(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 322 728 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.05.2011 Bulletin 2011/20

(21) Application number: **10190665.9**

(22) Date of filing: **10.11.2010**

(51) Int Cl.:
E02F 3/96 (2006.01) ***E02F 5/00*** (2006.01)
E02F 5/10 (2006.01) ***E02F 5/14*** (2006.01)
E02F 9/20 (2006.01) ***E02F 3/43*** (2006.01)
E02F 5/28 (2006.01) ***G05B 13/02*** (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **13.11.2009 NL 2003800**

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(54) **Backhoe dredger for dredging soil material under water**

(57) The invention relates to a device (1) for dredging soil material under water. The device comprises a pontoon (6), provided with an excavator (10) adapted to excavate soil under water, and actuating means (7,16,17,18,19) adapted to control the motion of the pontoon and/or the excavator. The device further comprises first monitoring means (30,35) adapted to monitor the position of the excavator; second monitoring means (31) adapted to monitor the forces experienced by the excavator; and computing means (33) adapted to compute, on the basis of data obtained from the first and the second monitoring means, control signals for the actuating means. The invention also relates to a method for dredging soil material under water, using the invented device, and to a computer program comprising program instructions that when loaded into a computer carries out the method.

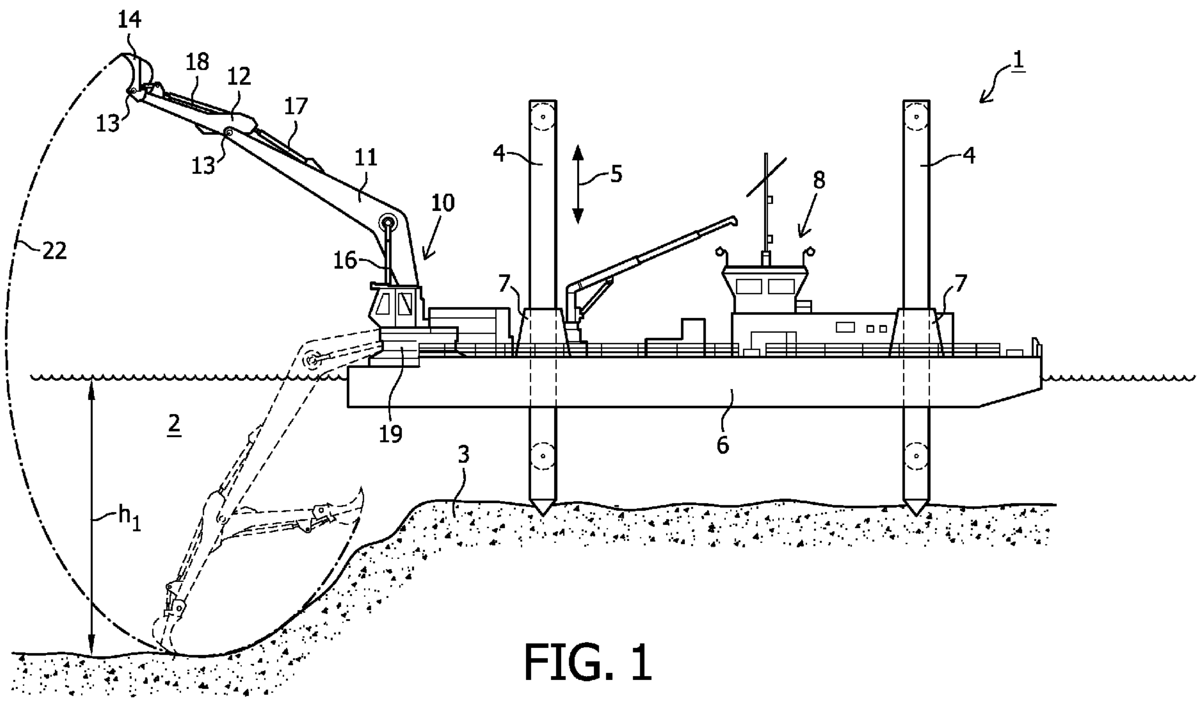

FIG. 1

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Description

[0001] This invention relates to a device, such as a backhoe dredger, for dredging soil material under water to a prescribed depth. The invention also relates to a method for dredging soil material under water, as well as to a computer program, comprising program instructions adapted to carry out the method.

[0002] A device, such as a backhoe dredger, is generally used to excavate or dredge soil material under water at locations where other dredgers such as trailing suction hopper dredgers and cutter suction dredgers are less suited. Such locations include busy access channels, hard soil types, (very) shallow waters and hard to reach places, for instance harbor entrances. A conventional backhoe dredger typically comprises a (sometimes land based) excavator mounted on a pontoon. The excavator comprises lifting booms, actuated by hydraulic cylinders, and a bucket to dig up soil material from under the water level. The dredged soil material is brought above the water level and dropped in and removed by a barge, located in the vicinity of the pontoon.

[0003] A typical dredging cycle using a backhoe dredger involves preparing a survey of the state of the underwater bottom, which state at least includes charting the depth of the bottom and/or the properties of the soil material in the area of interest. A work plan is then made up for the operator of the backhoe dredger and the excavator, roughly taking into account the state of the bottom area to be dredged and the desired state of the bottom area (typically the desired depth profile). The work plan involves determining the lines along which the pontoon should be positioned, as well as giving a rough indication of the excavating depth along said lines. The bottom area is then dredged by the operator, which typically involves the steps of positioning the pontoon onto a line to be excavated, excavate soil material along the line, repositioning the pontoon to another line to be dredged, and repeating the above.

[0004] However, as the soil properties are only known at very sparse points, this approach is only an average. The actual excavating action is determined by the operators feeling, based on very subjective feedback (response of the excavator in terms of noise, vibrations, motion, etc.) and on its previous experience in similar situations. The efficiency of dredging needs improvement.

[0005] It is an object of the present invention therefore to overcome the drawbacks of the above described prior art device and method, and provide a device and method for dredging soil material under water that permits a higher efficiency of operation.

[0006] In one aspect of the invention, there is thus provided a device for dredging soil material under water, the device comprising:

- a pontoon, provided with an excavator adapted to excavate soil under water;
- actuating means adapted to control the motion of the pontoon and/or the excavator;
- first monitoring means adapted to monitor the position of the excavator;

the device further comprising

- second monitoring means adapted to monitor the forces experienced by the excavator; and
- computing means adapted to compute, on the basis of data obtained from the first and the second monitoring means, control signals for the actuating means.

[0007] The device according to the invention allows to promptly and accurately excavate soil material under water to a predetermined depth profile, whereby the depth and /or the position in the plane of excavation are regulated automatically, depending on the actual position of the excavator and the force values obtained from the second monitoring means. The motion of the pontoon includes leveling of the pontoon.

[0008] The invention also relates to a method for dredging soil material under water, the method comprising the steps of:

- providing a device according to the invention;
- positioning the pontoon of the device in a water;
- controlling the motion of the excavator of the device by the actuator means such that soil is excavated under water;
- monitoring the position of the excavator and the forces experienced by the excavator during the motion thereof;
- computing, on the basis of data obtained from the first and the second monitoring means, control signals for the actuating means;

the excavator being moved according to these control signals.

[0009] The method according to the invention is particularly useful in optimizing a dredging operation along one cut line, i.e. in an embodiment when the pontoon is itself in a (temporarily) stationary position. The method of the invention eliminates substantially the variability associated with human action by providing a control loop, in which the excavator motion is controlled in function of its actual position and the actual forces it experiences.

[0010] The device and method of the invention allow to lower downtime, due to overloaded mechanical structures, protect against overload, and maintain a more constant quality of dredging over time. Also, the device and method of the invention allow to take into account varying soil sediment properties - the very nature of sedimentation causes such variation - which are not well known, for instance due to the generally rather low grid resolution of taking samples.

[0011] In a further aspect of the invention, a device is provided wherein the computing means are adapted to compute the control signals for the actuating means such that an optimum criterion is minimized. The optimum criterion can be chosen at will. In a particularly favorable device, the optimum criterion comprises the average power of the excavator used per unit volume excavated soil material. The power of the excavator can readily be obtained by multiplying the momentaneous displacements of the excavator and the forces experienced by the excavator, and summing these products. The power of the excavator can for instance be minimized or kept below a certain threshold value by lowering forces. Lowering forces can be achieved by limiting the excavating velocity and/or the cutting depth of excavation, whereby the cutting depth is the depth over which the bucket is driven into the soil. The forces generally also depend on the soil properties, whereby a denser or harder soil will lead to higher forces, and vice versa.

[0012] In another aspect of the invention, a device is provided wherein the optimum criterion comprises the maximum likely expected excavating time per unit volume excavated soil material.

[0013] A typical backhoe dredger is equipped with an excavator comprising a boom, pivotably provided on a substructure present on the deck of the pontoon, a stick, pivotable provided at one extremity of the boom, and a bucket, pivotably provided at one extremity of the stick. The pivoting movement of the boom with respect to the pontoon, of the stick with respect to the boom, and of the bucket, relative to the stick are brought about by hydraulic cylinders, provided on the substructure of the pontoon, on the boom, and on the stick respectively. The backhoe dredger preferably has the following degrees of freedom to perform its tasks:

- 3 rotations of the excavator around a horizontal axis (corresponding to the 3 pivoting points of the main and stick, and the bucket: these allow to position the bucket under water, to dig into the soil (haul) and to lift the material above the water;
- 1 rotation around a vertical axis: this degree of freedom enables the rotational positioning of the bucket, as well as the transport from the soil material to the barge aside;
- 1 horizontal translation (step) : when the digging of soil within the reach of the excavator has been finished, the pontoon needs to be moved to the next position, this is called stepping and is achieved by moving one of the spuds of the pontoon;
- 3 vertical translations providing lift and stability and enabling leveling of the pontoon (acquiring a horizontal position).

[0014] In specific conditions, trimming tanks may be used to distribute the weight to achieve horizontal leveling of the pontoon for instance. The specific rotations around a vertical axis locally lead to a typical circular digging pattern around a central point that corresponds to the pivot of the boom. Due to the stepping nature of the pontoon, the global patterns are cut lines next to each other at the same or varying depth along the center line or off the center line.

[0015] The device and method according to the invention allow to accurately excavate soil under water according to a predermined depth profile. When excavating a water bottom such as a sea floor or a navigation route near a quay, it is, generally speaking, extremely dangerous to excavate the sea floor or the navigation route beyond a prescribed excavation depth because such a deep excavation may destroy the foundation of the quay or walls formed in the sea floor. When excavating too deep, it becomes necessary to reload such an over-excavated portion, which however requires additional man power and time. The device and method according to the invention help in preventing this disadvantage.

[0016] In another aspect of the invention, a device is provided wherein the excavator comprises lifting booms, actuated by hydraulic cylinders, that are part of an hydraulic circuit, and the second monitoring means comprise hydraulic pressure sensors adapted to measure the pressure in the hydraulic circuit and/or cylinders. Hydraulic pressure sensors are known per se but not in the context of controlling the movement of for instance a backhoe dredger.

[0017] In still another aspect of the invention, a device is provided wherein the excavator comprises lifting booms, actuated by hydraulic cylinders, that are part of a hydraulic circuit, and the first monitoring means comprise displacement sensors adapted to measure the relative displacement of the lifting booms.

[0018] Although in principle providing first and second monitoring means is sufficient to carry out the method according to the invention, a device comprising third monitoring means adapted to monitor the position of the pontoon is preferred. In this way, the movement of the excavator can be related to the state of the underwater bottom as charted by a survey, which state at least includes the depth profile of the bottom and/or the properties of the soil material in the area of interest. Indeed a survey carried out before the actual start of the dredging operation yields an initial depth profile. After passage of the backhoe dredger, and with knowledge of the amount of soil material dredged, the new local depth can be calculated. By monitoring the position of the pontoon apart from the position of the excavator, an updated depth profile is obtained.

[0019] In an aspect of the invention, a device is provided wherein the third monitoring means comprise a global positioning system.

[0020] In yet another aspect of the invention, the device comprises an input/output device adapted to transfer the signals from the first monitoring means to the computing means. In yet another aspect of the invention, the device comprises an input/output device adapted to transfer the signals from the second and/or third monitoring means to the computing means.

[0021] In still another aspect of the invention, the device comprises display units adapted to display the position of the excavator and/or of the pontoon, as well as the forces experienced by the excavator.

[0022] In still another aspect of the invention, the device comprises a display unit adapted to display the depth of the soil under water.

[0023] The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a side view of the outline structure of a hydraulic backhoe ship;
Figure 2 is a top view of the backhoe ship shown in figure 1;
Figure 3 is a schematic diagram of the device according to an embodiment of the invention; and
Figure 4 schematically represents the degrees of freedom of an excavator according to an embodiment of the invention;

[0024] With reference to figure 1, a hydraulic backhoe ship 1 is schematically shown. The backhoe ship 1 comprises a pontoon 6 that is positioned in water 2 above a water bottom 3 to be dredged. Pontoon 6 is provided with a number of spuds 4 than can take support onto the water bottom 3. The pontoon 6 is held on the spuds 4 by a number of swivels 7 in such a way that the pontoon 6 is slidable up and down in the vertical direction 5 along the spuds 4, but is substantially restrained from moving horizontally across the water 2. The pontoon 6 ascends along the spuds 4 as the tidal level rises, and descends along the spuds 4 as the tidal level lowers. The depth h_1 of the water bottom 3 (and also the distance between the water bottom 3 and the pontoon 5) may therefore change in accordance with the tidal level. The backhoe ship 1 is further equipped with a bridge 8 that comprises at least the actuating means adapted to control the motion of the pontoon 6, and a backhoe excavator 10.

[0025] Backhoe excavator 10 comprises a boom 11 hingedly supported on the deck of pontoon 6, a stick 12 supported swingably on the boom 11 around hinge 13, an a bucket 14 supported turnably on the stick 12 around hinge 15. The lifting booms (11, 12) and bucket 14 of excavator 10 are actuated by hydraulic cylinders (16, 17 and 18), that are part of a hydraulic circuit (not shown). In the embodiment shown the degrees of freedom of the backhoe dredger 10 to perform its tasks comprise 3 rotations of the excavator around a horizontal axis, corresponding to the 3 pivoting points of the boom 11, the stick 12, and the bucket 14, and actuated by hydraulic cylinders (16, 17 and 18). These allow to position the bucket 14 under water, as shown by the position in dotted line in figure 1, to dig into the soil of bottom 3 by hauling, and to lift the soil material above the water 2. Another degree of freedom comprises the rotation of the boom 11 around a turntable 19. This degree of freedom enables the rotational positioning of the bucket 14, as well as the transport of the dredged soil material 20 to a barge 21, lying aside the pontoon 6, as shown in figure 2. Another degree of freedom comprises the horizontal translation of the pontoon 6 (a 'step'). When the digging of soil material 20 within the reach 22 of the excavator 10 has been finished, the pontoon 6 needs to be moved to a next position, a process referred to as 'stepping'. This is achieved by retracting at least one of the spuds 4 of the pontoon 6 from the bottom 3, moving (or swinging) the pontoon 6 and lowering the spud 4 into the bottom 3 again to fix the pontoon 6 in its new position. It is also possible to add 3 other degrees of freedom, being vertical translations of the pontoon 6 along the spuds 4, providing lift and stability and enabling leveling of the pontoon 6 in a substantially horizontal position.

[0026] The backhoe dredger 1 comprises actuating means (7, 16, 17, 18, 19) adapted to control the motion of the pontoon 6 and of the excavator 10. The actuating means among others comprise the swivels 7 for the spuds 4 and driving means (not shown) for positioning the pontoon 6, as well as turntable 19 and hydraulic cylinders (16, 17, 18) that form part of a hydraulic circuit controlling the motion of the excavator 10. The actuating means (7, 16, 17, 18, 19) are controlled by computing means as will be described in more detail further below.

[0027] With reference to figure 3, the backhoe dredger 1 is equipped with first monitoring means (30, 35) adapted to monitor the position of the excavator 10, and in particular the position of the bucket 14 thereof, second monitoring means 31, adapted to monitor the forces experienced by the excavator 10, third monitoring means 32 adapted to monitor the position of the pontoon 6, and computing means 33 adapted to compute, on the basis of data obtained from the first and the second monitoring means (30, 31), control signals for the actuating means (7, 16, 17, 18, 19). To transfer the excavator position signals from the first monitoring means to the computing means.

[0028] The first monitoring means (30, 35) comprise a number of position and/or angular sensors (not shown), mounted at several positions on the excavator 10. Figure 4 schematically shows a typical configuration, showing the fulcrum A of the boom 11 supported on the deck of the pontoon 6, the fulcrum B of the stick 12 supported on the boom 11, the fulcrum C of the bucket 14 supported on the stick 12 and the leading edge D of the bucket 14. Also shown are the length L_1 of line A-B, the length L_2 of line B-C, the length L_3 of line C-D, the angle α between a vertical line and the line A-B, the angle β between the line A-B and the line B-C and the angle γ between the line B-C and the line C-D. Furthermore, h_1 defines the present depth of the bottom 3 and h_2 the height of fulcrum A relative to the water level. To illustrate, the excavated depth h_1 from the water level can easily be expressed in function of the angles α, β and γ, and the lengths L_1, L_2, L_3 as well as height h_2. Since the lengths L_1, L_2, L_3 and height h_2 are known, the excavated depth h_1 relative to the water level can be determined when one detects the relative angles α, β and γ by suitable angle detectors. The angular signals 34 generated by the angular sensors are transmitted through a suitable input/output device 35 to a first monitoring means processing unit 30, at least comprising a memory for storing the angular signal data. If desired, the position of the excavator 10 can be visualized for the operator of the backhoe dredger 1 on a display 40.

[0029] The third monitoring means (32, 36) adapted to monitor the position of the pontoon 6 comprise a dynamic positioning/dynamic tracking (DP/DT) system 32, an input/output device 36 adapted to transfer position and/or force signals from the second and/or the third monitoring means to the computing means, and a number of pontoon position sensors (not shown). The DP/DT system 32 allows the backhoe dredge operator to view on-line through a display device 38 a chart of the bottom depth profile. Such a profile is obtained by inputting bathymetric data obtained beforehand in the DP/DT system 32. The depth profile of the bottom 3 is updated in real time as a result of the dredging operation. The DP/DT system 32 also comprises a global positioning system, enabling to locate the global position of the pontoon 6. When a backhoe dredger is manually operated, it generally relies on the above described set of monitoring equipment. As the operator is working underneath the water level, visibility of the bucket 14 is zero. The operator therefore needs to rely on a real-time visualization of the pontoon 6 and in particular excavator 10. The first monitoring means (30, 35) based on sensors for monitoring the boom/stick/bucket and slew/swing angles provide part of the input. This information is combined with the system dimensions to reconstruct the bucket position. When combining this information with a global positioning system signal from the DP/DT system 32, a real-time visualization of the position of the bucket 14 with respect to the bottom 3 is obtained.

[0030] According to the invention, the second monitoring means 31 are adapted to monitor the forces experienced by the excavator 10, and comprise a number of pressure or force transducers (not shown), typically incorporated in the hydraulic cylinders (16, 17, 18). The force signals 39 originating from the transducers are transmitted via the input/output device 36 to the computing means (31, 33) for further processing. If desired, a display unit 41 adapted to display the force signals 39 as experienced by the excavator 10 can be provided. Control signals (42, 43), generated by the computing means (33) may also be displayed on display unit 41.

[0031] The computing means (33) are adapted to compute, on the basis of the position signal data (34, 37), obtained from the first and the third monitoring means (30, 32), as well as on the basis of the force signal data (39), obtained from the second monitoring means 31 control signals (42, 43) for the actuating means (7, 16, 17, 18, 19).

[0032] The parameters involved in dredging a bottom 3 are many. Typically, a survey of the depth profile of the water bottom 3 is carried out first by taking bathymetric data and store these in the DP/DT system 32. A desired dredge profile depends on many properties such as underwater stability of the bottom 3 and the rheological properties of the soil material. Other factors that may be important include structural aspects of the dredging equipment (maximum load levels and the like), vessel stability, position control, tidal and water current behavior, and more. The device according to the invention allows to take into account a major part of these parameters by providing a closed loop control system wherein position and force data are combined to compute optimum actuator signals. The force data are the result of the action of a considerable number of relevant parameters related to the bottom and soil properties, which makes considering these force data particularly useful for the present purpose. The invention is not limited to the choice of a particular optimum criterion and may actually use any criterion that appears to be useful. Preferably, the optimum criterion comprises the average power of the excavator used per unit volume excavated soil material, or the maximum likely expected excavating time per unit volume excavated soil material. Typical limitations include dynamic limitations, such as power and force restrictions.

[0033] The algorithms loaded in the computing means are now described. Once the pontoon is substantially stable in its starting position, the excavation model, loaded in the computing means, is executed. The excavation model comprises a continuous path geometric trajectory algorithm, known per se. Such an algorithm is based on trajectories, as suggested by best practice training manuals and/or constructor's power tables for a given excavator set up (i.e. a boom/stick/bucket combination). The input for the algorithm is provided by the results of a bottom survey and a first best guess of a trajectory for the excavator, including the depth and reach of the bucket. With reach is meant the distance from the pivot point of the excavator to the position where the bucket touches the soil. The output of the algorithm provides the excavator kinematics that produces the needed boom/stick/bucket-joint angles at each stage of the excavation.

[0034] A second algorithm uses soil cutting theory to compute the forces experienced by the excavator components as a result of the interaction between the bucket and the soil (when the bucket is actually moving through the soil), and drag theory to compute the forces exerted by water currents on submerged parts of the excavator. This model yields the total expected forces, encountered by the excavator whilst digging. The output gives the overall model a starting point from which to proceed.

[0035] The starting point is preferably selected base don a most suitable combination cutting depth, cutting speed and reach or scraping length. Typically, the scraping length is chosen around 65% of the maximum reach at a particular depth, with a generally accepted minimum of 6m.

[0036] When the above two algorithms are loaded in the computing means and an excavation is started, the measurements of forces and kinematical parameters allow to recalculate operational parameters, preferably the depth of excavation, the velocity of excavation, and the reach of the bucket. With the knowledge of the above two models output, as well as of the power ratings of the individual hydraulic components of the excavator, the excavating operation may be optimised by the operator of the excavator by means of at each stage of operation limiting the forces in the excavator by turning back on the actuator settings, so as not to exceed the maximum tolerable power ratings. The maximum tolerable power settings for the hydraulic components, such as the hydraulic cylinders, are known from the manufacturer of these components and for a hydraulic cylinder for instance are given in terms of the product of maximum pressure p and flow Q. Given the speed at which forces vary in the hydraulic system, such a rather static system (controlled by an operator) would always try to intervene too late. In addition the combination of actuators, hydraulic system and excavator system/real world interaction will result in a highly non-linear system.

[0037] As such, prior to operations a number of open loop experiments that correlate actuator settings with hydraulic system characteristics (pressure p and flow rate Q measurements) and readings from the geometric measurement devices (i.e. the standard angle measurement devices that measure boom/stick/bucket-joint angles) is preferably conducted. These will serve as input for the refined instrument variable identification that will result in a proportional integral plus control algorithm for each joint in the excavator system. Once the parameters are known, the non-linear control algorithm (i.e. the proportional integral plus algorithm) can control the joint angles using the feedback from the angle measurement devices on the joint without the need for extra pressure or discharge sensors whilst remaining as close as possible to the permissible hydraulic settings for each system component.

[0038] The invention is not limited to any optimization algorithm and many may be used. Such algorithms are generally known to the skilled person and generally minimize some function f(x) subject to a condition such as h (x) $\geq$ 0. In the present embodiment the function f(x) may comprise the average power of the excavator used per unit volume excavated soil material for instance. The condition h(x) $\geq$ 0 may for instance comprise the condition that the depth h(x) of the bucket 14 has to be larger than a certain depth h_1. The condition then becomes h_1 - h(x) $\geq$ 0 (when depths are given in negative numbers). An optimization scheme is initiated by choosing initial values for x, and compute search directions Δx, using numerical algorithms such as the well known Newton's method. A step to a new point is then taken and the calculations repeated until the minimum is found. In the context of the present invention, the output of the optimization scheme yields a next movement of the bucket 14 of the excavator 10, including horizontal and vertical movement, tilt angles, defining the angle of attack, and speed of movement. It thus becomes possible to maximize throughput and obtain a more even quality. An additional advantage is that by obtaining the force data, data are also obtained on the soil properties during dredging. The method and device according to the invention therefore also allows to continuously update the soil properties, previously obtained by the bathymetric data.

[0039] The computing means 33 substantially control the movement of the excavator 10, and in particular the bucket 14 thereof, as well as the movement of the pontoon 6, by generating control signals (42, 43) for the excavator 10 and pontoon 6 respectively. In particular, after having positioned the pontoon 6, a zone is dredged within reach of the excavator booms (11, 12) by automatically lowering the bucket 14 to a calculated depth, by positioning the bucket 14 and scrape soil material 20 to fill the bucket 14 to a desired level, and then lifting the bucket 14, and swing it to empty its content in barge 21. In the meantime a new position is calculated through the optimization routine and the bucket 14 swung back to this optimal next position. After having dredged a zone within the reach of the excavator 10, the pontoon 6 is 'stepped' to a next position, that is also calculated by the optimization algorithm, and the cycle repeated.

[0040] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

Claims

1. Device for dredging soil material under water, the device comprising:

   - a pontoon, provided with an excavator adapted to excavate soil under water;
   - actuating means adapted to control the motion of the pontoon and/or the excavator;
   - first monitoring means adapted to monitor the position of the excavator;

   the device further comprising

   - second monitoring means adapted to monitor the forces experienced by the excavator; and
   - computing means adapted to compute, on the basis of data obtained from the first and the second monitoring means, control signals for the actuating means.

2. Device according to claim 1, wherein the computing

means are adapted to compute the control signals for the actuating means such that an optimum criterion is minimized.

3. Device according to claim 2, wherein the optimum criterion comprises the average power of the excavator used per unit volume excavated soil material.

4. Device according to claim 2, wherein the optimum criterion comprises the maximum likely expected excavating time per unit volume excavated soil material.

5. Device according to any one of the preceding claims, wherein the excavator comprises lifting booms, actuated by hydraulic cylinders, part of a hydraulic circuit, and the second monitoring means comprise hydraulic pressure sensors adapted to measure the pressure in the hydraulic circuit and/or cylinders.

6. Device according to any one of the preceding claims, wherein the excavator comprises lifting booms, actuated by hydraulic cylinders, that are part of a hydraulic circuit, and the first monitoring means comprise displacement sensors adapted to measure the relative displacement of the lifting booms.

7. Device according to any one of the preceding claims, the device comprising third monitoring means adapted to monitor the position of the pontoon.

8. Device according to claim 7, wherein the third monitoring means comprise a global positioning system.

9. Device according to any one of the preceding claims, the device comprising an input/output device adapted to transfer the signals from the first monitoring means to the computing means.

10. Device according to any one of the preceding claims, the device comprising an input/output device adapted to transfer the signals from the second and/or third monitoring means to the computing means.

11. Device according to any one of the preceding claims, the device comprising display units adapted to display the position of the excavator and/or of the pontoon, as well as the forces experienced by the excavator.

12. Device according to any one of the preceding claims, the device comprising a display unit adapted to display the depth of the soil under water.

13. Method for dredging soil material under water, the method comprising the steps of:

- providing a device according to any one of claims 1-12;
- positioning the pontoon in a water;
- controlling the motion of the excavator by the actuator means such that soil is excavated under water;
- monitoring the position of the excavator and the forces experienced by the excavator during the motion thereof;
- computing, on the basis of data obtained from the first and the second monitoring means, control signals for the actuating means;

whereafter the excavator is moved according to these control signals.

14. Method according to claim 13, wherein the control signals for the actuating means are computed such that an optimum criterion is minimized.

15. Method according to claim 14, wherein the optimum criterion comprises the average power of the excavator used per unit volume excavated soil material.

16. Method according to claim 14, wherein the optimum criterion comprises the maximum likely expected excavating time per unit volume excavated soil material.

17. Computer program comprising program instructions that when loaded into a computer carries out the method according to any one of the claims 13-16.

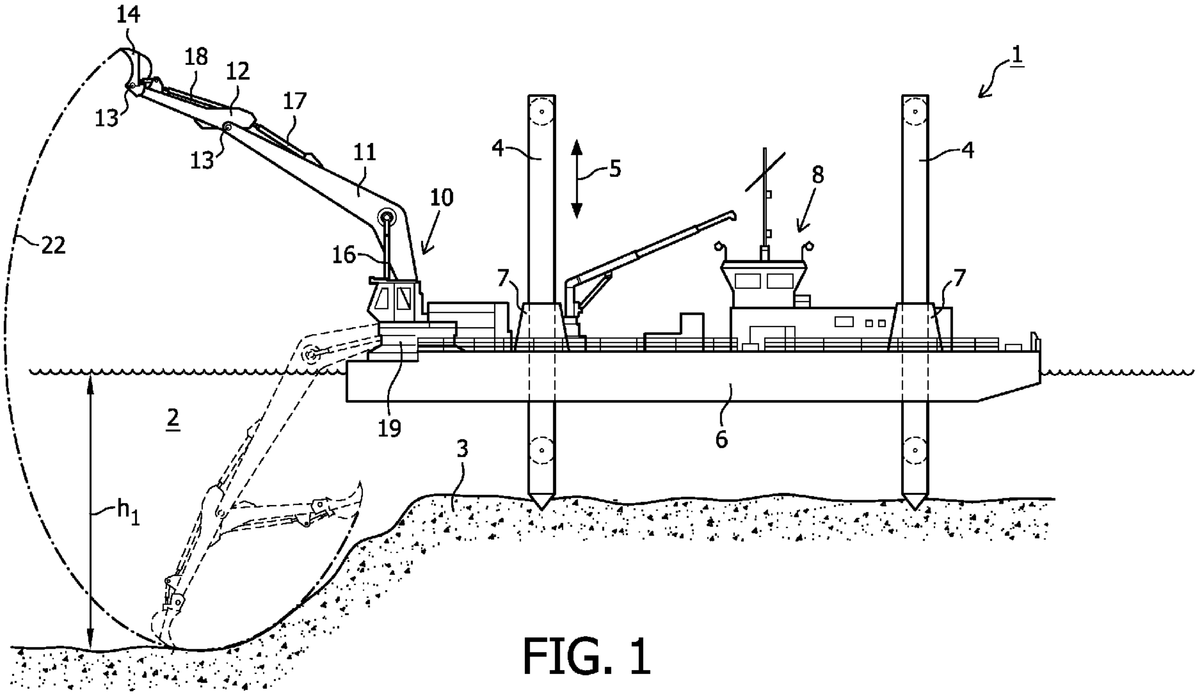

FIG. 1

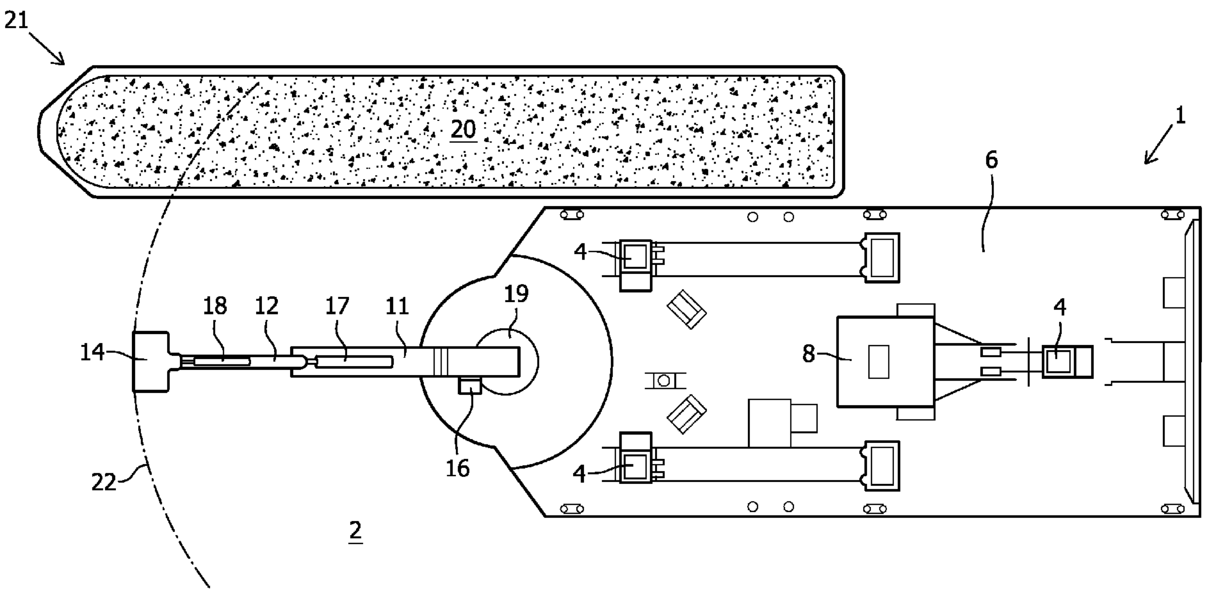

FIG. 2

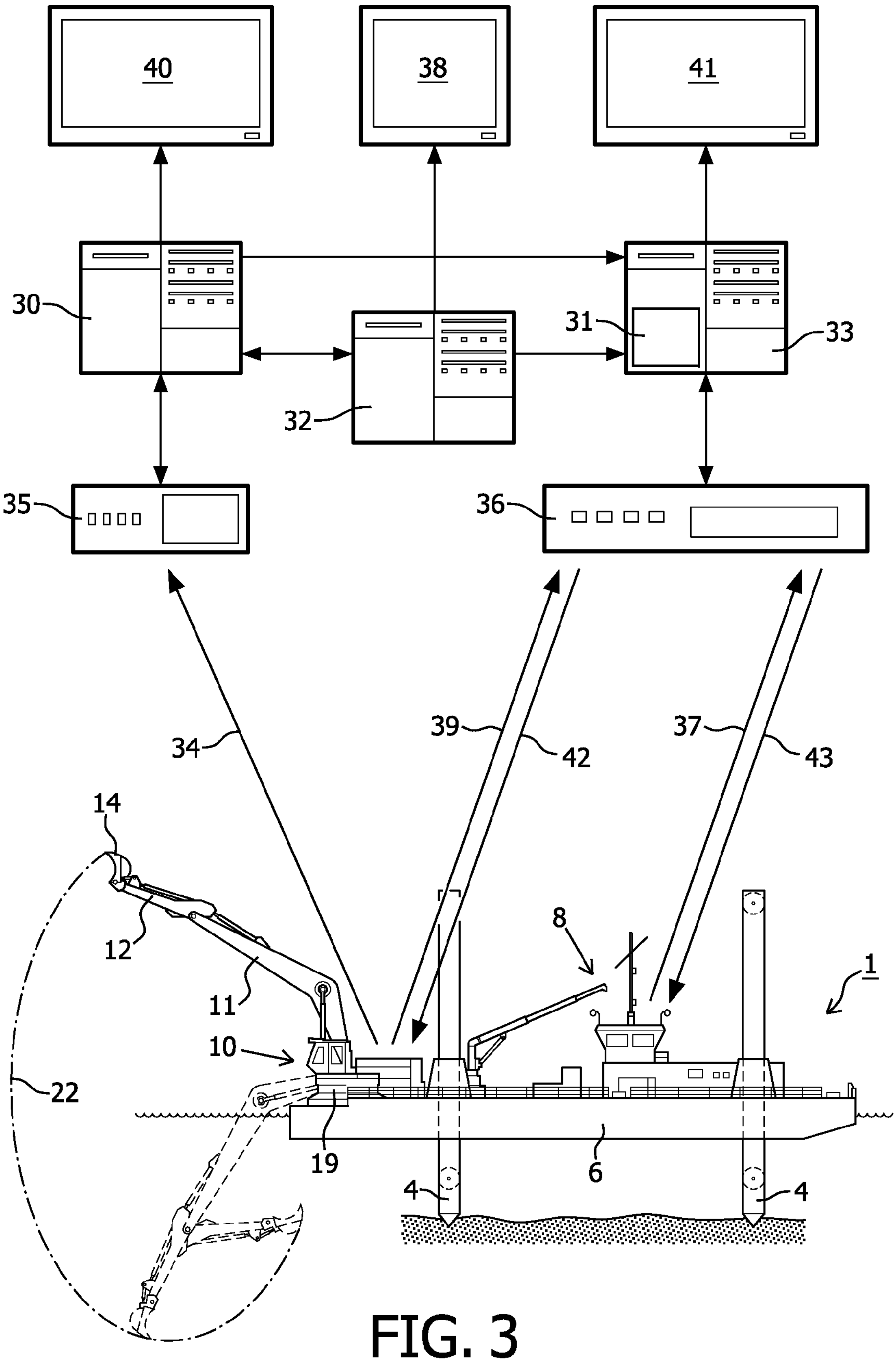

FIG. 3

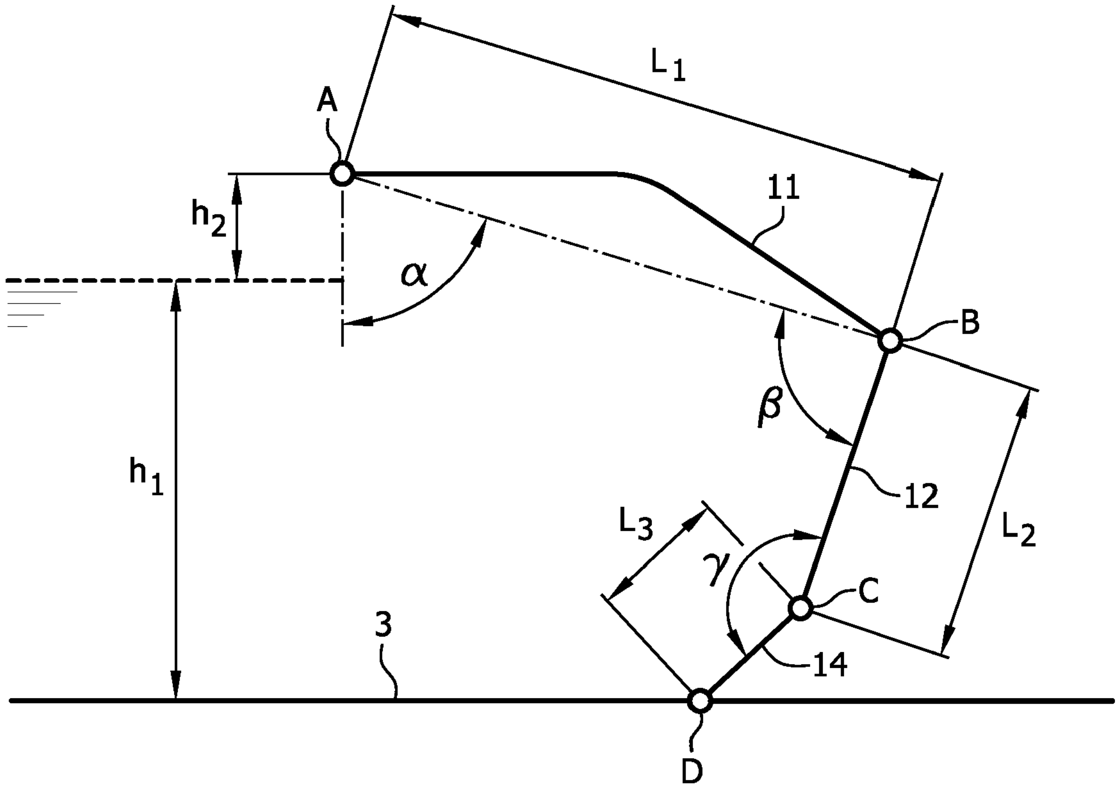

FIG. 4