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(73) Patenthaver: **Elmaco AS, Nedre Høgåsen 18, 4440 Tonstad, Norge**

(72) Opfinder: **HAUGHOM, Per Olav, Nedre Høgåsen 18, 4440 Tonstad, Norge**

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **APPARAT TIL ANVENDELSE PÅ BYGGERI- ELLER BYGGEPLADSMASKINER, FOR EKSEMPEL EN GRAVEMASKINE**

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US-A1- 2003 097 837
US-A1- 2005 103 006
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DESCRIPTION

Description

Technical field

[0001] The present invention relates in particular to the supply of energy for operating construction or worksite machines.

Background

[0002] The construction industry is faced with the challenge of reducing climate gas emissions to comply with requirements and targets. Construction and/or worksite machines have traditionally been provided with combustion engines which are used to operate drive wheels for moving the machine from location to location on the worksite. The combustion engines also act as primary energy source to transmit power to hydraulic circuits for operating hydraulic lifting components of such machines. Using combustion engines can result in undesired emissions of carbon dioxide into the atmosphere.

[0003] To address this matter, batteries have been adopted increasingly in construction and/or worksite machines to provide a cleaner operational solution. Today's solutions using batteries in such machines however face challenges in providing efficient charging and conversion of energy from the battery into work performed by the machine. Batteries can be costly to install and when energy consumption is high, then typically only short amounts of useful time are available between charges, and this can result in reduced efficiency of the machine. Document US 2005/103006 A1 discloses for example a construction machine storing generated power in a fuel cell.

[0004] At least one aim of the invention is to obviate or at least mitigate one or more drawbacks of prior art.

Summary

[0005] According to a first aspect of the invention defined in independent claim 1, there is provided apparatus for use on a construction or worksite machine, the machine being provided with a main body and at least one lift/lower element coupled to the main body, the apparatus comprising: at least one hydraulic cylinder for operating the lift/lower element; at least one

hydraulic pump that has at least one electric motor coupled thereto for operating the hydraulic pump, the pump being configured for pumping hydraulic fluid along a flowline for operating at least one hydraulic cylinder that is coupled to the lift/lower element; and energy supply means comprising: at least one battery to provide electrical energy to the electric motor; and at least one hydrogen fuel cell for generating and supplying the battery with electrical energy for charging the battery.

[0006] In this way, energy supplied to the electric motor can be generated by the fuel cell. The energy supply means may thus be configured for supplying the electric motor with energy generated by the fuel cell, the fuel cell in use supplying the battery with electrical power for charging the battery. Peak demands in power e.g. when extending/retracting the hydraulic cylinder for operating the lift/lower element, can thus be accommodated with the battery being replenished in periods of lower demand by energy from the fuel cell.

[0007] According to the invention, the hydraulic cylinder is configured to provide volumetric neutral operation. Hydraulic control valves for controlling the cylinder may therefore not be required. Energy losses may be minimised, and the pump may be readily driven in motor mode by the hydraulic fluid from the cylinder.

[0008] According to the invention, the hydraulic cylinder may be configured to retract or extend to under load, and the hydraulic pump may be operable in motor mode using hydraulic fluid driven by the load to communicate return energy from the cylinder to transfer the energy produced by the hydraulic cylinder under load to at least one energy storage unit. The energy storage unit comprises the at least one battery. The return energy may be used to charge the battery. The return energy may thus reduce consumption of hydrogen and/or power generation requirements.

[0009] The apparatus may further comprise at least one control member for controlling either or both the speed, e.g. rate of revolution, and the direction of the electric motor.

[0010] The hydraulic cylinder may be operable for producing movement of the lifting member, in dependence upon the speed or rate of revolution of the electric motor.

[0011] The control member may comprise a user-operable control member, e.g. an operator handle, button, or any other user-controllable member. The control member arranged to produce at least one signal for controlling the electric motor. The apparatus may further comprise at least one signal provider for producing at least one signal in accordance with user control of the control member.

[0012] The apparatus may further comprise at least one drive unit for controlling the supply of electrical power to the electric motor. More specifically, the drive unit may be operable to control the supply of electrical power to the electric motor in dependence upon at least one signal transmitted from at least one signal provider.

[0013] The apparatus may further comprise at least one hydrogen storage tank for storing hydrogen. The hydrogen storage tank may be coupled in fluid communication with the hydrogen fuel cell for supplying hydrogen to the hydrogen fuel cell, and the hydrogen fuel cell may be operable to generate electrical energy using the supplied hydrogen.

[0014] The hydrogen fuel cell may be configured to be operable for producing electrical energy and supplying the battery with energy that may be equal to that being taken out during operations for replenishing the battery level during operation of the electrical motor. The battery may operate in effect to regulate power usage.

[0015] Preferably, there is provided a construction or worksite machine provided with a main body and at least one lift/lower element coupled to the main body, wherein the machine includes the apparatus in accordance with the first aspect of the invention.

[0016] The construction or worksite machine may for example be an excavator, a tipper truck, or any other machine. In the example of the excavator, the lift/lower element or elements may comprise any of: a boom, an arm, and a bucket. In the example of a tipper truck, lift/lower element may comprise a loading base, and the hydraulic cylinder may be operable to lift or lower part of the loading base to tip the loading base, e.g. for offloading material from the loading base.

[0017] The battery may be used to supply a motor with power for propulsion of the construction machine between locations. To this end, the motor may provide power to drive one or more drive wheels or caterpillar tracks of the machine. The motor may operate to turn one or more axles which may be coupled to the one or more drive wheels or caterpillar tracks.

[0018] The machine may have an undercarriage and the main body may be rotatable with respect to the undercarriage, e.g. about a vertical axis. The machine may have a work assembly which may be rotatable with respect to the main body. The work assembly may comprise the at least one lift/lower element. The battery may be used to supply power for rotating the main body with respect to the undercarriage and/or for rotating the work assembly with respect to the main body.

[0019] According to a second aspect of the invention defined in independent claim 15, there is provided apparatus for use on a construction or worksite machine, the apparatus comprising: at least one hydraulic cylinder; at least one hydraulic pump that has at least one electric motor coupled thereto for operating the hydraulic pump, the pump being configured for pumping hydraulic fluid along a flowline for operating at least one hydraulic cylinder to extend or retract; and energy supply means comprising: at least one battery to provide electrical energy to the electric motor; and at least one fuel cell for generating and supplying the battery with electrical energy for charging the battery. The machine may be provided with a main body and at least one lift/lower element coupled to the main body. The hydraulic cylinder may be a hydraulic cylinder for operating the lift/lower element. The hydraulic cylinder may be coupled to the lift/lower element. The fuel cell may be a hydrogen fuel cell.

[0020] Preferably, there is provided a construction or worksite machine which includes the apparatus in accordance with the second aspect of the invention.

[0021] The machine may be provided with a main body and at least one lift/lower element coupled to the main body.

[0022] According to a third aspect of the invention, there is provided a method of operating the construction or worksite machine defined in dependent claims 16 and 17. The method may include the steps of: providing the construction or worksite machine; controlling at least one hydraulic cylinder to perform site operations. The site operations may be lifting/lowering operations. The method may include controlling lift/lower element(s), e.g. of a work assembly. The method may include using a control device or operating, for example at least one operating lever, handle or button, to control the hydraulic cylinder and/or the lift/lower element(s) to perform the operations.

[0023] Embodiments are advantageous in various ways as will be apparent from throughout the present specification.

Drawings and description

[0024] There will now be described, by way of example only, embodiments of the invention with reference to the accompanying drawings, in which:

Figure 1
: is a perspective representation of a construction or worksite machine in the form of an excavator according to an embodiment of the invention; and

Figure 2
: is a schematic representation of apparatus for transmitting energy to one or more hydraulic lifting components of the machine of Figure 1.

[0025] Turning firstly to Figure 1, a construction or worksite machine in the form of an excavator 1 is depicted. The excavator 1 has a work assembly that includes lift/lower elements in the form of a boom 2, an arm 16, and a bucket 15. The boom 2, the arm 16, and the bucket 15 are controllable respectively by first to third hydraulic cylinders 3, 4, 5.

[0026] The bucket 15 is coupled to the arm 16 and is movable about a pivot relative to the arm by operation of the third hydraulic cylinder 5. One end of the hydraulic cylinder 5 is mounted to the arm 16 and the other end of the hydraulic cylinder 5 is mounted to the bucket 15. The hydraulic cylinder 5 is operable to extend or retract, thereby varying the distance between the ends, to move the bucket 15 relative to the arm 16.

[0027] The arm 16 is coupled to the boom 2 and is movable about a pivot relative to the boom 2 by operation of the second hydraulic cylinder 4. One end of the hydraulic cylinder 4 is mounted to the boom 2 and the other end of the hydraulic cylinder 4 is mounted to the arm 16. The hydraulic cylinder 4 is operable to extend or retract, thereby varying the distance between the ends, to move the arm 16 relative to the boom 2.

[0028] The boom 2 is coupled to a main frame 9 of the excavator 9. The boom 2 is movable about a pivot relative to the main frame 9 by operation of the first hydraulic cylinder 3. One end of the hydraulic cylinder 3 is mounted to the main frame 9 and the other end of the hydraulic cylinder 3 is mounted to the boom 2. The hydraulic cylinder 3 is operable to extend or retract, thereby varying the distance between the ends, to move the boom 2 relative to the main frame 9.

[0029] Through operation and control of the hydraulic cylinders 3, 4, 5, the work assembly of the excavator can perform excavation operations on worksites or construction sites, such as digging, collecting earth or other materials into the bucket 15, and lifting, lowering, and manoeuvring the bucket 15, e.g. with materials loaded therein, from one location to another. The main frame 9 is provided on an undercarriage 12 with caterpillar drive tracks for allowing the excavator to travel around the site. The main frame 9 is mounted rotationally upon the undercarriage 12 to allow rotation of the main frame relative to the undercarriage 12 about a vertical axis for further manoeuvrability of the work assembly.

[0030] With reference now to Figure 2, the apparatus 50 for operating the work assembly is described in further detail. The apparatus 50 includes a hydraulic circuit 70 by which the hydraulic cylinder 3, 4, 5 is provided with hydraulic fluid. The circuit 70 has a hydraulic flowline 30 and an electrically operated pump 31 for driving the hydraulic fluid along the flowline 30. The flowline has a first in/out section 30a which is connected in fluid communication with at least one first-side chamber of the hydraulic cylinder 3, 4, 5, and a second in/out section 30b which is connected in fluid communication with at least one second-side chamber of the hydraulic cylinder 3, 4, 5.

[0031] To extend the hydraulic cylinder 3, 4, 5, hydraulic fluid is driven, by operation of the pump 31 at least if extending against a load, through the first in/out section 30a into the first-side chamber. The fluid in the first-side chamber of the cylinder acts upon the piston member and urges the piston member to move along the piston housing. By way of the movement of the piston member, hydraulic fluid in the second-side chamber is caused to be expelled into the second in/out section 30b. If extending with the load, e.g. under inertia due to gravity, the weight of the load may drive or assist the pump to drive the extension of the cylinder.

[0032] Conversely, to retract the hydraulic cylinder 3, 4, 5, hydraulic fluid is driven, by operation of the pump 31 at least if retracting against a load, in the opposite direction through the second in/out section 30b into the second-side chamber. The fluid in the second-side chamber of the cylinder acts upon the piston member and urges the piston member to move along the piston housing, and by way of the movement of the piston member, hydraulic fluid

from the first-side chamber is expelled into the first in/out section 30a. If retracting with the load, e.g. under inertia due to gravity, the weight of the load may drive or assist the pump to drive the retraction of the cylinder.

[0033] As will be explained further in the following, the energy of the load driving the retraction or extension of the cylinder can be transmitted through the hydraulic fluid and pump (in motor mode) back to the battery which may reduce overall energy consumption of the apparatus.

[0034] The hydraulic cylinder 3, 4, 5 in this example has a volumetric displacement which is equal in both directions. That is, the amount of fluid entering and being expelled over a full stroke of the piston member is the same in both directions. This behaviour is termed "volumetric neutral" herein. As a result, the flowline 30 forms a closed loop system which circulates a constant amount of hydraulic fluid at desired pressure cycling back and forth, depending on the direction of operation of the cylinder. There is no need for hydraulic fluid to be returned to hydraulic tank 13. Load-sensing directional control valves and associated hydraulic components as commonly provided in the prior art on the in/out lines to the two chambers of the cylinder are consequently also not required, and this can provide significant improvements in efficiency. The hydraulic circuit 70 does however include a replenishment valve 28 for topping up the hydraulic fluid in the circuit if needed, e.g. from hydraulic tank 13 into the first or second in/out lines 30a, 30b, if over time there have been losses through leakage, etc.

[0035] The volumetric neutral hydraulic cylinder 3, 4, 5 can be provided by way of the surfaces of the piston member inside the cylinder, e.g. on the piston member, against which the hydraulic fluid exerts force to move the piston member, being of equal area in both directions. Thus, in the one direction, hydraulic fluid may exert pressure against a first set of surfaces of the piston member, and in the other direction, hydraulic fluid may exert pressure against a second set of surfaces of the piston member, and the total area of the surfaces of each set is substantially equal. Various examples of volumetric neutral hydraulic cylinders are described in the published patent application PCT/NO2020/050165 with publication number WO2020/256564.

[0036] The pump 31 is electrohydraulic. It has an electric motor 10 for operating the pump 31 for pumping the hydraulic fluid in the flowline 30 in one direction or the other depending upon which direction the cylinder 3, 4, 5 is to be operated.

[0037] The apparatus 50 includes battery 7 for supplying electrical power for operating the motor 10. Furthermore, the apparatus 50 includes a hydrogen fuel cell 11. The hydrogen fuel cell 11 uses hydrogen to produce electrical energy. The hydrogen is obtained from a storage tank 8. The storage tank 8 is in fluid communication with the fuel cell 11. The hydrogen is supplied through a fluid line 18 between the tank 8 and the fuel cell 11. The hydrogen fuel cell 11 is electrically coupled through an electrical feed line 25 and a transformer 19 to the battery, such that the generated electrical current from the hydrogen fuel cell 11 is fed to the battery 7 to replenish the electrical charge of the battery 7. The transformer 19 is coupled electrically to

the battery 7 through electric line 20a. The transformer 19 converts the current from the fuel cell 11 to appropriate voltage and current for the proper charging of the battery 7.

[0038] The demand for power from the battery 7 is variable according to the work to be performed by the hydraulic cylinder 3, 4, 5. From time to time there can be peaks in the demand for battery power, for example when the hydraulic cylinder is to perform a lift and/or manoeuvre a load. The battery 7 is coupled electrically through electric line 20b to an electrical drive unit 17. The power is delivered from the battery 7 to the motor 10 through the electrical drive unit 17. The electrical drive unit 17 is arranged to control the delivery of power to the electric motor 10 based an input from an operator. The electrical drive unit 17 is arranged to receive a signal and/or instructions from the signal provider 22 and directs power from the battery 7 to the electric motor 10 in accordance with the received signal and/or instructions. The electric motor 10 is thus controlled accordingly, both in direction and speed, i.e. revolutions per minute.

[0039] An operating device 23 comprising a control handle is provided for controlling the operation of the hydraulic cylinder 3, 4, 5, in particular the speed and direction of the cylinder, i.e. the movement of the piston relative to the cylinder housing. The signal provider 22 cooperates with the operating device 23 so that it produces a signal corresponding to the input from the operating device 23. The signal provider 22 sends the signal to the electric drive unit 17 which in response draws power from the battery 7 correspondingly for the motor 10 so that the speed and direction of turning of the motor 10 is controlled in accordance with the input from the control handle 23. The signal provider 22 in this example is in communication with the electrical drive unit 17 through a signal carrier line 21 therebetween. The direction of rotation of the motor 10 and consequently the pump 31 corresponds to the direction of operation of the hydraulic cylinder 3, 4, 5, i.e. the motor 10 turning in one direction operates the hydraulic cylinder 3, 4, 5 to extend the piston, and the motor 10 turning in the opposite direction operates the hydraulic cylinder 3, 4, 5 to retract the piston. The motor speed determines and controls the pump speed which in turn determines and controls the fluid flow into and/or out of the hydraulic cylinder 3, 4, 5 and consequently the speed of extension and/or retraction of the cylinder 3, 4, 5.

[0040] By way of the volumetric neutral configuration, the fluid being expelled as the hydraulic cylinder 3, 4, 5 retracts is used to generate power and drive the pump 31. The pump 31 then acts as a motor to generate power with the surplus generated electrical energy being conveyed back to the battery 7 through the electric drive unit 17. The volumetric neutral configuration can help to maximise the amount of energy returned, providing for a more efficient overall system.

[0041] The proposed system can be highly advantageous. The battery 7 can be charged by a hydrogen fuel cell 11 so that the construction or worksite machine 1 can operate and perform lifting work without charging periods. The fuel cell 11 may in general have a relatively low effect but may operate continuously so that the amount of energy that is fed into the battery typically is equal to that taken out. The battery 7 functions as a form or regulator, so that peak power

can be provided when the machine 1 has a need for short duration power peaks. As an example of this, one can consider that the hydrogen fuel cell for example delivers continuously 30 kW over an example period of 10 hours supplying total energy of 300 kWh. The battery has a storage capacity of 300 kWh. From time to time, over short periods, power peaks of approximately 100 kW are drawn from the battery, but the energy extracted over time is 300 kWh.

[0042] By combining the hydrogen fuel cell 11 with the battery 7, an energy efficient power transmission solution is provided which can yield low or no emissions and long work period without requiring access to electric charging and requiring merely change and/or refilling of hydrogen storage tanks 8.

[0043] The hydrogen fuel cell 11 and hydrogen tank 8 can deliver electrical energy with constant power to a battery 7 such that the amount of energy that is delivered is equal to the energy that is taken out of the battery 7 with variable power. To reduce the energy losses, the machine 1 has an energy efficient transmission using the electric motors 10 for the hydraulic pumps 31 so that the volumetric flow and pressure to the volumetric neutral cylinders 3, 4, 5 are controlled according to the rate of revolutions of the electric motor 10 and not by valves. The hydraulic cylinder(s) 3, 4, 5 can be volumetric neutral so that when lowering the loads, the hydraulic pump(s) 31 are operated in motor mode and the electric motors 10 as electrical generators that supply and/or generate energy back to the battery 7. This can reduce the overall use of energy and reduce consumption of hydrogen, help to extend the periods available for operation of the machine 1, and/or alleviate performance requirements upon the fuel cell 11 and/or battery 7.

[0044] Various modifications and improvements may be made without departing from the scope of the invention herein described, the invention being defined in the appended claims. In particular, whilst the description above is made for simplicity with reference to one cylinder, it can be appreciated that such a system may be employed similarly for any number of required cylinders. Each cylinder respectively may have its own pump and associated electric motor and electric drive unit. The supply of electrical power may take place through one or several batteries, and one or more fuel cells may serve one or more batteries.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all

liability in this regard.

Patent documents cited in the description

- US2005103006A1 [0003]
- NO2020050165W [0035]
- WO2020256564A [0035]

Patentkrav

1. Apparat til anvendelse på en byggeri- eller byggepladsmaskine, som er forsynet med et hovedlegeme og mindst et løfte-/sænkeelement koblet til hovedlegemet, hvilket apparat omfatter:

mindst en hydraulikcylinder (3, 4, 5) til betjening af løfte-/sænkeelementet:

mindst en hydraulikpumpe (31), der har mindst en elektrisk motor (10) koblet dertil til drift af hydraulikpumpen, hvor pumpen er konfigureret til at pumpe hydraulikfluid langs en flowledning til drift af mindst en hydraulikcylinder, der er koblet til løfte-/sænkeelementet; og

energiforsyningsorgan omfattende:

mindst et batteri (7) til at levere elektrisk energi til den elektriske motor; og

mindst en brintbrændselscelle (11) til at generere og forsyne batteriet med elektrisk energi til opladning af batteriet;

hvor hydraulikcylinderen er konfigureret til at tilvejebringe volumetrisk neutral drift;

hvor hydraulikcylinderen er konfigureret til at køre ind eller ud under belastning, og **kendetegnet ved, at** hydraulikpumpen kan betjenes i motortilstand under anvendelse af hydraulikfluid drevet af belastningen for at viderebringe energi fra cylinderen for at overføre energien produceret af hydraulikcylinderen under belastning til mindst en energilagringsenhed, hvor energilagringsenheden omfatter batteriet.

2. Apparat ifølge krav 1, hvor hydraulikcylinderen kan betjenes til at frembringe bevægelse af løfteelementet, afhængigt af hastigheden eller omdrejningshastigheden af den elektriske motor.

3. Apparat ifølge krav 1 til 2, yderligere omfattende mindst et styreelement til styring af enten den ene eller både hastigheden og retningen af den elektriske motor.

4. Apparat ifølge krav 3, hvor styreelementet omfatter et brugerbetjent styreelement.

5. Apparat ifølge krav 4, hvor styreelementet er indrettet til at frembringe mindst et signal til styring af den elektriske motor.

6. Apparat ifølge et hvilket som helst af kravene 3 til 5, yderligere omfattende mindst en signalsender til frembringelse af mindst et signal i overensstemmelse med brugerstyring af styreelementet.

7. Apparat ifølge et hvilket som helst af de foregående krav, yderligere omfattende mindst en drivenhed til styring af forsyningen af elektrisk strøm til den elektriske motor.

8. Apparat ifølge krav 7, hvor drivenheden kan betjenes til at styre forsyningen af elektrisk strøm til den elektriske motor afhængigt af mindst et signal transmitteret fra mindst en signalsender.

9. Apparat ifølge et hvilket som helst af de foregående krav, yderligere omfattende mindst en brintlagertank til opbevaring af brint.

10. Apparat ifølge krav 9, hvor brintlagertanken er koblet i fluidforbindelse med brintbrændselscellen for at tilføre brint til brintbrændselscellen, og brintbrændselscellen kan betjenes til at generere elektrisk energi under anvendelse af det tilførte brint.

11. Apparat ifølge et hvilket som helst af de foregående krav, hvor brintbrændselscellen er konfigureret til at kunne betjenes til at producere elektrisk energi og forsyne batteriet med energi, der er lig med den, der udtages under drift til genopfyldning af batteriniveauet under drift af den elektriske motor.

12. Apparat ifølge et hvilket som helst af de foregående krav, hvor batteriet fungerer til at regulere strømforbruget.

13. Apparat ifølge et hvilket som helst af de foregående krav, hvor den elektriske motor kan betjenes således, at det volumetriske flow og trykket til de volumetriske neutrale cylindre styres i overensstemmelse med

omdrejningshastigheden af den elektriske motor og ikke af ventiler.

14. Apparat ifølge et hvilket som helst af de foregående krav, hvor flowledningen danner et lukket kredsløb, som cirkulerer en konstant mængde hydraulikfluid ved det ønskede tryk cyklisk frem og tilbage, afhængigt af cylinderens driftsretning.

15. Apparat til anvendelse på en byggeri- eller byggepladsmaskine, hvilket apparat omfatter:

mindst en hydraulikcylinder (3, 4, 5); mindst en hydraulikpumpe (31), der har mindst en elektrisk motor (10) koblet dertil til drift af hydraulikpumpen, hvor pumpen er konfigureret til at pumpe hydraulikfluid langs en flowledning til at betjene mindst en hydraulikcylinder til at køre ind eller ud; og

energiforsyningsorgan omfattende:

mindst et batteri (7) til at levere elektrisk energi til den elektriske motor; og

mindst en brændselscelle til at generere og forsyne batteriet med elektrisk energi til opladning af batteriet;

hvor den hydrauliske cylinder er konfigureret til at tilvejebringe volumetrisk neutral drift;

hvor hydraulikcylinderen er konfigureret til at køre ind og ud under belastning, og **kendetegnet ved, at** hydraulikpumpen kan betjenes i motortilstand under anvendelse af hydraulikfluid drevet af belastningen for at viderebringe energi fra cylinderen for at overføre energien produceret af hydraulikcylinderen under belastning til mindst en energilagringsenhed, hvor energilagringsenheden omfatter batteriet.

16. Byggeri- eller byggepladsmaskine, som inkluderer apparatet ifølge et hvilket som helst af de foregående krav.

17. Byggeri- eller byggepladsmaskine ifølge krav 16, der er en gravemaskine forsynet med et hovedlegeme og mindst et løfte-/sænkeelement koblet til hovedlegemet, hvor løfte-/sænkeelementet eller -elementerne er et af: en udligger, en arm, og en graveskovl.

18. Fremgangsmåde til betjening af byggeri- eller byggepladsmaskinen ifølge krav 16 eller 17.

DRAWINGS

Drawing

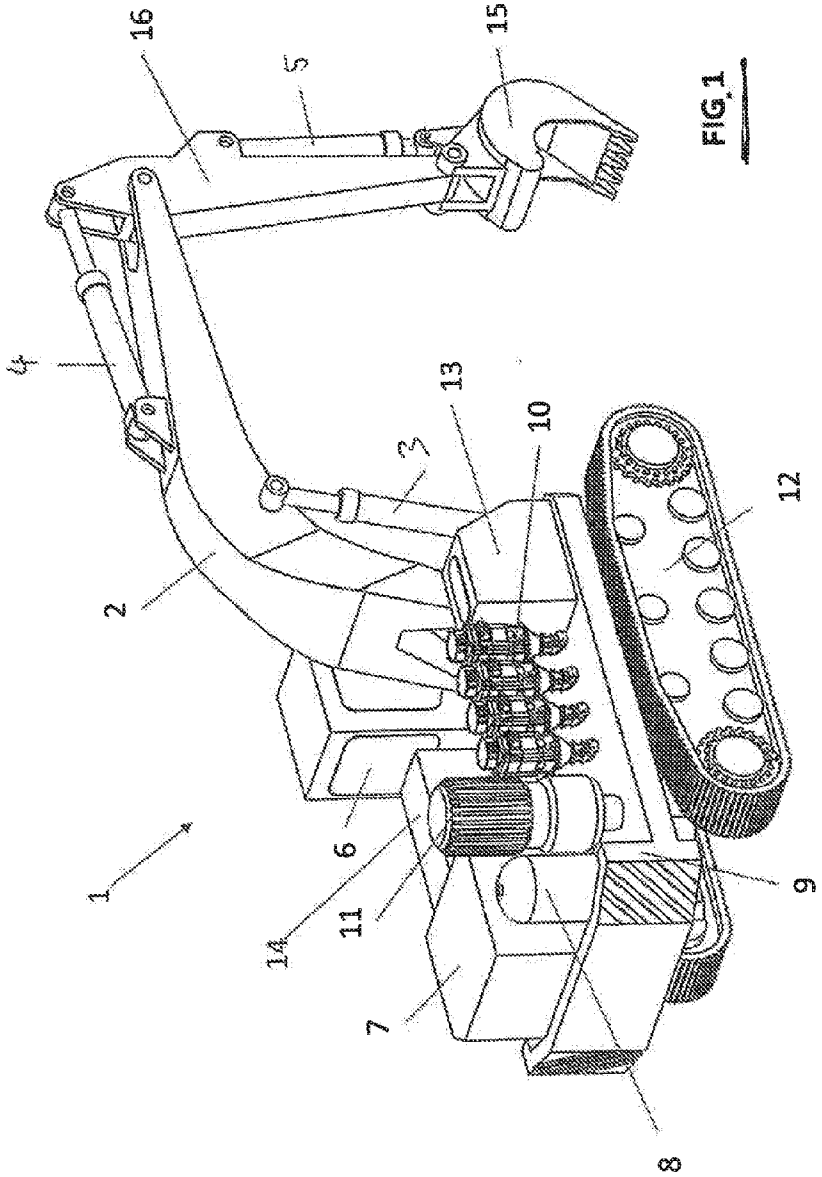
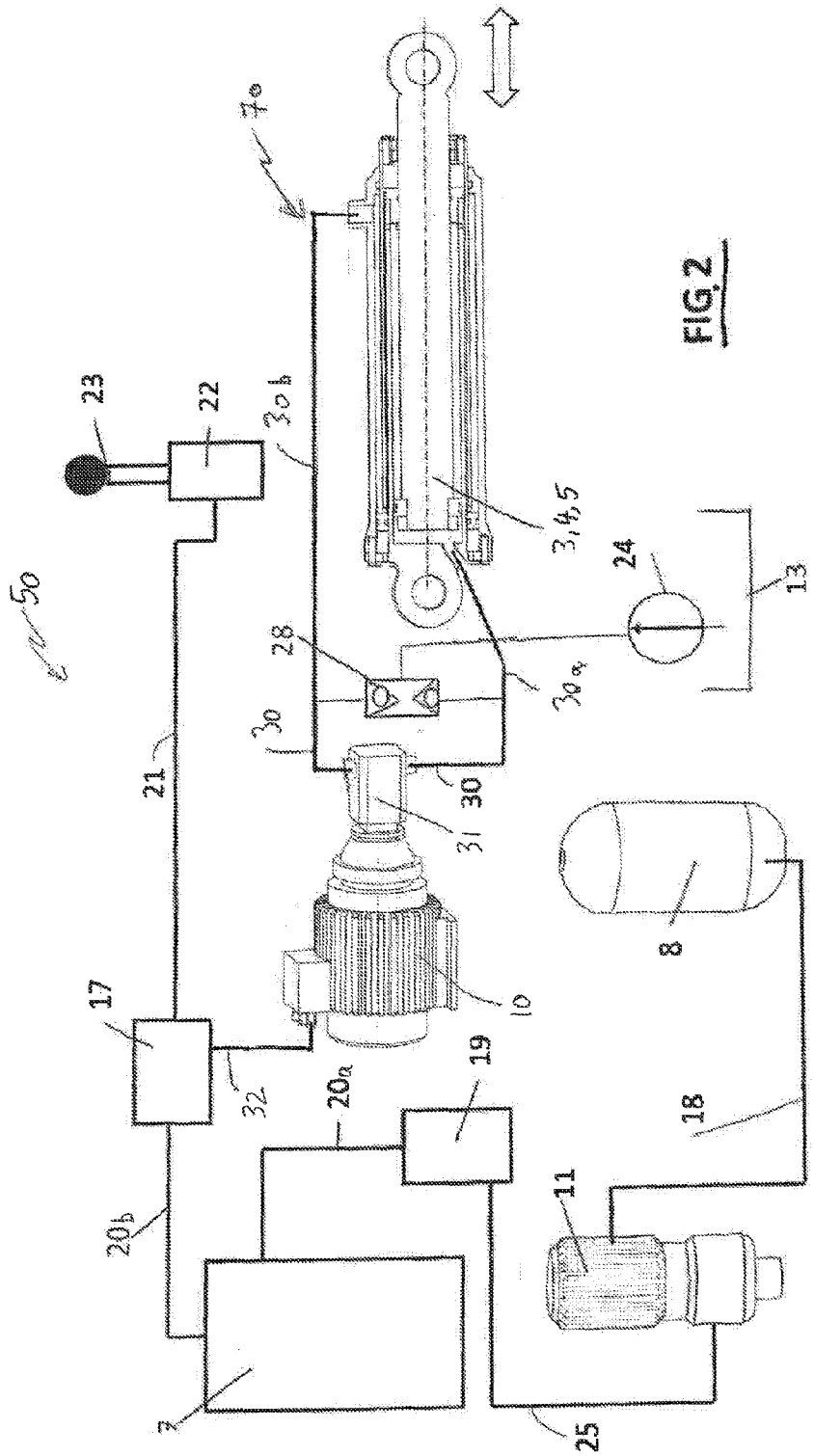


FIG.1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7a
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20a
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20b
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FIG.2