitting motion between a pair of offset shafts. However, in theory, the screw gear transmits motion through a point contact so that it is not suitable for transmitting power. Particularly, in the earth boring machine, a heavy load is applied on the motion transmitting mechanism and, for this reason, it is not suitable to use a screw gear.

This difficulty can be solved by the arrangement illustrated in the drawing. Referring to FIGS. 11 and 12, a gear (III–2) meshing with a gear (III–1) is provided with internal spline teeth (III–3) with which external spline teeth (III–4) are engaged. According to the feature of the present invention, the splines (III–3) and (III–4) are engaged with a gap as shown in FIG. **12.** By providing the gap, it becomes possible to incline the axis (S) of the drive shaft (**181**) with respect to the vertical line (V) or the axes of the gears (III–1), (III–2) and (III–3) by an angle (θ). Experiments performed by the inventor have proved that the spline connection is practically useful. The angle of inclination (θ) may be less than 5°, preferably 2° to 3°.

The machine (**1**) of the present invention can be suspended by a chain (**2**) as shown in FIG. **1.** In this case, the thrust force for downward feeding the machine can be provided by the weight of the machine itself. When it is estimated that the weight of the machine is insufficient to provide a thrust force in view of the property of the earth formations to be bored, weight means or the like may properly be added.

When the boring operation is performed by filling the hole with boring water such as mud water, a float may be used to adjust the thrust force. FIG. **13** shows an example of such an arrangement which includes an adjusting float (**200**) disposed above the boring machine (**1**) and suspended by a chain (**2**). When the thrust force required to bore the earth formation is to be reduced due to the change of property of the earth formation, compressed air may be supplied through an air hose (**202**) into an air reservoir (**201**) whereby the water in the reservoir (**201**) is forced out through a water port (**203**), so that the buoyancy of the float is increased. As the result, the thrust force of the machine is correspondingly reduced. Conversely, when the machine (**1**) encounters a hard earth formations, air may be removed from the reservoir (**201**) through the air hose (**202**) to increase the water level in the reservoir (**201**). Thus, the buoyancy of the float is reduced and the thrust force is correspondingly increased. The above arrangement is advantageous in that the machine can be used with the most suitable thrust force irrespective of the property of the earth formation to be bored.

From the above description, it will be apparent that according to the present invention it is not required to use a high strength drilling pipe or to provide bulky and complicated ground equipment, and it is possible to increase the efficiency of boring operation. Further, the present invention provides a novel machine which is effective to perform the novel boring method and is particularly suitable for use in a boring operation through a relatively loose earth formations.

What is claimed is:

1. A reaction minimized earth boring machine comprising a sun gear mounted on a rotary sleeve rotatable about a central member and driven by a power source through said rotary sleeve; planetary gears engaging with said sun gear so as to rotate and revolve in relation to said sun gear; a first internal gear mounted on a revolution casing around said planetary gears to engage therewith, said revolution casing being rotatable about said central member; a second internal gear mounted on a transmission member around said planetary gears to engage therewith, said transmission member being rotatable about said central member, said first and second internal gears having a small difference in their number of teeth and engaging the same planetary gear; a central gear mounted on said transmission member coaxially to said second internal gear; and further gears respectively mounted on rotary shafts driving cutters borne rotatably by said revolution casing, said further gears engaging with said central gear.

2. An earth boring machine according to claim **1** wherein the central member comprises an inner pipe and an outer pipe, both pipes being disposed coaxially with each other and extending to a position adjacent the cutters.

3. An earth boring machine according to claim **2** further comprising water-discharge nozzle means provided on a bracket formed on the revolution casing and connected to the space between the inner and outer pipes at the lower end thereof.

4. An earth boring machine according to claim **1** wherein the rotary axis of each cutter is forwardly inclined with respect to a vertical line at a small angle; said further gears are supported rotatably on the revolution casing, said further gears being provided with a splined inner peripheral surface; and the rotary shaft of the cutters is borne on said revolution casing with its axis being inclined and is provided with a splined outer peripheral surface engaging with said splined inner peripheral surface, a clearance sufficient for inclining said axis of the cutter being provided.

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