(12) STANDARD PATENT (11) Application No. **AU 2017204033 B2**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Apparatus for recuperating hydraulic energy with energy-efficient replenishment of the rod sides of differential cylinders and simultaneous pressure intensification

(51) International Patent Classification(s)
F15B 21/14 (2006.01)

(21) Application No: **2017204033** (22) Date of Filing: **2017.06.15**

(30) Priority Data

(31) Number	(32) Date	(33) Country
10 2016 007 286.5	**2016.06.15**	**DE**

(43) Publication Date: **2018.01.18**
(43) Publication Journal Date: **2018.01.18**
(44) Accepted Journal Date: **2019.04.04**

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(56) Related Art
US 20130318955 A1

2017204033 15 Jun 2017

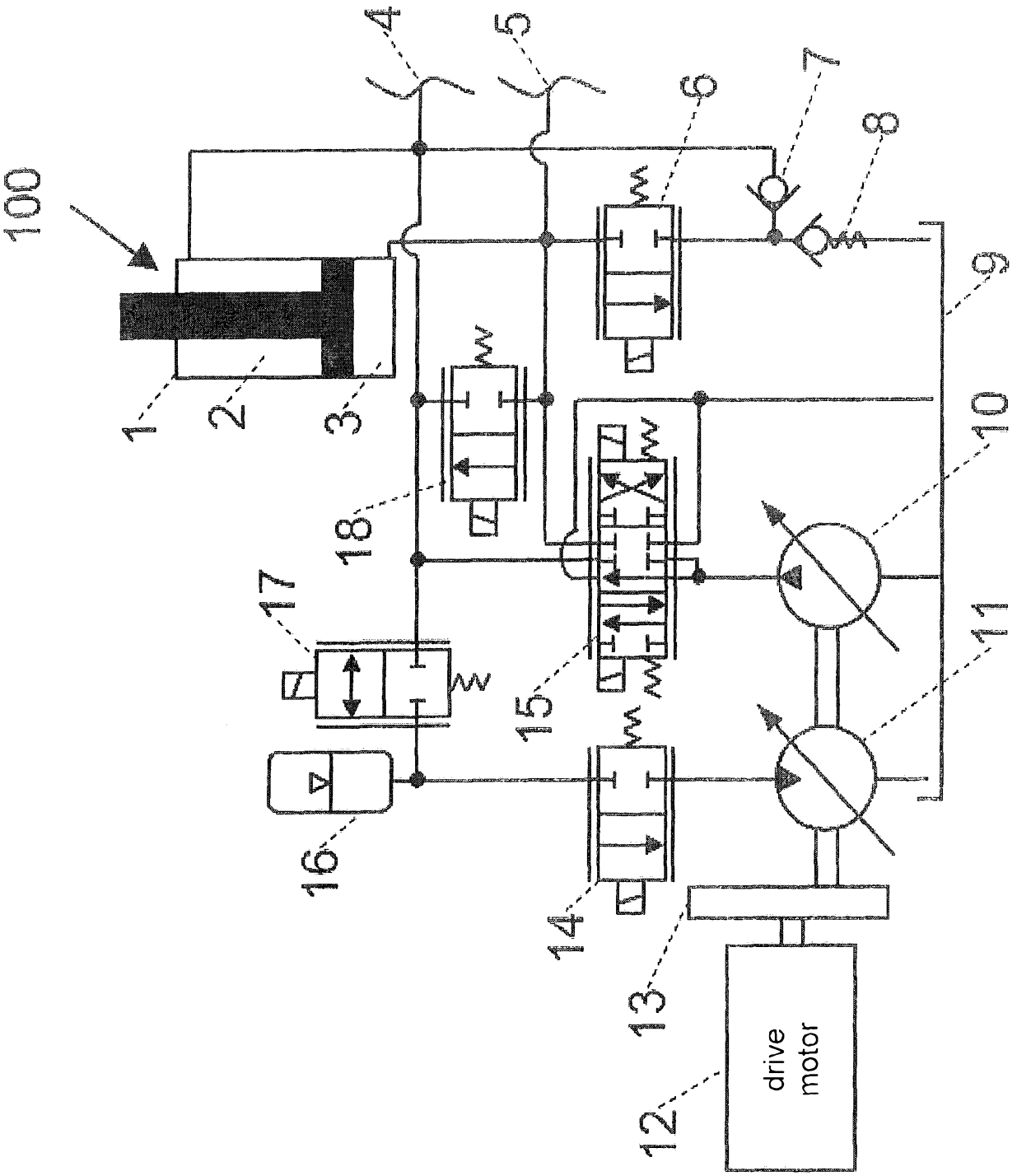
ABSTRACT

This invention relates to an apparatus for recuperating hydraulic energy in a working machine, with at least one first differential cylinder piston device (100) with a differential cylinder (1) and separate rod (2) and bottom (3) sides, with at least one hydraulic accumulator (16) which is hydraulically connectable with the differential cylinder piston device (100), wherein the potential energy of the differential cylinder piston device (100) retracting under pressing load is at least partly storable in the hydraulic accumulator (16), and wherein the rod (2) and bottom (3) sides are connectable with each other via at least one brake valve (6) for recirculating hydraulic fluid from the bottom side (3) into the rod side (2).

FIG 1

2017204033 15 Jun 2017

Figure 1



2017204033 26 Feb 2019

APPARATUS FOR RECUPERATING HYDRAULIC ENERGY WITH ENERGY-EFFICIENT REPLENISHMENT OF THE ROD SIDES OF DIFFERENTIAL CYLINDERS AND SIMULTANEOUS PRESSURE INTENSIFICATION

FIELD OF THE INVENTION

[0001] This invention relates to an apparatus for recuperating hydraulic energy in a working machine, comprising at least one first differential cylinder piston device with a differential cylinder and separate rod and bottom sides, with at least one hydraulic accumulator which is hydraulically connectable with the differential cylinder piston device, wherein the potential energy of the differential cylinder piston device retracting under pressing load is at least partly storable in the hydraulic accumulator, and wherein the rod and bottom sides are connectable with each other via at least one brake valve for recirculating hydraulic fluid from the bottom into the rod side.

BACKGROUND TO THE INVENTION

[0002] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

[0003] In known interconnections of hydraulic cylinders especially in mobile working machines, the retraction of hydraulic cylinders under pressing load, e.g. when the or a lifting cylinder is lowered without pressure, is realized by a throttle control. Here, the potential energy which is defined by the load acting on the cylinder is converted into heat by throttling the pressurized volume flow. The existing potential energy thereby is destroyed. Due to the conversion into heat, cooling capacity additionally must be applied within the machine.

[0004] A commonly used type of the hydraulic cylinders in mobile working machines is the differential cylinder. When the same is retracted by means of throttle control and pressing load, it must be ensured that a replenishment of the rod-side cylinder chamber is ensured. On the one hand, this is possible by adding a corresponding supply volume flow through the working pumps, and on the other hand a corresponding replenishment of the rod-side cylinder chambers can be carried out by recirculating the throttled volume flow. Due to the recirculation of the throttled volume flow a division of this volume flow corresponding to the area ratio of the hydraulic cylinders or corresponding to the area ratio

of rod and bottom side of the hydraulic cylinder or the hydraulic cylinders is made. A part of the volume flow here flows into the rod-side chambers of the cylinders, the other part is guided into the tank.

[0005] When the potential energy contained in the lowering operation of the lifting cylinders is to be stored, it is important to store as much of the existing energy as possible. In hydraulics, this corresponds to an oil quantity as large as possible under a pressure as high as possible. The hydraulic interconnections known from the prior art, which realize the recirculation of a part of the bottom-side volume flow into the rod-side chambers of the hydraulic cylinders, reduce the volume flow which can be available for storage.

[0006] Currently, different solutions for storing the potential energy when lowering the boom of mobile hydraulic working machines are known. For example apparatuses are known, in which one of two cylinders is used for storing energy. There is used a displacement machine in a closed circuit, in order to replenish the rod-side chambers of both cylinders with the return flow quantity of the second cylinder. A disadvantage of this kind of apparatuses is the non-existent exchange of oil on the bottom side of the hydraulic cylinder which is connected with the accumulator. The oil volume only is moved between hydraulic accumulator and bottom side of the cylinder.

[0007] There are also known apparatuses in which on retraction of the cylinders a hydraulic pump is used, in order to ensure the replenishment of the rod-side chambers. Replenishment by application of hydraulic power does not correspond to an energy-efficient actuation of the hydraulic consumers.

[0008] The absorption of the potential energy of the boom by a gas-filled cylinder likewise is known. In use of such apparatuses the additional integration of a gas cylinder into the machine is necessary, which means a disadvantageously high integration expenditure. In addition, the storage volume of the gas storage cylinder must be designed for the entire stroke of the drive, even if the entire stroke is not employed in normal working use.

[0009] For feeding in the stored hydraulic energy, apparatuses are known in which the energy is directly fed into the fan circuit of the machine. Based on the operating point of the fan circuit it is necessary to throttle the supplied volume flow from the hydraulic

accumulator to the fan circuit. There are caused throttling losses, and the quantity of the reusable hydraulic energy thus is reduced.

[0010] It furthermore is known to use the stored hydraulic energy directly for supplying the working pumps. This requires a circuitry which connects the suction side of the working pump either with the hydraulic tank or with the hydraulic accumulator. When the pump is not supplied via the hydraulic accumulator, pressure losses occur through the valve, which influence the intake pressure of the pump and thus can cause unfavorable operating conditions. In addition, cooling and filtering must be provided between hydraulic accumulator and intake of the working pump.

[0011] The known hydraulic interconnections correspondingly have three disadvantages:

1. The potential energy of the lifting-lowering operation is destroyed by the throttling operation and cannot be used for other processes.
2. The potential energy of the lifting-lowering operation is introduced into the hydraulic system in the form of thermal energy and subsequently must be dissipated again by corresponding cooling devices. These operations likewise are consuming energy.
3. The division of the bottom-side volume flow on lowering of the lifting cylinders leads to a reduction of the possible potential of storable energy.

SUMMARY OF THE INVENTION

[0012] It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

[0013] Advantageously, the invention in at least one preferred form stores the potential energy, which is defined by the pressing load on the hydraulic cylinder(s), and at the same time ensures an energy-efficient replenishment of the rod-side chambers of the hydraulic cylinders.

[0014] According to one aspect of the invention, there is provided an apparatus for recuperating hydraulic energy in a working machine, comprising at least one first differential cylinder piston device with a differential cylinder having a separate rod and a bottom side, at least one hydraulic accumulator which is hydraulically connectable with the

2017204033 26 Feb 2019

differential cylinder piston device and which, via an accumulator valve, stores at least part of a potential energy of the differential cylinder piston device retracting under pressing load, and each of a connecting valve and a brake valve fluidically connecting the rod and the bottom side for recirculating hydraulic fluid from the bottom side into the rod side with the accumulator valve open and closed.

[0015] According to a second aspect, there is provided a working machine, comprising an apparatus for recuperating hydraulic energy in a working machine, the apparatus comprising at least one first differential cylinder piston device with a differential cylinder having a separate rod side and bottom side, and at least one hydraulic accumulator which is fluidly connectable with the differential cylinder piston device via a hydraulic accumulator valve, wherein potential energy of the differential cylinder piston device retracting under pressing load is at least partly storable in the hydraulic accumulator, and wherein the rod side and the bottom side are fluidly connectable with each other via a brake valve and a connecting valve for recirculating hydraulic fluid from the bottom side into the rod side with the hydraulic accumulator valve open and closed.

[0016] According to another aspect, there is provided a method for recuperating hydraulic energy in a working machine, comprising applying a preloading pressure at a hydraulic accumulator, opening a hydraulic accumulator valve to fluidly connect the hydraulic accumulator with a rod side of a differential cylinder, retracting the piston by opening a connecting valve to fluidly connect a bottom side of the differential cylinder with the rod side and the hydraulic accumulator, and in response to the hydraulic accumulator reaching a threshold pressure, closing each of the connecting valve and the hydraulic accumulator valve and opening a brake valve fluidically coupling the bottom side with the rod side.

[0017] Advantageously, the potential energy withdrawn from the differential cylinder piston device initially can be stored and in a further state of the apparatus be used for operating the working machine. The quantity of the storable potential energy thereby is maximized, which can be used for other tasks within the working machine. Furthermore, the expended cooling capacity can be reduced, as less waste heat must be dissipated by the cooling system within the machine. Based thereon, the entire operation of the hydraulic working machine can be made more energy-efficient.

[0018] In a particularly preferred embodiment of the invention it is conceivable that the hydraulic accumulator is hydraulically connectable with more than the one differential cylinder piston device. Accordingly, it can be provided that further differential cylinder piston devices of the working machine release the potential energy contained in them to the at least one hydraulic accumulator. Accordingly, it is conceivable that for better energy recovery different differential cylinder piston devices of a working machine are coupled with the hydraulic accumulator or the hydraulic accumulators. Correspondingly, an increased energy recuperation rate can be achieved.

[0019] In another preferred embodiment it is conceivable that a support motor is provided, which is designed to feed the hydraulic energy stored in the hydraulic accumulator into a drive train of the working machine and thereby recuperate the same, wherein the support motor in particular is connectable with the hydraulic accumulator via a support motor valve. Advantageously, the energy stored in the hydraulic accumulator thus can be used to support a primary drive source such as a diesel engine or an electric motor of the working machine, in that energy can be fed into the drive train of the machine via the support motor.

[0020] In another preferred embodiment it is conceivable that the differential cylinder piston devices are arranged to be operated in parallel. In another preferred embodiment it can furthermore be provided that at least one working pump is provided for driving the differential cylinder piston device and/or that at least one control slide is provided for actuating the differential cylinder piston device and/or that at least one tank is provided and/or that a hydraulic accumulator valve is provided for shutting off the hydraulic accumulator against the differential cylinder piston device. The advantages of said formations can be taken from the description of the Figures.

[0021] In a particularly preferred embodiment it is conceivable that a connecting valve is provided for shutting off the bottom side against the rod side of the differential cylinder piston device. It also is conceivable that by shutting off the bottom side against the rod side a pressure intensification takes place and/or that the hydraulic accumulator is connectable with the rod side of the differential cylinder.

[0022] The invention furthermore is directed to a working machine, in particular to a wheel loader, hydraulic excavator or crane, comprising an apparatus for recuperating

hydraulic energy according to any of claims 1 to 8. Particularly preferably, it can be provided that the working machine is equipped to be operable without loss of further functions in the case of a failure of the apparatus for recuperating hydraulic energy.

[0023] Accordingly, the apparatus for recuperating hydraulic energy can be provided as merely an additional apparatus on the working machine, wherein even without the apparatus according to the invention the working machine is provided with all actuators necessary for the operation of the working machine. The apparatus according to the invention thus can be retrofitted in working machines known per se, wherein the functionality of the working machines does not depend on the apparatus.

[0024] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Further details and advantages of the invention are described with reference to the only Figure 1.

[0026] Figure 1 shows the schematic hydraulic circuit of the invention described here.

DETAILED DESCRIPTION

[0027] When a working machine with an apparatus according to the invention is put into operation, a corresponding preloading pressure can be applied in the hydraulic accumulator 16. When the storage operation is to be started, an external force must be applied at the differential cylinder 1 or at the corresponding piston, which leads to retraction. As a result, pressures are built up on the bottom side 3 of the differential cylinder 1, which define the existing potential energy. This potential energy is to be absorbed by the hydraulic accumulator 16. To start the lowering operation, the hydraulic accumulator valve 17 is opened and thus a connection between the hydraulic accumulator 16 and the rod side 2 of the differential cylinder 1 is created. The hydraulic accumulator valve 17 can be a 2-way valve. To initiate the retracting movement of the differential cylinder 1, the connecting valve 18 is actuated. This connecting valve 18 creates a connection between bottom side 3

2017204033 26 Feb 2019

and rod side 2 of the differential cylinder 1. Through the connecting valve 18 the volume flow gets from the bottom side 3 into the rod side 2 of the differential cylinder. Based on the area ratio between bottom side 3 and rod side 2 not the entire volume can be absorbed by the rod side 2. The differential volume, which is guided through the hydraulic accumulator valve 17, is absorbed by the hydraulic accumulator 16. Based on the opening area of the connecting valve 18 and the related throttling of the oil volume flow from the bottom side 3 of the differential cylinder 1, the speed of retraction of the differential cylinder 1 under load can be influenced. When the retracting movement of the differential cylinder 1 is to be stopped, the connecting valve 18 and the hydraulic accumulator valve 17 are closed. By closing the hydraulic accumulator valve 17 the hydraulic accumulator 16 is shut off and the hydraulic energy absorbed remains stored in the hydraulic accumulator 16.

[0028] After the storage operation the energy of the pressurized oil volume in the hydraulic accumulator 16 can again be fed into the drive train of the machine. For this purpose, the support motor 11 is connected with the hydraulic accumulator 16 via the hydraulic support motor valve 14. The support motor 11 can be mounted directly on the transfer gear 13 of the machine and is operated with a speed imparted by the drive motor 12. Depending on the absorption volume of the support motor 11 energy then is fed into the drive train of the machine, corresponding to the operating conditions of the hydraulic accumulator 16. Upon completion of the feeding operation the support motor valve 14 is closed and the connection between hydraulic accumulator 16 and support motor 11 thus is separated.

[0029] The hydraulic accumulator 16 can be designed for the entire or also only for a part of the stroke path of the differential cylinder 1. When the hydraulic accumulator 16 is designed only for a part of the stroke path of the differential cylinder 1 and a retracting movement of the differential cylinder 1 is to be effected beyond the design limit of the hydraulic accumulator 16, the connecting valve 18 and the hydraulic accumulator valve 17 are closed and the brake valve 6 is actuated. Through the brake valve 6 of the differential cylinder 1 a part of the volume flow from the bottom side 3 of the differential cylinder 1 gets through the check valve 7 to the rod side 2 of the differential cylinder 1 at a preloading pressure which is specified by the preloading valve 8. A lack of filling on the rod side 2 of the differential cylinder 1 during the retracting movement thereby is prevented. The volume flow from the bottom side 3 of the differential cylinder 1, which is not absorbed by the rod side 2 of the differential cylinder 1, gets into the tank 9 via the preloading valve 8.

2017204033 26 Feb 2019

[0030] When in the working cycle of the machine an extending or retracting movement of the differential cylinder 1 subsequently is effected by a corresponding actuation of the working pump 10 and the control slide 15, the connecting valve 18 and the hydraulic accumulator valve 17 are kept closed. The inflow and outflow of the volume flows of the differential cylinder 1 then is effected corresponding to the interconnection of the control slide 15.

[0031] The invention comprises at least one differential cylinder 1. Further differential cylinders can be integrated into the system at the rod-side port 4 and the bottom-side port 5 of the differential cylinder 1.

[0032] The circuit includes at least one working pump 10 and at least one control slide 15.

[0033] As hydraulic accumulator 16 all kinds of hydraulic accumulators can be used with different energy storage media, e.g. nitrogen. Designs as bladder accumulator, piston accumulator, diaphragm accumulator or spring accumulator as well as different combinations of accumulator designs are conceivable.

[0034] The valves shown are usable as individual 2/2-way valves or also as combination on a valve rod. A proportional or switching actuation also is possible.

[0035] The invention is characterized in that one or more differential cylinder piston devices 100 can be retracted under pressing load and the existing potential energy thereby can be stored for a large part by means of one or more hydraulic accumulators 16. The differential cylinder piston devices 100 can be designated as hydraulic linear drives. The term cylinder or differential cylinder can relate to the differential cylinder piston device of the invention depending on the context and in a manner which is obvious for the skilled person.

[0036] The invention furthermore is characterized in that one or more differential cylinders can be retracted under pressing load and filling of the rod sides of the cylinders is effected at a high pressure level. During the retracting operation, a connection between bottom and rod side of the one or more differential cylinders is created via a valve. The bottom-side pressure thereby is applied on the rod side. Based on the area ratios a

pressure intensification is produced, which leads to an increase of the bottom-side pressure. At the same time, one or more hydraulic accumulators are connected with the rod sides of the differential cylinders during the retracting operation. By throttling the connection between bottom and rod side of the differential cylinders a control of the speed can be performed. The difference in volume between bottom- and rod-side chamber of the differential cylinders is absorbed by the one or more hydraulic accumulators. Due to the small pressure difference between bottom and rod side of the differential cylinders only a small part of the potential energy is converted into heat and thus more energy is available for storage.

[0037] The invention furthermore is characterized in that the hydraulic linear drive can be retracted and extended without the one or more hydraulic accumulators and hydraulic valves having to be activated for storing the potential energy. This is achieved within the hydraulic circuit by a corresponding parallel interconnection of the hydraulic linear drive.

[0038] The invention furthermore is characterized in that the storage of energy is possible on the entire or only on a part of the possible travel path of the differential cylinder.

[0039] The invention is characterized in that the stored energy of the lowering operation of the one differential cylinder or of the several differential cylinders can be reused. This can be achieved in that a hydraulic motor can be connected with the corresponding hydraulic accumulator and the energy contained in the hydraulic accumulator can be fed into the drive train of the machines to support the primary drive source such as for example a diesel engine or an electric motor of the working machine.

[0040] The invention also is characterized in that it can be integrated into the drive train of a machine without influencing the functions of the drive train such that the complete operability of the machine depends on the invention. This means that the machine can properly be operated also without the operability of the invention.

2017204033 26 Feb 2019

CLAIMS

1. An apparatus for recuperating hydraulic energy in a working machine, comprising:

at least one first differential cylinder piston device with a differential cylinder having a separate rod side and a bottom side,

at least one hydraulic accumulator which is hydraulically connectable with the differential cylinder piston device and which, via an accumulator valve, stores at least a part of a potential energy of the differential cylinder piston device retracting under pressing load; and,

each of a connecting valve and a brake valve fluidically connecting the rod side and the bottom side for recirculating hydraulic fluid from the bottom side into the rod side with the accumulator valve open and closed.

2. The apparatus according to claim 1, wherein the hydraulic accumulator is hydraulically connectable with more than the one differential cylinder piston device.

3. The apparatus according to claim 1 or claim 2, wherein a support motor is provided, which is designed to feed the hydraulic energy stored in the hydraulic accumulator into a drive train of the working machine and thereby recuperate the hydraulic energy, wherein the support motor is connectable with the hydraulic accumulator via a support motor valve.

4. The apparatus according to claim 2, wherein the differential cylinder piston devices are arranged to be operated in parallel.

5. The apparatus according to claim 1, wherein at least one working pump is provided for driving the differential cylinder piston device, at least one control slide valve is provided for actuating the differential cylinder piston device, and at least one tank is provided, and a hydraulic accumulator valve is provided for shutting off the hydraulic accumulator against the differential cylinder piston device.

6. The apparatus according to claim 5, wherein the connecting valve is housed in a first loop fluidically coupling the rod side of the differential cylinder and the bottom side of

2017204033 26 Feb 2019

the differential cylinder, the connecting valve provided for shutting off the bottom side against the rod side of the differential cylinder when the brake valve is closed.

7. The apparatus according to claim 6, wherein, by shutting off the bottom side against the rod side, a pressure intensification takes place.

8. The apparatus according to any one of the preceding claims, wherein the hydraulic accumulator is connectable with the rod side of the differential cylinder.

9. The apparatus according to claim 6, wherein the brake valve is housed in a second loop fluidically coupling the rod side of the differential cylinder and the bottom side of the differential cylinder via a check valve, the second loop at least partially overlapping with the first loop.

10. A working machine, comprising:

an apparatus for recuperating hydraulic energy in a working machine, the apparatus comprising at least one first differential cylinder piston device with a differential cylinder having a separate rod side and bottom side, and at least one hydraulic accumulator which is fluidly connectable with the differential cylinder piston device via a hydraulic accumulator valve;

wherein potential energy of the differential cylinder piston device retracting under pressing load is at least partly storable in the hydraulic accumulator; and

wherein the rod side and the bottom side are fluidly connectable with each other via a brake valve and a connecting valve for recirculating hydraulic fluid from the bottom side into the rod side with the hydraulic accumulator valve open and closed.

11. The working machine according to claim 10, wherein the working machine is equipped to be operable in the case of a failure of the apparatus for the direct recuperation of hydraulic energy.

12. The working machine according to claim 10, further comprising a control unit having non-transitory memory with instructions stored therein, the instructions executable by a processor to:

during application of the pressing load on the differential cylinder piston device, fluidly connect the hydraulic accumulator with the rod side of the differential cylinder by

opening the hydraulic accumulator valve, and fluidly connect the bottom side of the differential cylinder with the rod side of the differential cylinder by opening the connecting valve.

13. The working machine according to claim 12, wherein the instructions further comprise instructions executable by the processor to:

determine a desired speed of retraction of a piston of the differential cylinder piston device; and

adjust an opening amount of the connecting valve based on the desired speed of retraction.

14. A method for recuperating hydraulic energy in a working machine, comprising:

applying a preloading pressure at a hydraulic accumulator;

opening a hydraulic accumulator valve to fluidly connect the hydraulic accumulator with a rod side of a differential cylinder;

retracting the piston by opening a connecting valve to fluidly connect a bottom side of the differential cylinder with the rod side and the hydraulic accumulator; and

in response to the hydraulic accumulator reaching a threshold pressure, closing each of the connecting valve and the hydraulic accumulator valve and opening a brake valve fluidically coupling the bottom side with the rod side.

15. The method in accordance with claim 14, wherein an amount of hydraulic fluid circulated from the bottom side to the rod side is based on an area ratio between the bottom side and the rod side.

16. The method in accordance with claim 14, wherein a differential amount of hydraulic fluid not absorbed at the rod side is stored in the hydraulic accumulator.

17. The method in accordance with claim 14, further comprising adjusting an opening area of the connecting valve to throttle a flow of hydraulic fluid from the bottom side to the rod side based on a desired retraction speed of the piston.

18. The method in accordance with claim 14, further comprising, after retracting the piston, closing the connecting valve and the hydraulic accumulator valve, opening a support motor valve to fluidly connect the hydraulic accumulator with a support motor, and

feeding hydraulic energy stored in the hydraulic accumulator into a drive train of the working machine via the support motor.

2017204033 15 Jun 2017

Figure 1