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(54) **MECHANIZED, REMOTE CONTROLLED, GUIDED LOWERING OF A PNEUMATIC CAISSON**

(57) The invention relates to the mechanized and remotely controlled excavation of the working chamber under a, preferably pneumatic, caisson or shaft, with the aim of sinking the caisson or shaft. One could also call this invention "unmanned" or "without divers" sinking. In

addition, in the working chamber an excavation technique, such as a dredge technique, is used, so in the working chamber there is a layer of water and an in the water protruding excavating element, such as a dredge element, for example dredge pump.

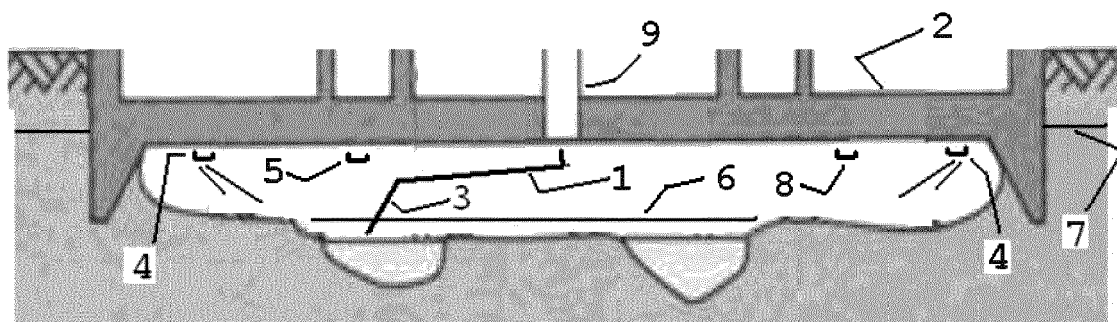


Fig. 6

Description

[0001] The invention relates to the mechanized and remotely controlled excavation of the working chamber under a, preferably pneumatic, caisson or shaft, with the purpose of forming the caisson or shaft, which is a structure such as a building with, for example, accommodation spaces and, as a rule, a height of at least 5 or 10 or 25 or 50 meters, to sink, for example where the structure moves vertically downwards during sinking over a distance of at least 5 or 10 or 25 or 50 meters. One could also call this invention "unmanned" or "without diver" sinking. In this document the term "caisson" also means "shaft". Although the invention is particularly intended for a pneumatic caisson, it could also be applicable to a non-pneumatic caisson. This document mainly discusses the application for a pneumatic caisson.

[0002] In this document, a distinction is made between a water jet and a water spray. A water jet is supplied by a water cannon and is thick and powerful. A water spray is thin and less powerful. A water jet is independently capable of eroding the soil sufficiently. A water jet system is used to support a mechanical eroding the ground element, such as a milling or cutter head.

[0003] A pneumatic caisson is used in an area with relatively high water level or groundwater level. At the under side of the bottom (which, with a view to generating a pneumatic vacuum in the working chamber, is sufficiently and preferably completely airtight, possibly with the exception of slight air leaks due to, for example, functional penetrations) of the caisson, there is a downwardly projecting cutting edge which laterally delimits sufficiently and preferably completely airtight a working chamber. The caisson bottom forms the ceiling and the soil the bottom of the work room. By digging out the work room, the caisson sinks under its own weight in the soil and becomes a fully or partly underground or underwater structure, such as building. The caisson bottom drops below the local water level, for example ground water level, below and around the caisson. By introducing air, the (pneumatic) air pressure in the workroom is increased and the water level under the caisson is thus temporarily reduced, so that the workroom remains dry and therefore accessible to people.

[0004] Traditionally, the sinking of a caisson takes place by workers in the work room who spray the ground with hand-operated water cannons and the resulting dredge is pumped away. Mechanized systems are known, but they are defective. Examples about the state of the art can be found in, for example: JPH07119155, JPH03125722, JP H11-152753 A, WO2010/111947, WO2010/139380, NL7903255, EP0260143 and CN1766238.

[0005] The object of the invention is versatile. In one aspect, the aim is to avoid having workers in the work room present during sinking. In one aspect the goal is a mechanization such that outside the workroom, for example on top of the caisson, the process of excavating

in the workroom can be followed reliably, so that the process can be controlled outside the workroom. In one aspect, the aim is to make the soil pumpable not only by means of spraying loose, but also by means of mechanical cutting. Loosening has the advantage that soil can be pumped away and removed in larger chunks, so that the separation of the water outside the caisson can take place more quickly and effectively. This is particularly important for extremely fine granular materials such as silt, malm and clay. In one aspect, the goal is to be able to measure the process of loosening and discharging soil so as to be able to control the process on efficiency. Other aspects will be apparent from the foregoing or the following.

[0006] According to the invention, in the working chamber an excavation technique, such as a dredge technique, is used, so in the working chamber there is a layer of water and an in the water protruding element, such as a dredge element, for example dredge pump. This element forms part of, for example, a device comprising the following: A rotating central attachment, an adjustable arm construction, for example sliding or articulating several parts for a flexible range of the free end with a soil removing tool such as a dredge pump with sprays, a cutting or milling head. This earth removing device is preferably suspended from the ceiling. The excavation element excavates and/or erodes the water bottom

[0007] According to the invention, liquid (such as water) is used for excavating the soil, and the excavation takes place under wet conditions and the material released from the soil is made pumpable by mixing with this liquid, and the material released is pumped out of the work chamber. and flows away from the work room by a pipe extending from the work room.

[0008] Preferably, an air layer is present in the work chamber above the layer of water (the usual English term for this is "head space"), preferably this air layer has a height from the ceiling of the workroom such that the view in the workroom is optimally free, the dredge pump is sufficient under water and quick switching is possible for specific situations between completely dry working chamber (supply of extra air, pumping of water), and completely under water (removal of air, the supply of water). For example, the air layer has a height of 0.5 or 1.0 or 2 meters or a height of at least 0.5 or 1.0 or 2.0 meters.

[0009] The air layer gives one or more of the following advantages: protection of parts of the workroom and/or tools or parts thereof located therein against the groundwater located in the workroom and substances therein, such as sand; better monitoring with cameras which are located above water in the working chamber and of which the vision is not impeded by the turbidity of water; provides the possibility to work efficiently with water jets directed at the bottom from a high level, for example from the ceiling.

[0010] In order to support the range or efficiency of the excavating element, one or more water jets are used in the working chamber, preferably from a water cannon in

the working chamber, preferably suspended from the ceiling. The water jets preferably process the soil in areas that are unreachable for the excavation element/dredge element. The suspension points of the water cannons are located mutually and/or in relation to the suspension point of the excavating element at a distance, preferably measured parallel to the caisson bottom, for instance at least 0.5 or 2 meters (mutually) respectively 3 or 5 meters (excavation element).

[0011] Excavation element and/or water cannons/water jets are preferably controlled in distance from their suspension point and/or in direction to cover a bottom area and thus to be excavated over the entire range.

[0012] A possible procedure is as follows: during operation of the water jets, the water layer is minimal or missing so that the water jets can work the soil as good as possible.

[0013] During operation of the excavating element/dredge element, the water layer is sufficiently deep to be able to dredge properly, for example at least 0.5 or 1.0 meters. Preferably, one or more of the following applies: during the sinking, the caisson rests directly or interposed with one or more shape solid bodies on the ground and/or does not float on a liquid such as water; the method or apparatus is suitable for all in a delta area, such as Holland, common types of soil, such as peat, clay, loam, sand, gravel, and that, in consistencies of loosely to very solid, or where appropriate consolidated; cohesive types of soil, such as clay, are in small chunks dredged/excavated, for example, in order to allow fast settling after discharge; an excavation or dredge element, such as a dredge pump, possibly loosening the soil, such as one or more of water sprays, cutting head or milling head for excavating and possibly pumping the soil as a groundwater suspension as a discharge system; the excavation/dredge element is part of a, preferably spatially, movable support arm, for example, attached to a central, preferably rotating, attachment point of the caisson, for example an attachment point situated at the caisson bottom; a rotatable and/or slidable support arm under the caisson bottom/work space ceiling; the supporting arm has a length of at least 5 meters, for example, about 8 meters, which length relates to the fully extended supporting arm in the case of a supporting arm of adjustable length, for instance by telescoping means; the supporting arm drive is located above the caisson bottom and/or the ceiling of the work room; application of remote-controlled water jets independent of the excavating element, which preferably cover the area to be excavated in the work area where the excavation element can not enter; the attachment of the suspension structure of the carrying arm is on top of the caisson bottom; a guiding slide structure for the supporting arm, preferably for sliding in the longitudinal direction, with the required drive; a fixed length of the support arm, preferably mounted on sliding means for shifting the support arm longitudinally; a straight arm over at least 80% or 90% of its length; a drive for directing the excavating/dredge element/pump

housing; a dredge pump with a connection for sand hive with, optionally, water sprays or cutter head with water sprays if necessary; measure and control technology for monitoring attitude pump house/excavation/dredge element; swivel connection soil for example dredge sludge discharge line of the dredge pump/excavation element, possibly with remote-controlled emergency shut-off valve; swivel connection water supply line of the dredge pump, possibly with remote-controlled emergency shut-off valve; remote-controlled water cannons, which supply water jets, mounted on the ceiling of the work space; monitoring and recording systems for air pressures and air purity in the work space; dredge element capacity at least 10 or 20 or 30 or 60 m³/hour dry matter net for loose-grained materials, such as sand, which in practice usually corresponds to at least 15 or 30 or 45 or 50 or 100 m³/hour of gross excavated soil (a sandy bottom usually has a pore content of between 30 and 40%; thus, for example, at a pore content of 40% at a capacity of 50 m³/h gross excavation 30 m³/hour of dry matter net is excavated); dredge element capacity for cohesive soil types net minimum 10 or 20 or 30 m³/h; dredge pump capacity at least 50 or 100 m³/hour and/or at most 500 or 1000 m³/hour, for example 400 m³/hour; the liquid mixture which is pumped away from the working chamber, for example, by the dredge pump, contains at least 10% and/or at most 35 or 40 or 50% dry matter, preferably between 20 and 30%, such as about 25% dry matter (too little dry matter is inefficient, too much leads to clogging of the from the workroom extending drain pipe); in the work room, depending of the prevailing water pressure, a pneumatic overpressure, preferably at least 0.01 or 0.25 or 0.5 or 1 or 2 or 2.5 or 5 or at most 5 bar (in practice usually not higher than 3 bar) increased with respect to atmospheric pressure; the groundwater level directly below the caisson has been temporarily artificially lowered to a distance, preferably at least 0.5 or 1 meter, below the ceiling of the workroom; the ground water level is inside the working chamber, in particular when using a dredge pump, such that preferably of the dredge pump, the head is at least 0.5 or 1 meter under water; the supporting arm carries at its extremity an excavating member, for example dredge pump with, for example, cutting head; the dredge pump/excavation element is connected to a water supply pipe and a soil/dredge sludge pipe, which both pipes debouch outside the working chamber; the working chamber has a maximum height of 5 or 10 meters during the immersion of the caisson (the vertical distance between the levelled soil (formed by the substrate to be excavated) of the workroom and the ceiling (formed by the caisson bottom) of the workroom).

[0014] Possible alternatives for the suspension point and/or the excavation element: water cannon or bucket or jet needles or dredge wheel or grab or plough or harrow; excavating element on an articulated arm with, for example, fixed pivot point; the suspension point moves along rigid arm suspended around a vertical axis; the suspension point is movable along rails at e.g. ceiling;

the suspension point is located on a chassis running over the ground. Preferably, the movements of the excavating element become one or more of measured, recorded and visualized with the use of an apparatus, for example a camera, which is placed inside the workspace, for example for dimensional representation where soil has been dredged away.

[0015] Preferably, data, for example one or more of power, speed, flow rate, fluid pressure, flow rate and dry matter content, of one or more of the excavating element, the cutting head and the contents of the dredge sludge pipe are measured and/or recorded, for example to control process efficiency.

[0016] If desired, the working space can be filled with, preferably solid, filling material, such as granular material such as sand or hardening material such as concrete, after completion of the sinking.

[0017] The work space has, for example, seen in plan view, an elongated, for instance rectangular, shape, for example a length at least 1.5 times the width, for example 15 meters wide and 25 meters long. For example, a straight side is at least 10 meters long.

[0018] The dry matter content of the dredge sludge can, for example, be determined by measuring the density of the dredge sludge.

[0019] The dredge sludge discharge pipe is preferably provided with one or more sensors sensitive to the contents of the pipe, for instance for measuring the flow velocity and/or pressure of the liquid inside the pipe, preferably near the pipe end debouching into the working space. For example, the dredge sludge pipe is at least 10 or 50 or 100 meters long.

[0020] The terms "excavation element", "dredge element", "pump housing" and "dredge pump" can be considered as synonymous with each other.

[0021] The accompanying drawing shows one of the many possible embodiments of the invention.

FIG. 1 AC schematically shows the three main phases during traditional sinking, with people in the workspace;

FIG. 2 and 3 show perspectives view of an embodiment of the inventive dredge arm in operation from opposite view directions;

FIG. 4 is a perspective view of a detail of FIG. 3;

FIG. 5 is a perspective view of another detail of FIG. 3, at two different times during disassembly;

FIG. 6 schematically shows the application of the invention in the workspace;

FIG. 7 shows a water cannon as an excavating element on an articulated arm with fixed pivot point;

FIG. 8 shows how the suspension point moves along a rigid arm suspended rotatably about a vertical axis; the excavating element is a bucket;

FIG. 9 shows Jet needles as an alternative excavation element;

FIG. 10 shows the suspension point movable along rails on the ceiling, the dredge wheel is excavation

element;

FIG. 11 shows the suspension point on an undercarriage running over the ground, the dredge head is excavation element;

FIG. 12 shows a gripper as excavation element; and FIG. 13 shows a plow or harrow as an excavation element.

[0022] FIG. 1A shows the beginning of the excavation in the workspace, where a worker is in the workspace. An airlock is indicated by 11. In FIG. 1B the workspace is completely excavated so that the caisson can move downwards. There are now three workers in the workspace. In FIG. 1C, the sinking is completed, the desired final depth is achieved with the caisson. In this example, the working space is filled with filling material, such as hardening material such as concrete.

[0023] Meaning of the reference signs: 1 arm; 2 bottom caisson; 3 dredge head; 4 water jet; 5 camera; 6 water level; 7 level local groundwater; 8 lighting; 9 suspension point arm 1; 10 sliding guide of suspension point 9; 11 lid; arrow X direction of slide movement arm 1; arrow A outflowing water, for example water jet; arrow B incoming dredge sludge.

[0024] The dredge head 3 pivots about a horizontal axis relative to the arm 1; the arm 1 pivots about a vertical axis with respect to the bottom 2 and can slide in its longitudinal direction (arrow X).

[0025] The dredge head 3 contains a pump which emits water via the cutting head (arrow A) and draws dredge material behind the cutting head (arrow B). The supply and discharge lines for water and dredge sludge run from the head 3 along the arm 1 to the suspension point 9 of the arm and from there up through the mounting hole in the caisson bottom 2 and open out of the working chamber into a water source or a water source. grout.

[0026] With disassembled arm 1 (Fig. 5, so the arm 1 is missing in Fig. 5), the sliding guide 10 can be seen at the lower end of the vertical suspension tube 9. The suspension tube 9 is mounted on top of the bottom 2 in Fig. 5 by mounting means (e.g. threaded ends) and can be designed with a lifting device. The lower end of the mounting tube can be retracted into the bottom 2. In the retracted position (right-hand image of Fig. 5), the mounting hole can be closed airtight from below with a cover 11 so that the mounting hole is freely accessible from above for handling the suspension tube. When the suspension tube is installed according to the regulations, the mounting hole is closed air-tight from above and the suspension tube can be fitted leak-free at the bottom of the bottom 2 (left-hand picture of fig. 5). Thus, the air-tightness of the workroom is ensured during operation and also during the assembly/disassembly of the excavation device.

[0027] FIG. 6 shows a workspace that is partially submerged. In the flooded part the dredger head 3 is active and is flooded. In the part where the bottom of the workroom is dry, water jets supplied by water cannon 4 are active. The water-sand mixture made by the water jets

flows to the lower area where the dredger head is active. With a camera 5, the process inside the workspace is supervised from outside the workspace. Water canon 4 and camera 5 are located above the liquid mirror 6 in the working chamber. In order to keep the upper part of the workroom dry, the groundwater level is artificially lowered directly from the level 7 to the level 6 below the caisson by using a pneumatic pressure well above the atmospheric pressure in the workroom.

[0028] At the beginning of the process of sinking of the caisson the working chamber is at a pneumatic pressure, for example, approximately equal to the atmospheric pressure, it is in the course of the process of lowering elevated dependent from the local groundwater pressure at the depth at which the caisson is located in order to control the height of the dry space sufficiently accurately, in order to artificially and temporarily reduce the groundwater level in the workroom. This pressure increase is as a rule at least 0.01 or 0.25 or 0.5 bar.

[0029] The features disclosed herein can be taken together individually in any other conceivable combination and permutation to provide an alternative to the invention. Included are also technical equivalents and genus or generalizations of the revealed features. A feature of an example is also generally applicable within the scope of the invention. A feature disclosed herein, for example of an example, can be readily generalized for inclusion in a general definition of the invention, for example to be found in a patent claim.

[0030] The invention also relates to an apparatus for carrying out the method defined in one of the accompanying claims.

Claims

1. Method of mechanized and remote, from outside the workspace, controlled, digging out of the workroom under a structure, such as pneumatic caisson, with the aim to sink the caisson for example where the caisson is at least 5 meters high and moves vertically downwards during sinking over a distance of at least 5 meters, whereby the method is used in an area with relatively high local water level and during the sinking the caisson with its complete weight rests directly or with the interposition of one or more form-retaining bodies on the ground and does not float on a liquid such as water; wherein at the underside of the at least substantially airtight bottom of the caisson there is a downwardly extending cutting edge which laterally delimits the at least substantially airtight working chamber; and the caisson bottom forms the ceiling of the workroom and the ground forms the bottom of the workroom, and by excavating the workroom the caisson sinks under its own weight in the soil and becomes a complete or partial underground or underwater construction work; the caisson bottom sinks below the local

water level below and around the caisson; by introducing air the air pressure in the working chamber is increased and the water level below the caisson is thus temporarily reduced, so that the working chamber remains at least partly dry;

the air pressure in the workroom is increased in the course of the sinking process depending on the locally prevailing water pressure at the depth at which the caisson is located in order to control the height of the dry space inside the workroom with sufficient accuracy, in order to maintain the artificially and temporarily reduced water level in the work room; the substrate that is excavated in the workspace is preferably sandy soil;

in the working chamber a wet excavation technique, such as a dredge technique, is used, so in the working chamber there is a layer of water and an excavating member protruding into the water, such as a dredge element, is employed in the working chamber, wherein this excavating element is part of an excavating device.

2. Method according to claim 1, wherein the excavating device comprises one or more of the following: a rotating central attachment; an adjustable arm construction with a length of at least 5 meters in the fully extended state, for instance from several parts sliding or articulating, for example articulated, for a flexible range of the free end with the excavating element thereby spatially movable; the excavating device is suspended by its rotating central fixing to the ceiling of the working chamber and/or excavates and erodes the ground, such as water bottom, of the working chamber with the purpose of making the excavated soil pumpable.

3. Method as claimed in claim 1 or 2, the excavating element is equipped with soil loosening provisions, comprising one or more of: one or more water sprays; a mechanically ground eroding element, such as a milling or cutting head, and a dredge pump, for excavating and pumping the soil as dredge spoil of soil and water.

4. Method according to one of claims 1 - 3, one works with water jets coming from the ceiling of the working chamber and directed to the substrate, and the water jets come from a water cannon, which is arranged in the working chamber, for example is suspended from the ceiling, these water jets treat the soil in areas which are unreachable for the dredge element, in which a water jet is relatively thick and powerful and is capable of independently eroding the soil; and/or the dredge element is controlled in distance from its suspension point and pivotally around its suspension point and the water cannon is controlled in direction, depending on the image shown on the screen, and thus at least substantially the entire bottom area is

covered and thus the entire bottom area is excavated, and this management takes place from outside the workspace.

5. Method according to one of Claims 1 - 4, with one or more of the following:

- the excavation element removes at least 10 m³/hour net of dry matter, such as sand, from the work room;
- the water level directly below the caisson is temporarily artificially lowered to a distance of at least 0.5 meters below the ceiling of the work room so that an air layer with a height of at least 0.5 meters is located in the work room above the layer of water;
- the excavating element is connected to a water supply pipe and a dredge sludge discharge pipe, which both pipes discharge outside the working chamber;
- to the water cannon, and via the water-supply pipe to the excavating element, water is supplied from outside the working chamber and a dredge sludge of soil and water is made inside the working chamber by the action of the excavating element and the water cannon and the dredge sludge is brought via the sludge drain pipe, which is connected to the excavation element, outside the working chamber;
- in the area where the from the water cannon coming jets are active the water layer is absent so that the water jets are able to process the bottom as well as possible, in the area where the excavating element is operable, the water layer is at least 0.5 meters deep in order to properly dredge;
- at the end of the process, the working space is filled with filling material, such as hardening concrete.

6. A method according to any one of claims 1 - 5, the excavating element (3) pivots relative to the arm (1) around a horizontal axis; and/or the arm (1) pivots about a vertical axis with respect to the bottom (2) and/or can slide in its longitudinal direction (arrow X).

7. Method according to one of Claims 1 - 6, with one or more of the following: the excavation element comprises a pump which emits water via the cutting head (arrow A) and/or draws dredge material behind the cutting head (arrow B); the supply and discharge lines for water and dredge sludge run from the excavation element (3) along the arm (1) to the suspension point of the arm and from there upwards, for example into the installation hole, through the caisson bottom (2) and debouches outside the working chamber in a water source resp. sludge container.

8. Method according to one of claims 1 to 7, with one or more of: the arm (1) is mounted to the lower end of a vertical suspension tube mounted on top of the bottom (2) by mounting means and projects through a mounting hole in the bottom (2); the lower end of the mounting tube can be retracted into the bottom (2); in the retracted position the mounting hole can be closed airtight from below with a cover so that the mounting hole is freely accessible from above for handling the suspension tube; when the suspension tube is mounted, the mounting hole is sealed airtight from above and the suspension tube can extend from below the bottom (2) leak-free; thus the air-tightness of the working chamber is ensured during operation and also during the assembly/disassembly of the excavation device.

9. A method according to any one of claims 1 - 8, with one or more of: the floor of the work room shows a difference in level and the work room is partially submerged; in the lower, flooded part, the excavation element (3) is active and is flooded; in the upper part where the bottom of the workroom is dry, water jets supplied by the water cannon (4) are active; the mixture of water and soil, such as sand, that is made by the water jets flows to the lower area where the excavation element is active.

10. Method according to one of claims 1 - 9, with a camera (5), the process inside the work room is supervised from outside the work room; and/or water cannon (4) and/or camera (5) are located above the liquid level (6) in the workroom.

11. Method according to any one of claims 1-10, liquid such as water is used for excavating the soil, and the excavation takes place under wet conditions and the material released from the soil is made pumpable by mixing with this liquid, and material released is pumped out of the workroom and flows out of the workroom by a pipe extending from the workroom; and/or where the workroom is without any diver during sinking.

12. Method according to one of Claims 1 - 11, the suspension points of the water cannons are located mutually and/or in relation to the suspension point of the excavating element at a distance, preferably measured parallel to the caisson bottom, for instance at least 0.5 meters mutually respectively 3 meters to the excavation element; and/or the excavation element and/or water cannons/water jets are controlled in distance to their suspension point and/or in direction to cover a bottom area and thus to be able to excavate over the entire range.

13. Method according to one of Claims 1 - 12, with one or more of: the dredge pump pumping at least 50

and/or at most 1000 m³/h; the liquid mixture that is pumped out of the working chamber contains a minimum of 10% and/or a maximum of 50% dry matter; in the working chamber there is a pneumatic overpressure of at least 0.25 and/or a maximum of 5 bar increased in relation to atmospheric pressure; the workroom has a maximum height of 10 meters during the sinking of the caisson. 5

14. Method according to one or more of claims 1-13, and data, for example one or more of power, rotational speed, flow rate, fluid pressure, flow amount and dry matter content, of one or more of the excavation element, the cutting head and the contents of the dredge sludge pipe are measured and/or recorded, for example to control the process efficiency; and/or the dredge sludge discharge pipe is provided with one or more sensors sensitive to the contents of the pipe, for instance for measuring the flow velocity and/or pressure of the liquid inside the pipe, preferably near the pipe end opening into the working space. 10 15 20

15. Method as claimed in any of the claims 1-14, with one or more of: the dredge sludge discharge pipe is at least 10 meters long; the work space has, in plan view, an elongate, for example rectangular, shape, for example a length at least 1.5 times the width; of the working chamber a straight side is, at least 10 meters long. 25 30

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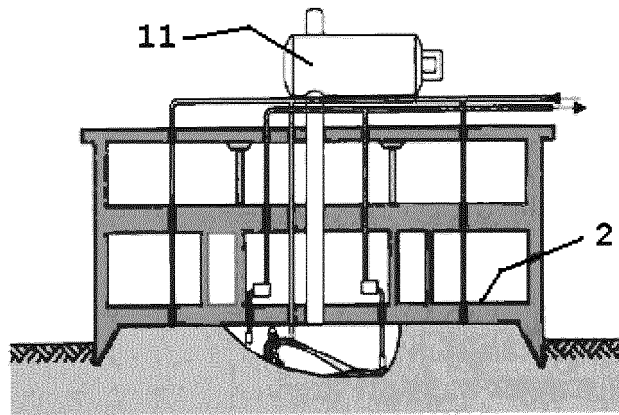


Fig.1A

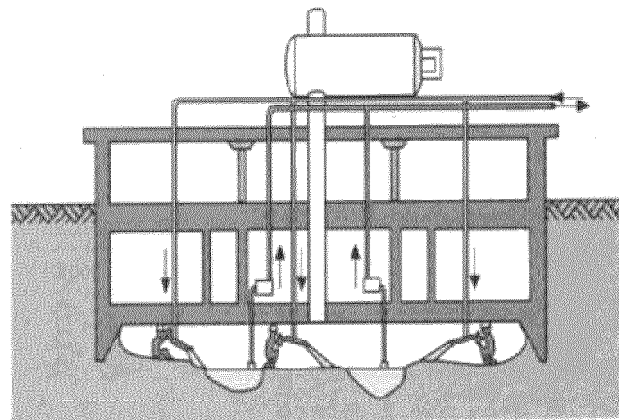


Fig.1B

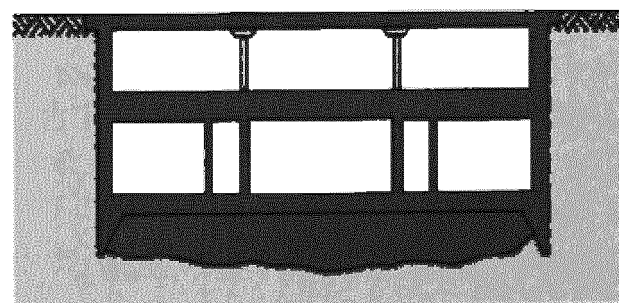


Fig. 1C

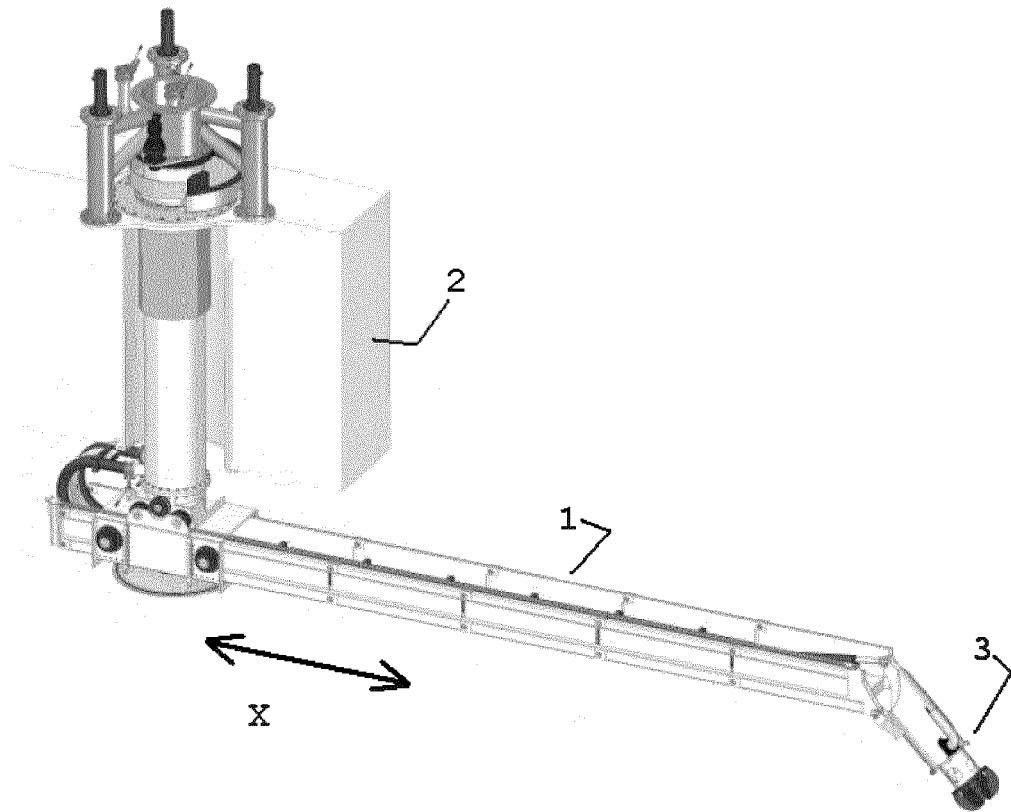


Fig. 2

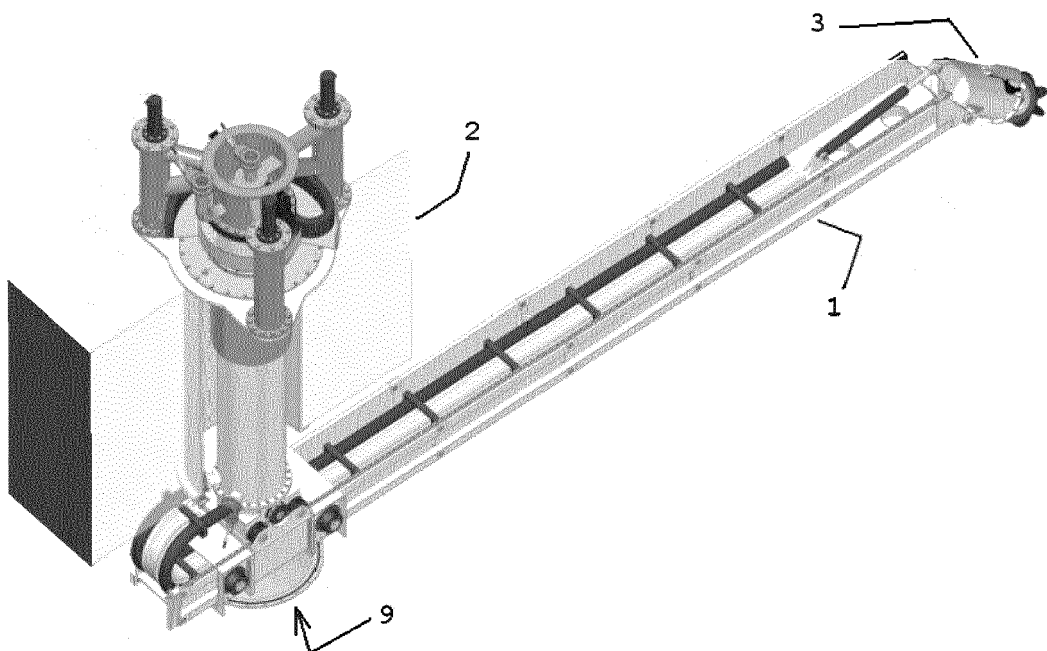


Fig. 3

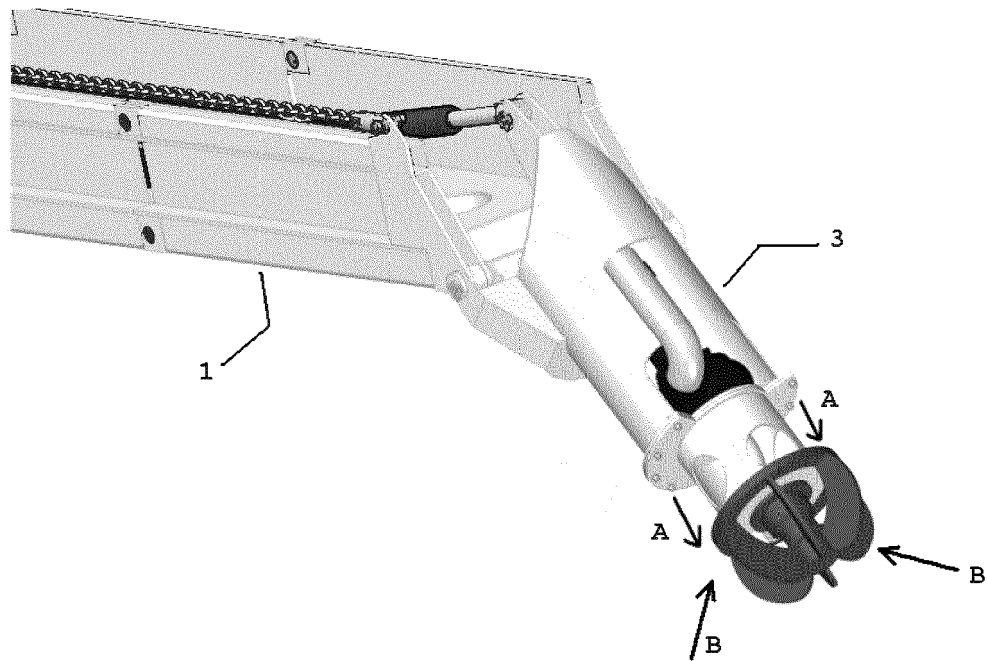


Fig. 4

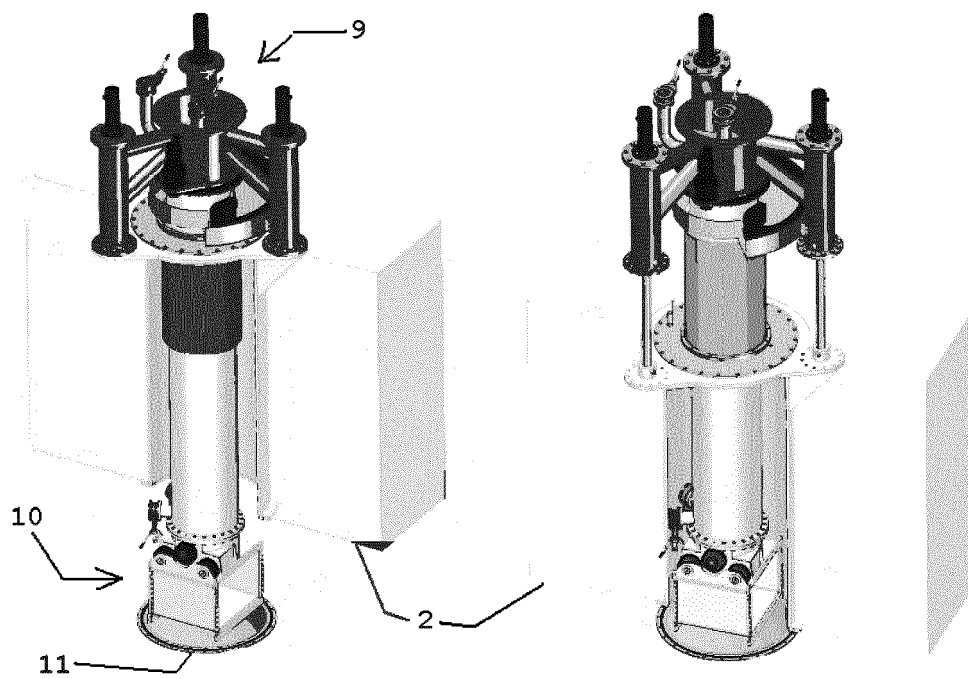


Fig. 5

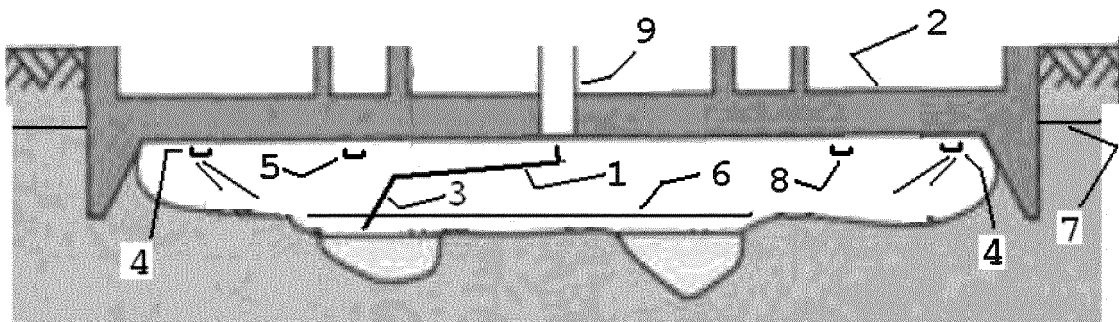


Fig. 6

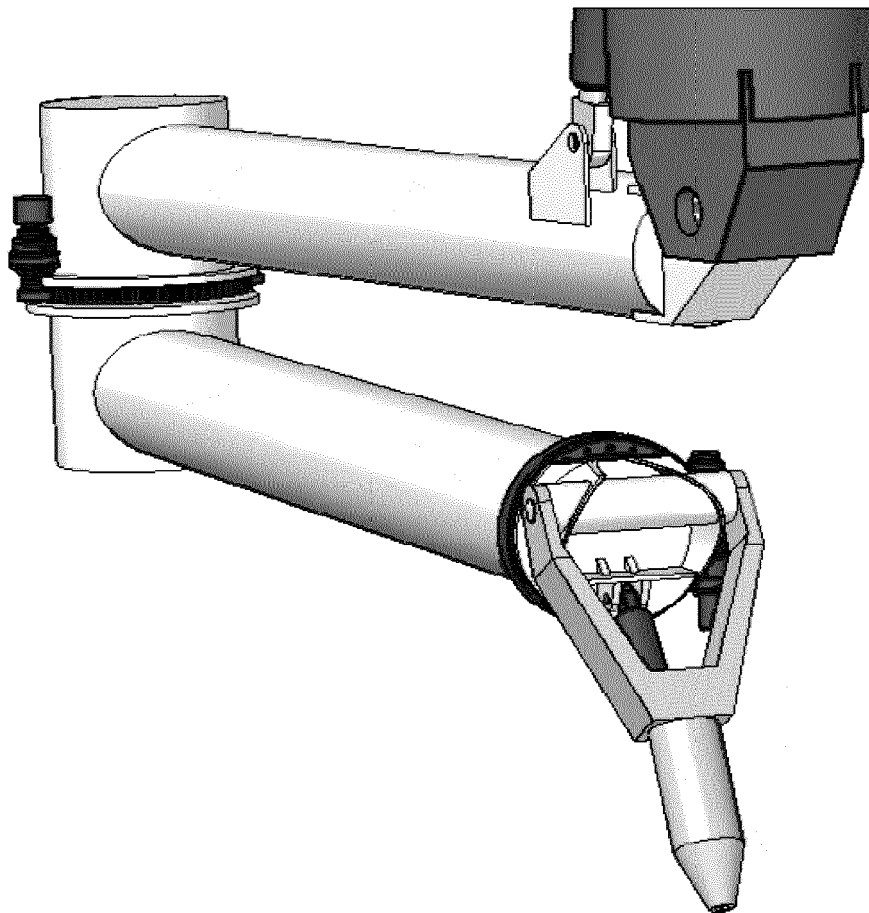


Fig. 7

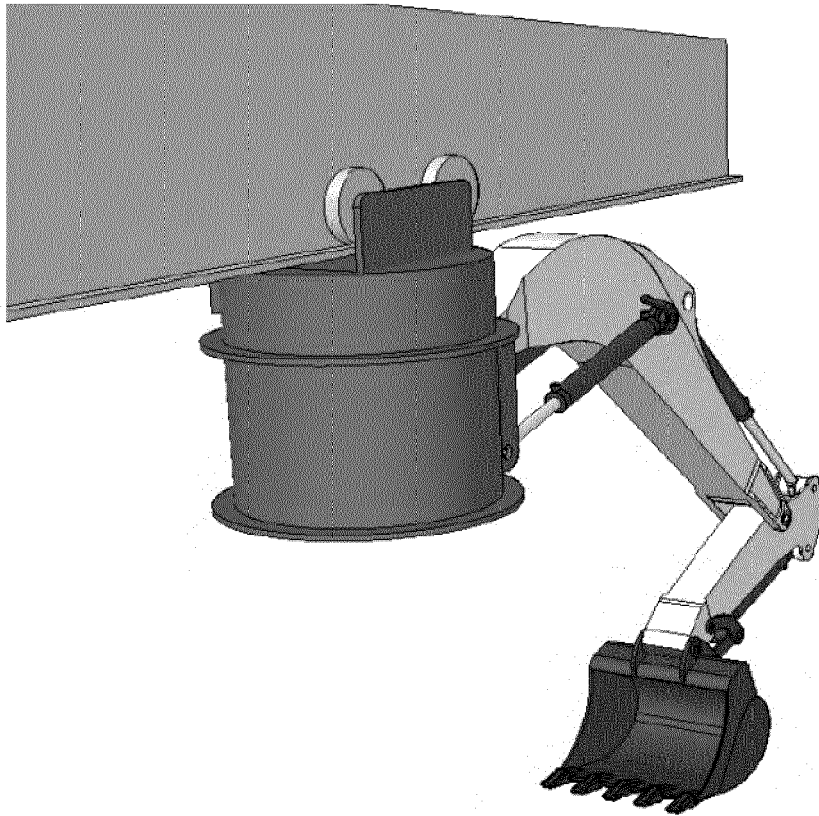


Fig. 8

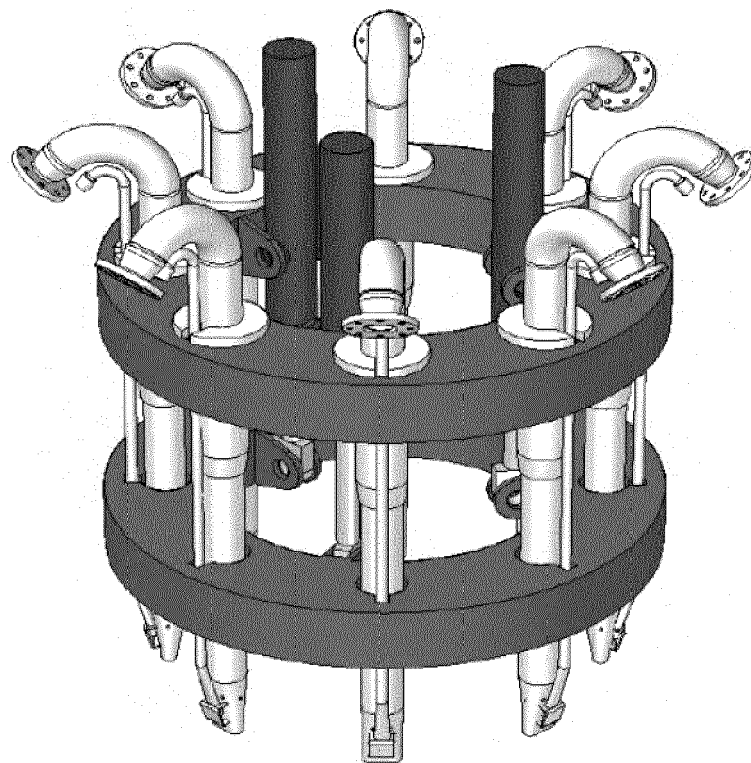


Fig. 9

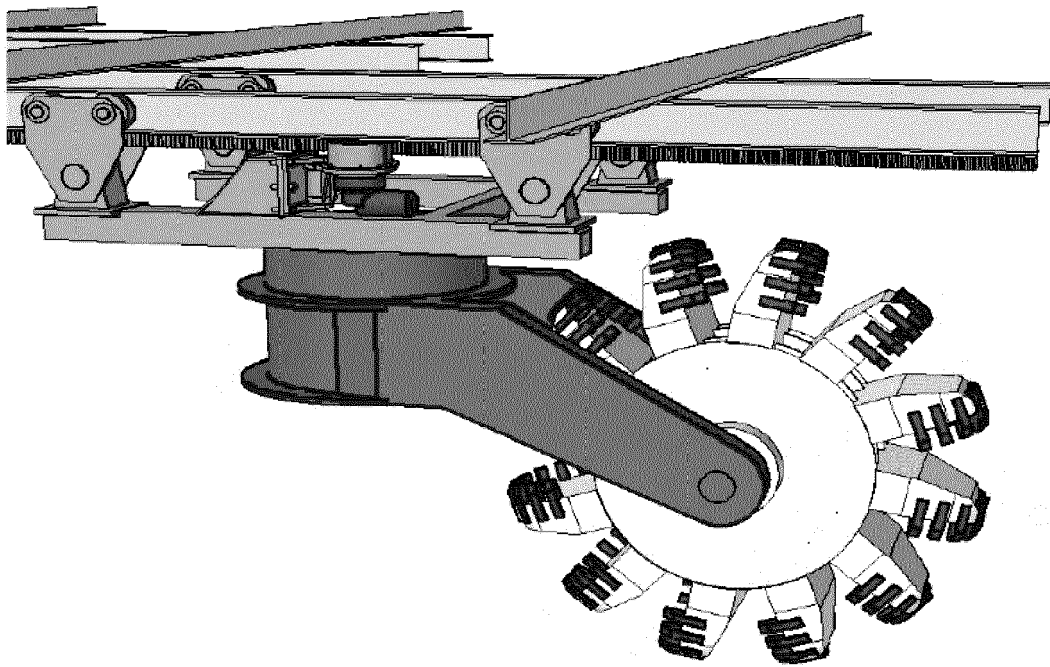


Fig. 10

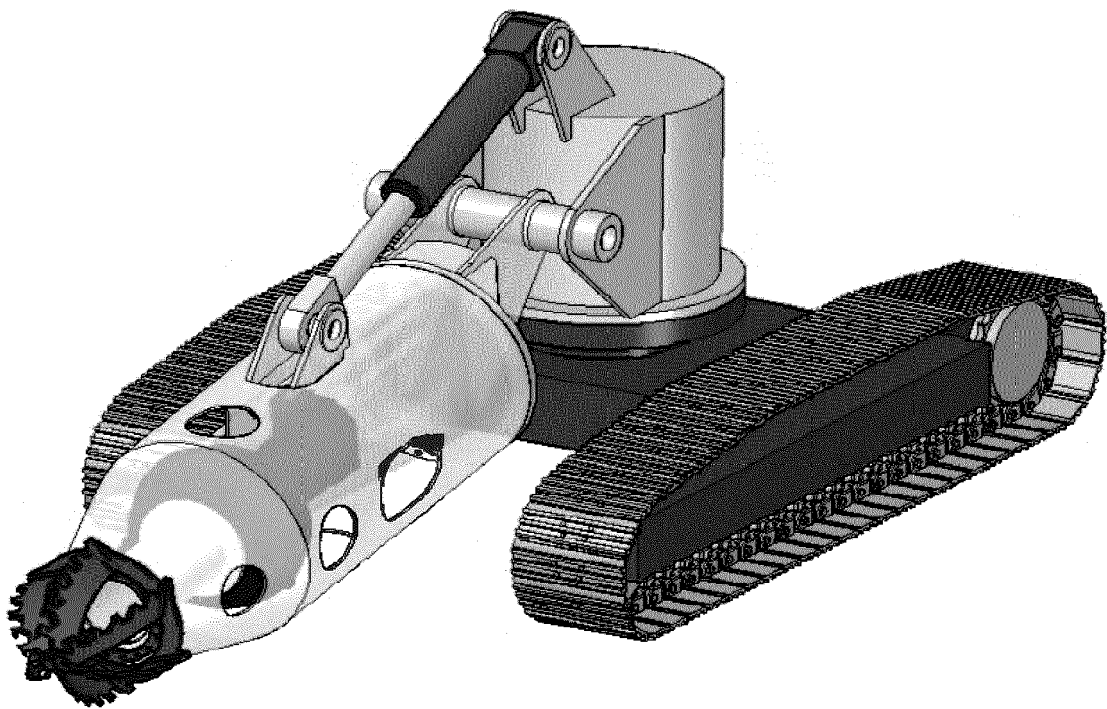


Fig. 11

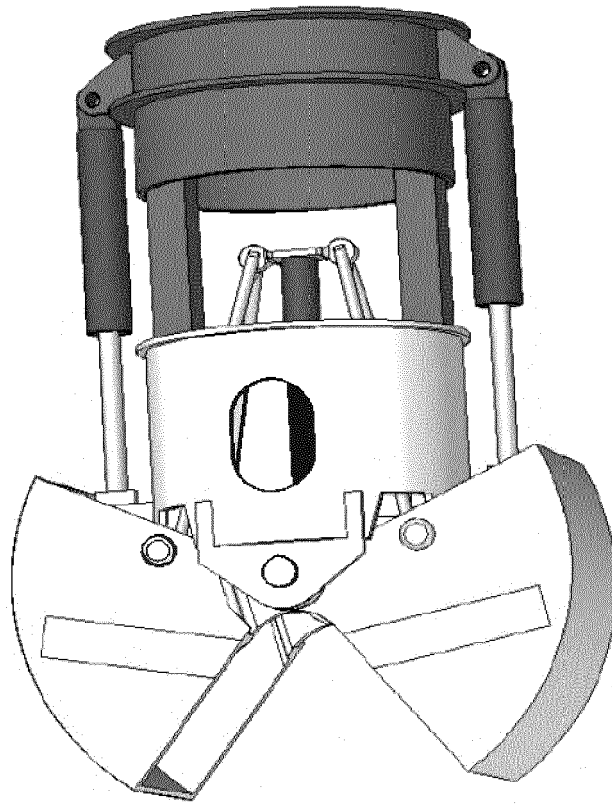


Fig. 12

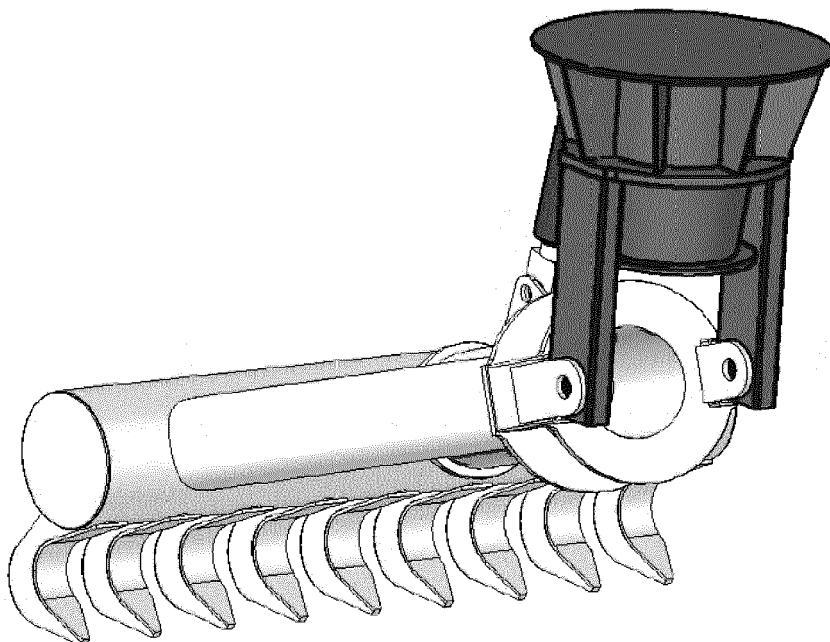


Fig. 13



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Place of search Munich		Date of completion of the search 10 October 2018	Examiner Friedrich, Albert
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