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(54) **IMPROVED HYDRAULIC ARRANGEMENT FOR A WORK MACHINE AND WORK MACHINE COMPRISING SUCH HYDRAULIC ARRANGEMENT**

(57) A hydraulic arrangement (14) for a work machine (1) comprising a body (2) and a hydraulically actuated work implement (6) carried by the body (2) and configured to perform earth moving operations; the hydraulic arrangement (14) comprises: a source of pressurized hydraulic fluid (17); at least one hydraulic actuator (7), carried by the work implement (6) and configured to operate the hydraulically actuated work implement (6); a hydraulic circuit (20), which is arranged on said body (2), is configured to put the source of hydraulic fluid (17) in fluid communication with the hydraulic actuator (7) and has a common pressure rails configuration; a control valve arrangement (26) configured to selectively put the hydraulic circuit (20) in fluid communication with the hydraulic actuator (7); and at least one pressure multiplier hydraulic cylinder (30) configured to increase the pressure of the hydraulic fluid provided by said hydraulic circuit (20) and fed towards said hydraulic actuator (7).

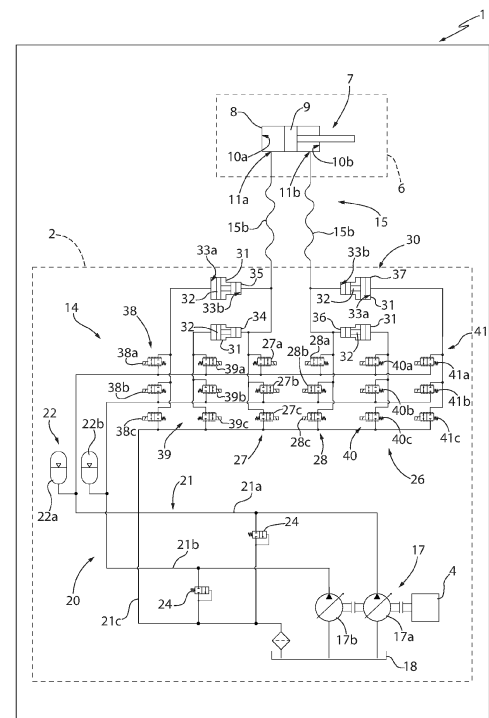


FIG.2

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Description

TECHNICAL FIELD

[0001] The present invention relates to a hydraulic arrangement for a work machine, in particular for an earth-moving machine such as an excavator, a digger, a mechanical shovel or the like. The present invention further relates to a work machine comprising such a hydraulic arrangement.

[0002] The present invention finds its preferred, although not exclusive, application in a hydraulic arrangement provided with a common pressure rails (CPR) configuration and adapted to control at least one hydraulic actuator of a hydraulically actuated arm of a work machine, in particular an excavator. Reference will be made to this application by way of the example below, without however losing in generality.

BACKGROUND OF THE INVENTION

[0003] As is known, work machines such as excavators, diggers or the like are provided with a hydraulically actuated work implement carried by a body of the work machine and configured to perform multiple earth-moving operations.

[0004] In particular, such hydraulic actuated work implement usually comprises: a boom rotatably carried by the body of the work machine; a stick or dipper or arm rotatably carried by the boom; a bucket or similar work attachment rotatably carried by the arm; and a plurality of hydraulic actuators adapted to rotate the boom, the arm, and the bucket with respect to their hinge points.

[0005] In addition, such work machines comprise a hydraulic circuit, which is configured to provide pressurized hydraulic fluid towards at least one of the aforementioned hydraulic actuators, in order to operate this latter.

[0006] Traditionally, such hydraulic circuit comprises a source of pressurized hydraulic fluid and directional proportional control valves configured to throttle the flow of hydraulic fluid provided to each hydraulic actuator, to control its operation. This allows a precise control of the operation of each hydraulic actuator, but unfortunately results in a great deal of hydraulic fluid routed back to tank, with the waste in energy that this entails.

[0007] To reduce waste of energy and allow some energy recovery, some manufacturer recently developed hydraulic circuits including variable displacement linear actuators fluidly connected to a source of pressurized hydraulic fluid by means of common pressure rails (CPR) and a set of logic on-off hydraulic valve configured to selectively fluidly connect the source of pressurized hydraulic fluid with the variable displacement linear actuator.

[0008] An example of such a simplified hydraulic circuit is schematically represented in Figure 1 and is denoted as a whole with reference number 100.

[0009] Hydraulic circuit 100 comprises a hydraulic

pump 110, which is carried by an internal combustion engine 120 of the work machine and is configured to suck hydraulic fluid from a tank 130 and to provide at outlet a pressured flow of such hydraulic fluid.

[0010] Hydraulic pump 110 is configured to be fluidly connected to at least one hydraulic actuator 140, in order to feed to the same hydraulic actuator 140 the hydraulic fluid provided at outlet. Hydraulic actuator 140 may be, for instance, the boom actuator, the arm actuator or the bucket actuator of the aforementioned work machine.

[0011] Hydraulic actuator 140 is a double-acting asymmetrical multi-chamber hydraulic cylinder, in particular a double-acting asymmetrical four-chamber hydraulic cylinder. Hydraulic actuator 140 comprises two chambers A and B configured to contain pressurized hydraulic fluid to exert forces on the piston of the actuator 140 along a first direction, and two chambers C and D configured to contain pressurized hydraulic fluid to exert forces on the piston along a second direction opposite to the first one.

[0012] Therefore, the resulting hydraulic force F_{hyd} acting on the piston of the hydraulic cylinder will follow the following formula:

$$F_{hyd} = p_A A_A + p_B A_B - p_C A_C - p_D A_D,$$

wherein p and A respectively indicates the pressure within and the area of the respective chambers.

[0013] In addition, hydraulic circuit 100 comprises a plurality of hydraulic lines, also referred to as hydraulic pressure rails, fluidly connecting the hydraulic pump 110 with the hydraulic cylinder 140.

[0014] With reference to the example illustrated in Figure 1, hydraulic circuit 100 comprises three distinct pressure rails 150, 160 and 170 fluidly connecting the hydraulic pump 110 with the hydraulic actuator 140. In particular, each pressure rails 150, 160 and 170 is selectively connectable to the chambers A, B, C and D of hydraulic actuator 140.

[0015] In addition, each pressure rail 150, 160 and 170 is provided with its own hydraulic accumulator 155, 165 and 175, which is configured to accumulate hydraulic fluid at a predetermined pressure level, in order to set the pressure level of the fluid flowing through the respective pressure rail 150, 160 and 170.

[0016] In particular, the pressure levels within hydraulic accumulator 155, 165 and 175 and pressure rails 150, 160 and 170 are differentiated to each other. Accordingly, hydraulic circuit 100 may be provided with a high-pressure rail 150, a medium-pressure rail 160 and a low-pressure rail 170.

[0017] In addition, the hydraulic circuit 100 comprises a valve arrangement 180, which is configured to allow selectively fluidly connecting each pressure rail 150, 160 and 170 to each chamber A, B, C and D of the hydraulic cylinder 140.

[0018] In particular, valve arrangement 180, for each chamber A, B, C and D, comprises three logic/discrete

valves, each of which is operatively interposed between the respective chamber port and the respective constant pressure rail 150, 160 and 170.

[0019] Therefore, being connected to the pressure lines 150, 160 and 170 by on-off hydraulic valves, the hydraulic force F_{hyd} acting on the hydraulic cylinder 140 piston will be discrete.

[0020] In particular, the number of discrete values of the hydraulic force F_{hyd} acting on the hydraulic cylinder 140 piston can be calculated according to following formula

$$\#_{F_{hyd}} = \#_{rails} \#_{chamber},$$

[0021] Wherein $\#_{F_{hyd}}$ is the number of discrete values of the hydraulic force F_{hyd} acting on the hydraulic cylinder 140 piston, $\#_{rails}$ is the number of rails present in the common pressure rails architecture and $\#_{chamber}$ is the number of chambers of the multi-chamber cylinders.

[0022] In the example illustrated in Figure 1, the number of discrete values of the hydraulic force F_{hyd} acting on the hydraulic cylinder 140 is equal to 3^4 , i.e. 81.

[0023] Although the above hydraulic architecture allows to reduce waste of energy and allows some energy recovery by accumulating pressurized hydraulic fluid within the hydraulic accumulators during deceleration of the work machine arm, the same hydraulic architecture still poses several drawbacks and there is still plenty of room for improvements.

[0024] In particular, asymmetrical multi-chambers hydraulic cylinders are difficult to design, really expensive and unreliable, with all the obvious drawbacks that this entails. In particular, the cost of the asymmetrical multi-chambers hydraulic cylinders has a non-negligible impact on the overall cost of the work machine.

[0025] Furthermore, it is really cumbersome to provide multi-chambers hydraulic cylinders provided with a high number of different chambers, in particular more than four. This unfortunately strongly limits the number of discrete force level available and so the resolution of the hydraulic circuit 100.

[0026] In addition, to avoid multiplication of flexible hoses on the excavator arm and therefore to reduce the risks of failures, the valve arrangement 180 is arranged close to the respective hydraulic cylinder 140 and is carried directly by the hydraulically actuated arm of the work machine. This drastically increases the weight and the inertia of the hydraulically actuated arm and reduces the lifting capacity of the work machine, with the obvious drawbacks that this entails.

[0027] In view of the above, the need is felt to provide an improved hydraulic arrangement for a work machine able to overcome the aforementioned drawbacks.

[0028] Aim of the present invention is to satisfy the above-mentioned need in an optimized and cost-effective manner.

SUMMARY OF THE INVENTION

[0029] The aforementioned aims are reached by a hydraulic arrangement and by a work machine as claimed in the appended set of claims.

BRIEF DESCRIPTION OF DRAWINGS

[0030] For a better understanding of the present invention, a preferred embodiment is described in the following, by way of a non-limiting example, with reference to the attached drawings, wherein:

- Figure 1 is a schematic illustration of a hydraulic arrangement for a hydraulically actuated work implement of a work machine as known in the art;
- Figures 2 and 3 are schematic illustrations of two embodiments a work machine realized according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] With reference to Figure 2, number 1 denotes, as a whole, a work machine, in particular an earth-moving machine such as an excavator, a digger, a mechanical shovel or the like.

[0032] Work machine 1 comprises a body 2 movable on the ground via ground engaging wheels or tracks (not illustrated).

[0033] In particular, body 2 preferably comprises: a lower frame or undercarriage (not illustrated), which carries the ground engaging wheels or tracks to allow motion of body 2 with respect to the ground; and an upper frame (not illustrated) or superstructure, which is carried in a rotatable manner by lower frame preferably about a rotation axis orthogonal to the advancing plane of work machine 1, i.e. orthogonal to the ground.

[0034] In addition, work machine preferably comprises an internal combustion engine 4, which is configured to provide torque to allow motion of the work machine 2, for instance by driving a hydraulic pump, which in turn is fluidly connected to hydraulic motors that drive in rotation the ground engaging wheels or tracks.

[0035] In addition, work machine 1 comprises a hydraulically actuated work implement 6, which is carried by body 2 and is configured to perform multiple earth moving operations, such as digging, handling earth or gravel, loading trucks and/or similar operations. In particular, work implement 6 is rotatably carried by the upper frame of work machine 1.

[0036] As known, the hydraulically actuated work implement 6 preferably comprises: a boom rotatably carried by the body 2; a stick or arm or dipper rotatably carried by the boom; and a bucket and/or other similar tools rotatably carried by the arm.

[0037] In addition, work machine 1 preferably comprises one or more hydraulic actuators 7, which are

configured to operate the hydraulically actuated work implement 6.

[0038] In particular, the one or more hydraulic actuators 7 may be configured to rotate the boom, the arm and/or the bucket with respect their corresponding hinge points.

[0039] More in detail, such a hydraulic actuator 7 preferably comprises a double-acting hydraulic cylinder, in particular a two-chamber double-acting hydraulic cylinder.

[0040] With reference to the exemplary embodiment illustrated in Figure 2, in particular, hydraulic actuator 7 preferably comprises a housing 8 which accommodates in a sliding and fluid tight manner a piston 9. The piston 9 defines within the housing 8 two opposite chamber 10a and 10b, which are adapted to contain pressurized hydraulic fluid and are configured to exert opposite forces on the piston 9.

[0041] As known, the hydraulic force F_{hyd} acting on piston 9 can be calculated according to the following formula:

$$F_{hyd} = p_{10a}A_{10a} - p_{10b}A_{10b},$$

wherein p_{10a} and p_{10b} is the pressure within chamber 10a and chamber 10b respectively and A_{10a} and A_{10b} is the area of chamber 10a and chamber 10b respectively.

[0042] In addition, housing 8 is preferably provided with two openings/ports 11a and 11b, which allow to put the respective chamber 10a and 10b in fluid communication with the outside.

[0043] In addition, hydraulic actuator 7 is preferably carried by work implement 6.

[0044] In other words, the one or more hydraulic actuators 7 are preferably carried by the boom and/or the arm of work implement 6.

[0045] More in detail, the housing 8 of the one or more hydraulic actuators 7 is fixedly carried by work implement 6, in particular by the boom and/or the arm of work implement 6.

[0046] With reference to a possible embodiment, hydraulic actuators 7 preferably comprise one or more boom actuators, which are carried by the body 2, are operatively interposed between the body 2 and the boom and are configured to rotate the boom with respect to the body 2. Preferably, hydraulic actuators 7 comprise two boom actuators arranged on opposite sides of the boom.

[0047] Preferably, hydraulic actuators 7 further comprises at least one arm actuator (not illustrated), which is carried by the arm and is configured to rotate the arm with respect to the boom.

[0048] In addition, hydraulic actuators 7 preferably comprise also at least one bucket actuator (not illustrated), which is preferably carried by the arm and is configured to rotate the bucket with respect to the arm.

[0049] With reference to the preferred embodiment illustrated in Figure 2, work machine 1 further comprise

a hydraulic arrangement 14, which is fluidly connected to hydraulic actuator 7 and is configured to actuate this latter, in order to operate said work implement accordingly.

[0050] In particular, hydraulic arrangement 14 is carried by body 2 and is adapted to be fluidly connected to hydraulic actuator 7 by means of hydraulic lines 15, in particular by means of flexible hydraulic hoses 15.

[0051] With reference to the exemplary embodiment illustrated in Figure 2, hydraulic lines 15 preferably comprises a line or hose 15a configured to be fluidly connected to opening 11a of hydraulic actuator 7 and a line or hose 15b configured to be fluidly connected to opening 11b of hydraulic actuator 7.

[0052] In addition, hydraulic arrangement 14 preferably comprises a source of pressurized hydraulic fluid 17, which is configured to provide at outlet a flow of pressurized hydraulic fluid.

[0053] More in detail, the source of pressurized hydraulic fluid preferably comprises pumping means 17, which are carried by internal combustion engine 4 and are configured to suck hydraulic fluid from a tank 18 and to provide at outlet a pressurized flow of such hydraulic fluid.

[0054] In particular, the source of pressurized hydraulic fluid preferably comprises at least one hydraulic pump, which is preferably configured to be driven in rotation by internal combustion engine 4.

[0055] More in detail, with reference to the example illustrated in Figure 2, the source of pressurized hydraulic fluid may comprise two hydraulic pumps 17a and 17b, in particular two variable displacement hydraulic pumps 17a and 17b, which are arranged in parallel to each other.

[0056] With reference to the exemplary embodiment illustrated in Figure 2, hydraulic arrangement 14 further comprises a hydraulic circuit 20 which is adapted to put the outlet of the source of pressurized fluid, i.e. of hydraulic pump 17 in fluid communication with the hydraulic actuator 7.

[0057] More in detail, the hydraulic circuit 20 is preferably provided with a common pressure rails (CPR) configuration, i.e. it comprises a plurality of separate hydraulic lines/ pipes/rails/conduits 21, which are arranged in parallel to each other and are each configured to be fluidly connected between the source of pressurized fluid and hydraulic actuator 7.

[0058] That is, all the hydraulic lines 21 of hydraulic circuit are selectively connectable to hydraulic actuator 7, in particular to both chambers 10a and 10b of hydraulic actuator 7.

[0059] In particular, according to the CPR configuration, hydraulic lines 21 of hydraulic circuit 20 are preferably configured to operate with a pressure setting which is advantageously constant and is different to each other, in order each to be able to provide pressurized hydraulic fluid to hydraulic actuator 7 with different pressure levels.

[0060] More in detail, hydraulic circuit 20 comprises at least two lines 21, which are arranged in parallel to each

other and are adapted to fluidly connect the source of pressurized fluid with hydraulic actuator 7.

[0061] Preferably, the first one between the two lines 21 is connected to the source of pressurized hydraulic fluid, while the second is preferably connected to tank 18.

[0062] Accordingly, in operation, the first one between lines 21 will define a high-pressure line and the other one between lines 21 will define a low-pressure line.

[0063] In particular, with reference to the example illustrated in Figure 2, hydraulic circuit comprises at least three lines 21a, 21b and 21c arranged in parallel to each other.

[0064] Line 21a is preferably connected to the outlet of hydraulic pump 17a, line 21b is preferably connected to the outlet of hydraulic pump 17b and line 21c is preferably connected to tank 18.

[0065] In addition, hydraulic circuit 20 preferably comprises at least one hydraulic accumulator 22, which is fluidly connected to the first one between the two lines 21.

[0066] More in detail, with reference to the exemplary embodiment illustrated in Figure 2, hydraulic circuit 20 preferably comprises two hydraulic accumulators 22a and 22b respectively fluidly connected to lines 21a and 21b.

[0067] In use, by controlling the operation of pumps 17a and 17b it is possible to set the pressure within lines 21a and 21b and within accumulators 22a and 22b at different levels. In particular, lines 21a and 21b, together with accumulator 22a and 22b, may define a high-pressure line and a medium-pressure line respectively. Line 21c, being connected to tank, may define a low-pressure line.

[0068] With reference to the exemplary embodiment illustrated in Figure 2, hydraulic circuit 20 preferably comprises at least one pressure relief valves 24, that are arranged downstream the source of pressurized hydraulic fluid along the first one between lines 21 and is configured to open when the pressure within the same line exceed a predetermined threshold.

[0069] More in detail, hydraulic circuit 20 may comprise two pressure relief valves 24, which are operatively connected to lines 21a and 21b.

[0070] With reference to the exemplary embodiment illustrated in Figure 2, hydraulic arrangement 14 further comprises a control valve arrangement 26, which is fluidly interposed between hydraulic circuit 20 and hydraulic actuator 7 and is configured to regulate the pressurized hydraulic fluid fed toward the same hydraulic actuator 7.

[0071] More in detail, control valve arrangement 26 configured to selectively put at least the high-pressure line 21a and/or the low pressure line 21c in fluid communication with chamber 10a and/or chamber 10b of hydraulic actuator 7.

[0072] In other words, in operation control valve arrangement 26 is configured to allow to selectively fluidly connect the chambers 10a and 10b of hydraulic actuator 7 with lines 21 of hydraulic circuit 20.

[0073] In addition, control valve arrangement 26 is preferably carried by body 2. Control valve arrangement 26 is preferably configured to be fluidly connected to hydraulic actuator 7 via hydraulic lines 15.

[0074] More in detail, with reference to the exemplary embodiment illustrated in Figure 2, control valve arrangement 26 comprises at least a first valve set 27, which is operatively interposed between the hydraulic circuit 20 and the first chamber 10a of hydraulic actuator 7.

[0075] In addition, control valve arrangement 26 comprises a second valve set 28, which is operatively interposed between the hydraulic circuit 20 and the second chamber 10b of hydraulic actuator 7.

[0076] Valve sets 27 and 28 are preferably configured to be fluidly connected to the respective chambers 10a and 10b of hydraulic actuator 7 respectively via hydraulic line 15a and hydraulic line 15b.

[0077] Preferably, each first valve set 27 and second valve set 28 comprises as many valves as many lines 21 there are provided within hydraulic circuit 20. Each valve of the first valve set 27 and of second valve set 28 is configured to be fluidly interposed between a line 21 of hydraulic circuit 20 and the respective chamber 10a or 10b of hydraulic actuator 7, and is configured to selectively fluidly connect the corresponding line 21 of hydraulic circuit 20 with the respective chamber 10a or 10b of hydraulic actuator 7.

[0078] Preferably, valves or first valve set 27 and second valve set 28 are solenoid-controlled two-way two-position valves, in particular solenoid-controlled two-way two-position on-off valves, which are operable independently to each other and are operable between an open position and a closed position.

[0079] With reference to the exemplary embodiment illustrated in Figure 2, in particular, valve sets 27 and 28 preferably each comprise three valves 27a-27c and 28a-28c, which are fluidly interposed respectively between high-pressure line 21a, medium-pressure line 21b and low-pressure line 21c and the respective chamber 10a and 10b of hydraulic actuator 7.

[0080] According to the above, each chamber 10a and 10b of hydraulic actuator 7, in operation, may assume at least three different pressure levels depending on the operation of valve sets 27 and 28.

[0081] With reference to the exemplary embodiment illustrated in Figure 2, in addition, hydraulic arrangement 14 preferably comprises one or more pressure multiplier or pressure amplifier or pressure booster hydraulic cylinders 30, which are operatively interposed between control valve arrangement 26 and hydraulic actuator 7 and are configured to selectively increase the pressure of the hydraulic fluid provided towards hydraulic actuator 7.

[0082] Preferably, the one or more pressure multiplier hydraulic cylinders 30 are carried by body 2.

[0083] In addition, the one or more pressure multiplier hydraulic cylinders 30 are each preferably adapted to be fluidly connected to hydraulic actuator 7 via hydraulic lines 15.

[0084] With reference to the exemplary embodiment illustrated in Figure 2, the one or more pressure multiplier hydraulic cylinders 30 preferably comprises single acting cylinders.

[0085] More in detail, the one or more pressure multiplier hydraulic cylinders 30 comprises a housing 31, which accommodates in a fluid tight and sliding manner a piston 32. The piston 32 defines a first chamber and a second chamber opposite to each other within the housing. Preferably, the first chamber has an area which is larger than the area of the second chamber, in particular the area of the first chamber may be twice the area of the second chamber.

[0086] Preferably, the first chamber, i.e. the larger chamber, of pressure multiplier hydraulic cylinder is fluidly connected to hydraulic circuit 20 and the second chamber, i.e. the smaller chamber is fluidly connected to hydraulic actuator 7, in order to be able to increase the pressure of the hydraulic fluid fed towards hydraulic actuator 7.

[0087] Accordingly, the pressure of the fluid fed towards the chambers 10a and 10b of hydraulic actuator by pressure multiplier hydraulic cylinder 30 is equal to the pressure of the fluid received by pressure multiplier hydraulic cylinder 30 from one of the lines 21, multiplied by the pressure multiplication factor, i.e. by the area ratio, of the same pressure multiplier hydraulic cylinder 30.

[0088] In other words, the pressure of the hydraulic fluid fed towards the chamber 10a and 10b of hydraulic actuator 7 can be calculated according to the following formula:

$$p_{10} = \alpha_{30} \cdot p_{21}$$

wherein p_{10} is the pressure of the hydraulic fluid fed towards chamber 10a or chamber 10b of hydraulic actuator 7, p_{10} is the pressure of the hydraulic fluid fed by lines 21 towards pressure multiplier hydraulic cylinder 30 and α_{30} is the ratio between the areas of the two chamber of pressure multiplier hydraulic cylinder 30.

[0089] In addition, valve arrangement 26 preferably comprises at least one further valve set, which is operatively interposed between hydraulic circuit 20 and pressure multiplier hydraulic cylinder 30, and is configured to selectively fluidly connect the lines 21 of hydraulic circuit 20 with pressure multiplier hydraulic cylinder 30, in particular with the first chamber of pressure multiplier hydraulic cylinder 30.

[0090] Preferably, also the further valve set comprises as many valves as many lines 21 there are provided within hydraulic circuit 20. Each valve of the further valve set is configured to be fluidly interposed between a line 21 of hydraulic circuit 20 and the first chamber of pressure multiplier hydraulic actuator 30, and is configured to selectively fluidly connect the corresponding line 21 of hydraulic circuit 20 with the first chamber of pressure multiplier hydraulic actuator 30.

[0091] Preferably, also the valves or the further valve

set are solenoid-controlled two-way two-position valves, in particular solenoid-controlled two-way two-position on-off valves, which are operable independently to each other and are operable between an open position and a closed position.

[0092] With reference to the exemplary embodiment illustrated in Figure 2, in particular, the further valve set preferably comprises three valves, which are fluidly interposed respectively between high-pressure line 21a, medium-pressure line 21b and low-pressure line 21c and the first chamber of pressure multiplier hydraulic cylinder.

[0093] In addition, hydraulic arrangement 14 preferably comprises at least two pressure multiplier hydraulic cylinders 30, which are configured to be fluidly connected to a respective chamber 10a and 10b of hydraulic actuator 7 via lines 15a and 15b respectively.

[0094] Accordingly, control valve arrangement 26 preferably comprises two further valve sets, each operatively coupled to a respective pressure multiplier hydraulic cylinder 30.

[0095] In more detail, with reference to the example illustrated in Figure 2, hydraulic arrangement 14 may comprise four pressure multiplier hydraulic cylinders 34, 35, 36 and 37, which are arranged in parallel to each other.

[0096] Preferably, pressure multiplier hydraulic cylinders 34, 35 may be connected to chamber 10a of hydraulic actuator 7, and pressure multiplier hydraulic cylinders 36 and 37 may be connected to chamber 10b of hydraulic actuator 7.

[0097] Preferentially, the dimensions of pressure multiplier hydraulic cylinders 34 and 35 and the dimension of pressure multiplier hydraulic cylinders 36 and 37 may differ to each other, so as to provide a different pressure multiplication factor.

[0098] In addition, with reference to the exemplary embodiment illustrated in Figure 2, control valve arrangement 26 preferably comprises four further valve sets 38, 39, 40, and 41, which are operatively interposed respectively between hydraulic circuit 20 and pressure multiplier hydraulic cylinders 34, 35, 36 and 37.

[0099] In particular, valve sets 38, 39, 40, and 41 each comprise three valves 38a-c, 39a-c, 40a-c, and 41a-c, which are fluidly interposed respectively between high-pressure line 21a, medium-pressure line 21b and low-pressure line 21c and the respective chamber pressure multiplier hydraulic cylinders 34, 35, 36 and 37.

[0100] According to the above, each pressure multiplier hydraulic cylinders 34, 35, 36 and 37, in operation, may assume at least three different pressure levels depending on the operation of valve sets 10a and 10b.

[0101] Preferably, valves of valve sets 38-41 are solenoid-controlled two-way two-position valves, in particular solenoid-controlled two-way two-position on-off valves, which are operable independently to each other and are operable between an open position and a closed position.

[0102] The operation of the above-described hydraulic arrangement 14 is the following.

[0103] During operation, the three lines 21a, 21b and 21c of the common pressure rails hydraulic circuit 20 are set at a different pressure level, to define a high-pressure line 21a, a medium-pressure line 21b and a low-pressure line 21c.

[0104] By operating the valves of control valve arrangement 26, it is possible to selectively connect each of the line 21 with the two chambers 10a and 10b of hydraulic actuator, either multiplying the pressure of the hydraulic fluid through the pressure multiplier hydraulic cylinders 30 through valve sets 38-41 or bypassing such pressure multiplier hydraulic cylinders 30 and feeding directly the hydraulic fluid from lines 21 to the chambers 10a and 10b of hydraulic actuator 7 via valve sets 27 and 28.

[0105] In view of the foregoing, the advantages of a hydraulic arrangement 14 according to the present invention are considerable and apparent.

[0106] In particular, the provision of pressure multiplier hydraulic cylinders 30 carried by the body 2 of work machine 1 allows to increase the number of discrete levels of hydraulic force F_{hyd} the hydraulic cylinder 7 is able to provide without however the need to employ asymmetrical multi-chamber hydraulic cylinders and to provide heavy and bulky valve arrangement on the work implement 6 of the work machine 1, with the evident advantages that this entails.

[0107] In particular, with reference to the exemplary embodiment illustrated in Figure 2, by providing three different constant pressure rails 21 and four different pressure multiplier cylinders 30, it is possible to greatly increase the number of different discrete force level at actuator 7 available.

[0108] More in detail, the number of discrete values of the hydraulic force F_{hyd} acting on the hydraulic actuator 7 piston can still be calculated according to following formula

$$\#_{F_{hyd}} = \#_{rails} \#_{chamber},$$

but according to the proposed layout, the number of different chambers $\#_{chamber}$ is equal to the number of chambers of hydraulic actuator 7 plus the number of chambers of pressure multiplier hydraulic cylinders.

[0109] In the example illustrated in Figure 2, there are provided 6 different chambers, i.e. two of the hydraulic actuator 7 and four of the four pressure multiplier hydraulic cylinders 30.

[0110] Therefore, the number of discrete values of the hydraulic force F_{hyd} acting on the hydraulic actuator 7 piston will be equal to 3^6 , i.e. 729.

[0111] In addition, the proposed layout allows to continue arranging the traditional double-effect hydraulic cylinders on the work implement 6 of the work machine 1, which are much cheaper, reliable and simpler than

asymmetrical multi-chamber hydraulic cylinders and at the same time does not impact on the inertia and weight of the work implement 6 of work machine 1, i.e. it does not affect the lifting capacity of work machine 1.

[0112] Furthermore, by simply increasing the number of pressure multiplier cylinders 30 and/or lines or common pressure rails 21 it is possible to easily increase the number of discrete levels of hydraulic force F_{hyd} the hydraulic cylinder 7 is able to provide, i.e. to increase the resolution of the hydraulic force F_{hyd} the hydraulic cylinder 7 is able to provide. On the contrary, in the hydraulic circuit 100 according to the prior art, the use of asymmetrical multi-chamber hydraulic cylinders does not allow to easily increase the number of discrete hydraulic force levels.

[0113] Lastly, by providing pressure multiplier hydraulic cylinder 30, it is possible to increase the pressure at the hydraulic actuator 7 and therefore the hydraulic force the hydraulic actuator 7 is able to exert without increasing the fluid pressure within the high-pressure rail 21a.

[0114] It is clear that modifications can be made to the described hydraulic arrangement 4, which do not extend beyond the scope of protection defined by the claims.

[0115] In particular, the number of pressure multipliers hydraulic cylinders and/or the configuration of control valve arrangement 26 may be different, on the basis of the number of discrete levels of the hydraulic force F_{hyd} to be obtained.

[0116] In addition, the layout of the source of pressurized fluid, pressure relief valves 24 and/or hydraulic accumulators may be different.

[0117] Lastly, Figure 3 illustrates a hydraulic arrangement 214, which is similar to hydraulic arrangement 14 and whose corresponding parts will be denoted with the same reference numbers as hydraulic arrangement 14.

[0118] Hydraulic arrangement 214 distinguishes from hydraulic arrangement 14 in that pressure multiplier cylinder 30 are double acting hydraulic cylinders.

[0119] More in detail, according to the embodiment illustrated in Figure 2, pressure multiplier cylinder 30 may comprise a housing 231, which accommodates in a fluid tight and sliding manner a piston assembly 232. The piston assembly 32 defines four chambers within housing 231, two side chambers 233a between the two axial end of housing 231 and facing portion of the piston assembly and two central chambers 233b between portion of the same piston assembly 232.

[0120] More in detail, the piston assembly 232 is preferably realized in one piece and comprises three pistons, which are rigidly fixed to each other and delimit the four chambers.

[0121] Side chambers 233a are preferably smaller than central chambers 233b and are fluidly connected to hydraulic actuator 7.

[0122] Central chambers 233b, on the other hand, are preferably fluidly connected to hydraulic circuit 20 via a respective valve set of control valve arrangement 26.

[0123] In even more detail, control valve arrangement

26 preferably comprise as many pairs of valves as many lines 21 there are provided in hydraulic circuit 20, wherein each pair of valves is operatively interposed between the corresponding central chambers 233b and a corresponding line 21.

[0124] In particular, according to the illustrated example in Figure 3, valve sets 38, 39, 40, and 41 each comprise three valve pairs 238a'-c", 239a'-c", 240a'-c", and 241a'-c", which are fluidly interposed respectively between high-pressure line 21a, medium-pressure line 21b and low-pressure line 21c and the respective central chambers 233b of pressure multiplier hydraulic cylinders 34, 35, 36 and 37.

[0125] In addition, valve sets 38, 39, 40, and 41 are preferably provided with check valves in fluid communication with side chambers 233a, which are configured to allow unidirectional flow of the hydraulic fluid from hydraulic circuit 20 within side chambers 233a and towards hydraulic actuator 7.

[0126] The technical effect associated with the provision of double effect pressure multiplier hydraulic cylinder is related to the possibility of providing a continuous flowrate of pressurized hydraulic fluid towards the hydraulic actuator even when the piston 232 reaches an end of its stroke, as it is possible to invert the piston 232 stroke within housing 231 by commuting the respective valve set 38, 39, 40 or 41.

Claims

1. A hydraulic arrangement (14) for a work machine (1); said work machine (1) comprising: a body (2) movable on the ground by means of ground engaging means; and a hydraulically actuated work implement (6), which is rotatably carried by said body (2) and is configured to perform multiple earth moving operations;

said hydraulic arrangement (14) comprising:

- a source of pressurized hydraulic fluid (17), which is configured to suck hydraulic fluid from a tank (18) and to provide at outlet a pressurized flow of the hydraulic fluid;
- at least one hydraulic actuator (7), which is configured to operate said hydraulically actuated work implement (6); and
- a hydraulic circuit (20), which is configured to be arranged on said body (2) and is configured to put the outlet of said source of hydraulic fluid (17) in fluid communication with said hydraulic actuator (7);

said hydraulic actuator (7) comprising: a housing (8), and a piston (9), which is accommodated in a fluid-tight and sliding manner within said housing (8) and defines within said housing

(8) a first chamber (10a) and a second chamber (10b), opposite to said first chamber (10a); said hydraulic circuit (20) comprising:

- a first hydraulic line (21a), which fluidly connects said source of pressurized hydraulic fluid (17) with said hydraulic actuator (7);
- a first hydraulic accumulator (22a) fluidly connected to said first hydraulic line (21a);
- a second hydraulic line (21c), which is arranged in parallel to said first hydraulic line (21a) and fluidly connects said tank (18) with said hydraulic actuator (7);

said hydraulic arrangement (14) further comprising:

- a control valve arrangement (26), which is operatively interposed between said hydraulic circuit (20) and said hydraulic actuator (7) and is configured to selectively put said first hydraulic line (21a) and/or said second hydraulic line (21c) in fluid communication with said first chamber (10a) and/or said second chamber (10b); and
- at least one pressure multiplier hydraulic cylinder (30), which is operatively interposed between said control valve arrangement (26) and said hydraulic actuator (7) and is configured to increase the pressure of the hydraulic fluid provided by said hydraulic circuit (20) to be fed towards said hydraulic actuator (7).

2. Hydraulic arrangement (14) according to claim 1, wherein said control valve arrangement (26) comprises:

a first valve set (27) operatively interposed between said hydraulic circuit (20) and the first chamber (10a) of said hydraulic actuator (7); and
a second valve set (28) operatively interposed between said hydraulic circuit (20) and the second chamber (10b) of said hydraulic actuator (7).

3. Hydraulic arrangement according to claim 2, wherein said control valve arrangement (26) further comprises a third valve set (38, 39, 40, 41), which is operatively interposed between said hydraulic circuit (20) and said pressure multiplier hydraulic cylinder (30).

4. Hydraulic arrangement according to claim 3, wherein each said first valve set (27), said second valve set (28) and said third valve set (38, 39, 40, 41) com-

prises a plurality of control valves, each configured to be fluidly interposed between a corresponding line (21a, 21b, 21c) of said hydraulic circuit (20) and said hydraulic actuators (7).

5. Hydraulic arrangement according to claim 4, wherein said control valves are solenoid controlled two-way two-position valves, in particular two-way two-position logic valves.

6. Hydraulic arrangement according to claim 4 or 5, wherein each said first valve set (27), said second valve set (28) and said third valve set (38, 39, 40, 41) comprises as many control valves as many separate lines (21) there are provided within said hydraulic circuit (20).

7. Hydraulic arrangement according to any of the preceding claims, comprising at least a first pressure multiplier hydraulic cylinder (30) fluidly connected to the first chamber (10a) of said hydraulic actuator (7) and at least a second pressure multiplier hydraulic cylinder (30) fluidly connected to the second chamber (10b) of said hydraulic actuator (7).

8. Hydraulic arrangement according to any of the preceding claims, wherein said pressure multiplier hydraulic cylinder (30) comprises a second housing (31) and a second piston (32) which is accommodated in a sliding and fluid tight manner within said second housing (31) and defines a third chamber (33a) and a fourth chamber (33b) opposite to said third chamber (33a);

said third chamber (33a) being fluidly connected to said hydraulic circuit (20) and said fourth chamber (33b) being fluidly connected to said hydraulic actuator (7);

said third chamber (33a) having an area larger than the area of said fourth chamber (33b).

9. Hydraulic arrangement according to any of the preceding claims, wherein said hydraulic circuit (20) further comprises:

- a third hydraulic line (21b), which fluidly connects said source of pressurized hydraulic fluid (17) with said hydraulic actuator (7) and is arranged in parallel to said first hydraulic line (21a); and
- a second hydraulic accumulator (22b) fluidly connected to said second hydraulic line (21b).

10. A work machine (1) comprising: a body (2) movable on the ground by means of ground engaging means; a hydraulically actuated work implement (6), which is rotatably carried by said body (2) and is configured to perform multiple earth moving operations; and an

hydraulic arrangement (14), which is realized according to any of the preceding claims.

11. Work machine realized according to claim 10, wherein said hydraulically actuated work implement (6) comprises: a boom rotatably carried by said body (2); an arm rotatably carried by said boom; and a bucket or other similar tool rotatably carried by said arm;

said hydraulic actuator (7) being carried by said hydraulically actuated work implement (6) and being configured to rotate said boom with respect to said body (2) and/or said arm with respect to said boom, and/or said bucket or other similar tool with respect to said arm.

12. Work machine according to claim 10 or 11, wherein said hydraulic circuit (20) is arranged on said body (2).

13. Work machine according to claim 12, wherein said hydraulic arrangement (14) comprises two lines (15a, 15b), in particular two flexible hoses (15a, 15b) fluidly connecting said hydraulic circuit with said hydraulic actuator (7), in particular respectively with the first (10a) and the second chamber (10b) of said hydraulic actuator (7).

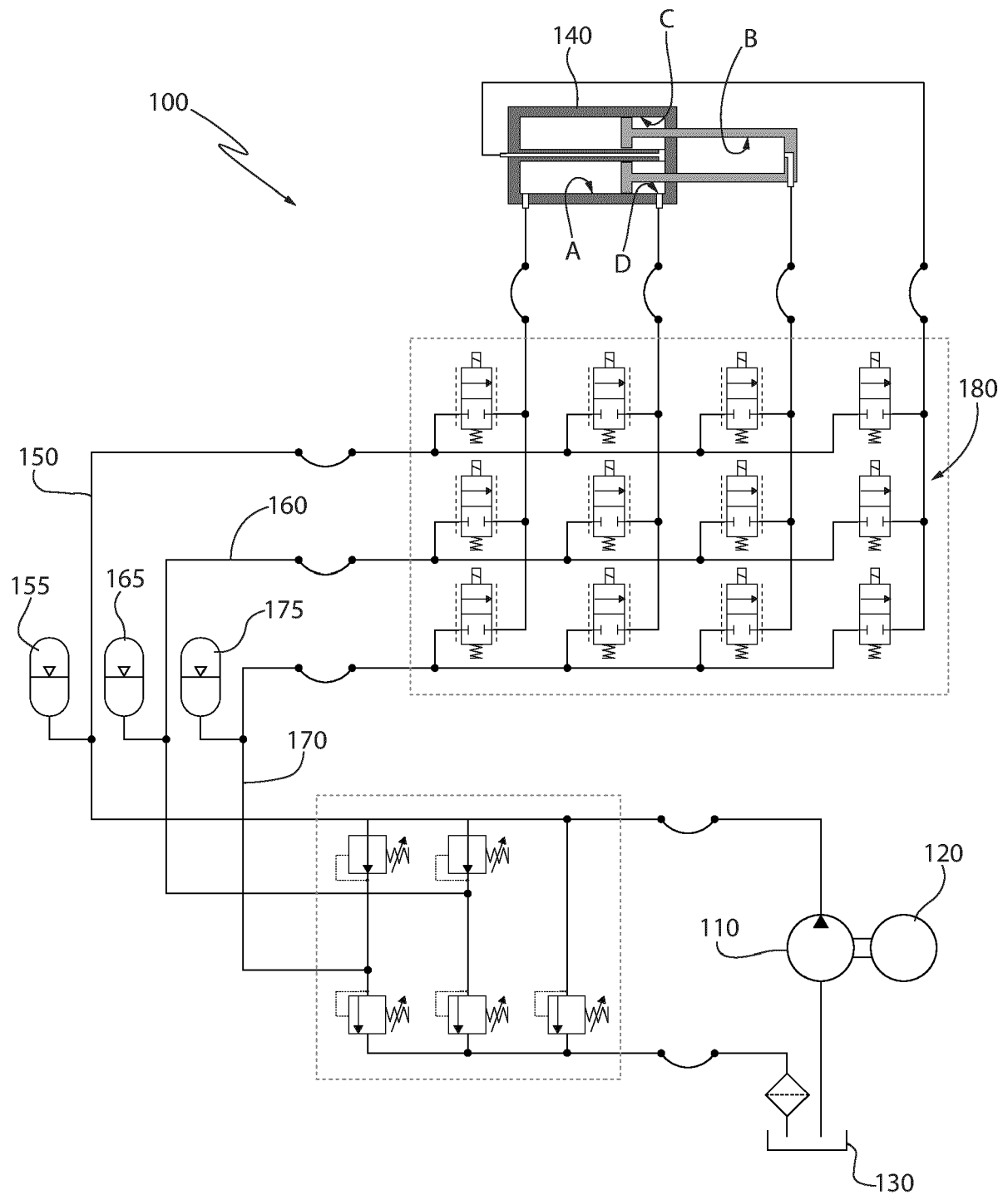


FIG.1
PRIOR ART

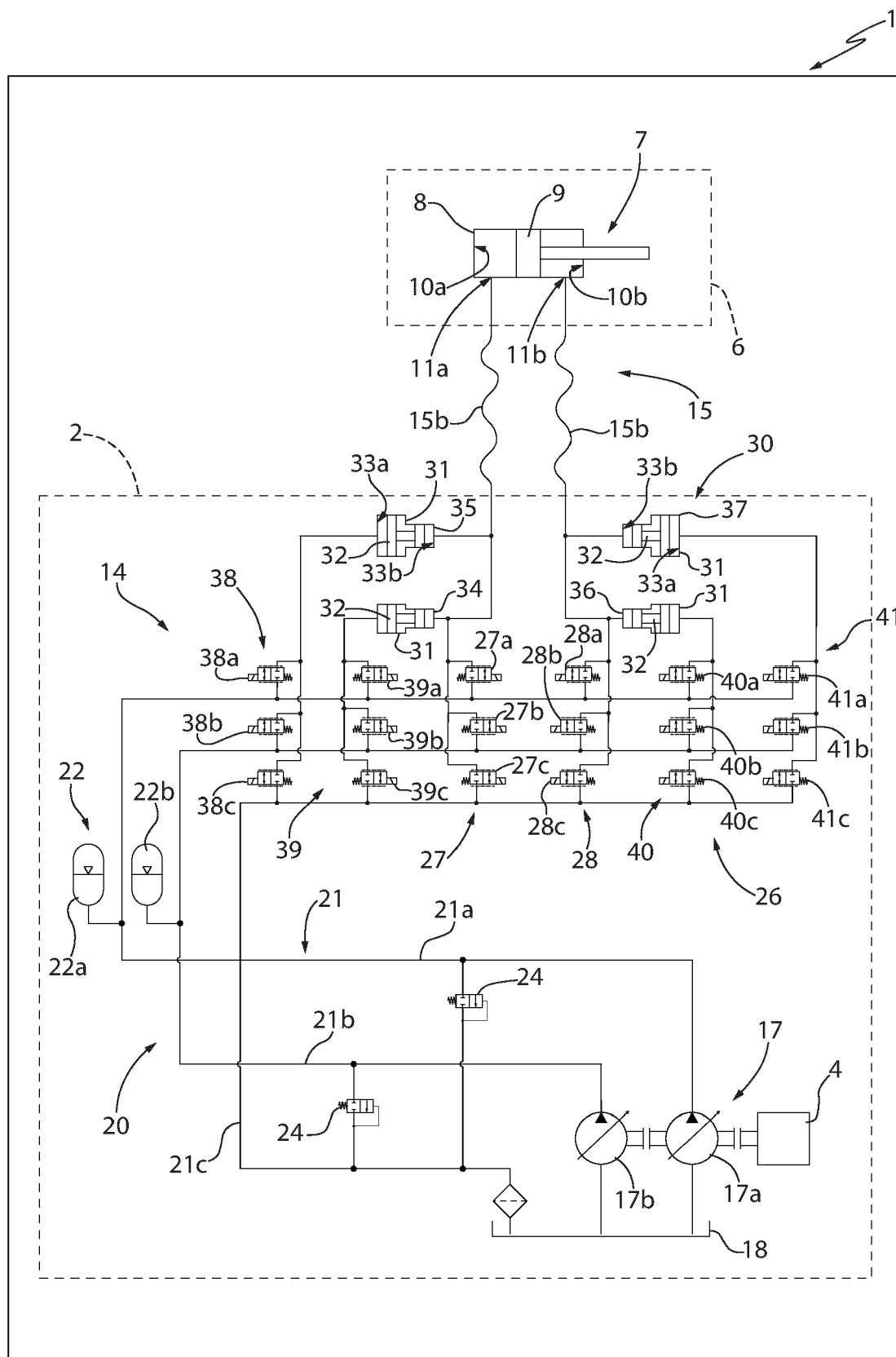


FIG.2

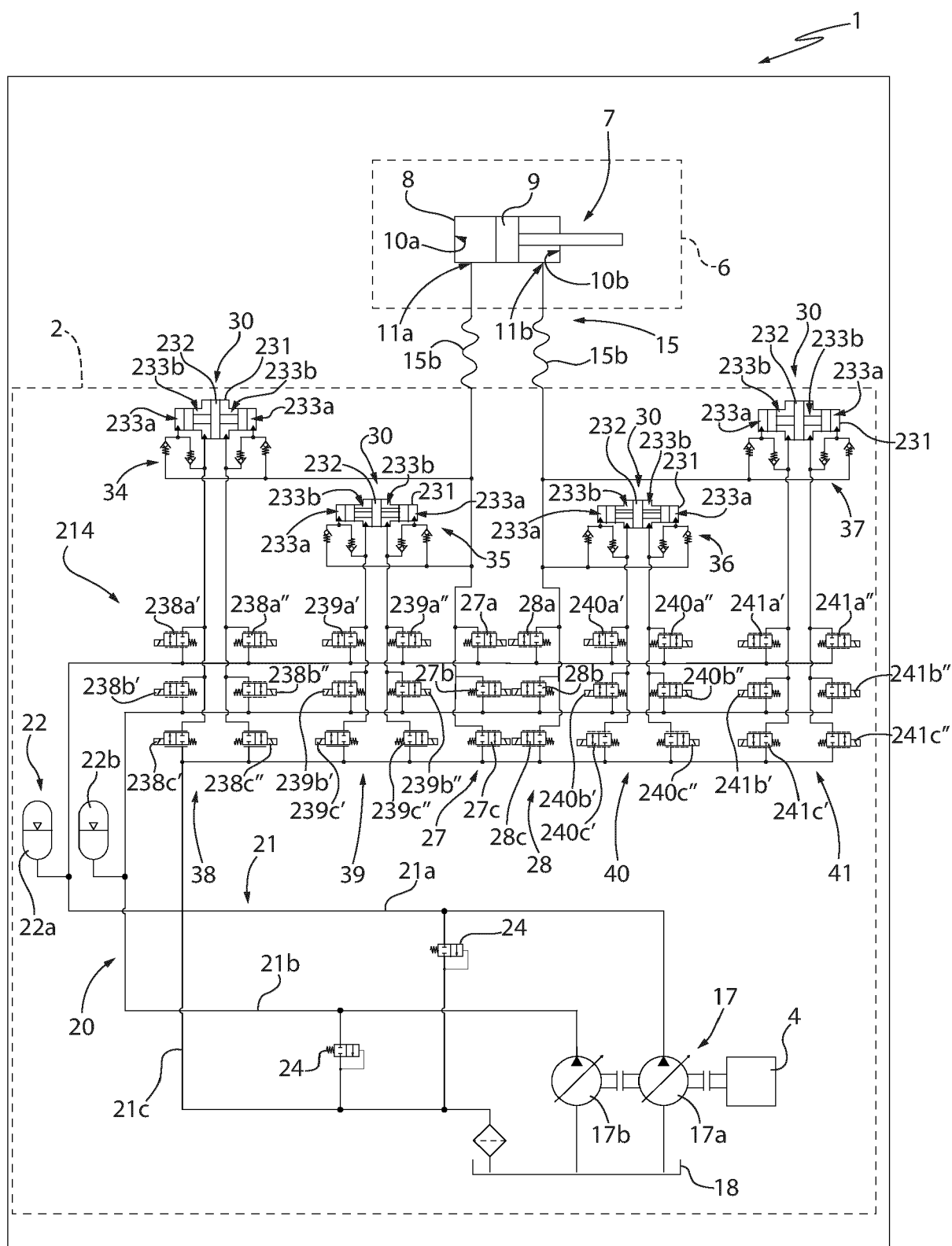


FIG.3

Application Number

EP 24 18 8431

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			E02F F15B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 November 2024	Examiner Dreyer, Christoph
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ON EUROPEAN PATENT APPLICATION NO.

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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13 - 11 - 2024

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