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(54) Title: BALANCED LINKAGE

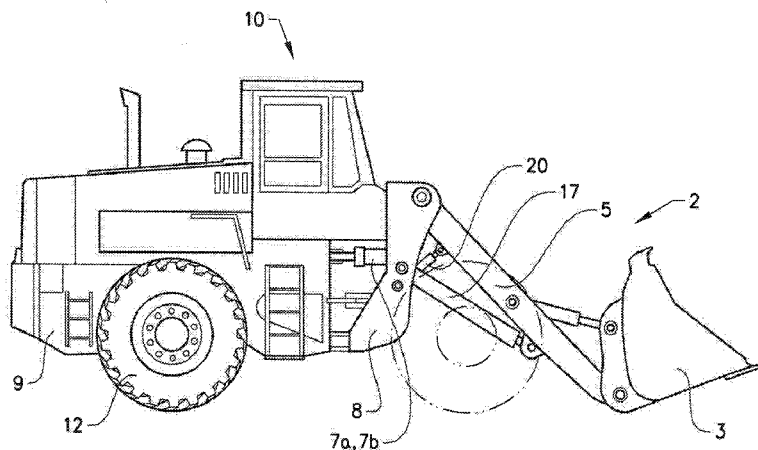


FIG. 1

(57) Abstract: There is provided a lift arrangement for a working machine, comprising: a lift arm in one end pivotably connectable to the body of a working machine; a hydraulic lift actuator connected to the arm for pivoting the arm about a pivot axis relative to the body of a working machine; a balance actuator connected to the arm and configured to provide a lift force on the lift arm; wherein the balance actuator is arranged separately from the hydraulic lift actuator, the balance actuator being actuated by a closed volume of pressurized gas for creating the lift force. There is also provided a working machine comprising such a lift arrangement.



BALANCED LINKAGE

Field of the Invention

The present invention relates to a linkage system for a working machine.

The invention is applicable on working machines within the fields of industrial construction machines, in particular wheel loaders and articulated haulers. Although the invention will be described with respect to a wheel loader, the invention is not restricted to this particular machine, but may also be used in other working machines such as dump trucks, excavators or other construction equipment.

10

Technical Background

A working machine is provided with a bucket, container or other type of tool for lifting, carrying and/or transporting a load.

Such a working machine may for example be a wheel loader having a lift arrangement for raising and lowering the tool, such as a bucket. The lift arrangement commonly comprises an arm, one or more hydraulic cylinders for movement of the arm and of the bucket connected to the arm. Hydraulic cylinders are arranged for lifting the arm and for tilting the tool connected to the arm.

20 The wheel loader also has a pair of hydraulic cylinders for turning/steering the wheel loader by pivoting a front part and a rear part of the wheel loader relative to each other.

The hydraulic system of the wheel loader may preferably comprise a working cylinder pump and a steering cylinder pump. The pumps may typically be powered by the internal combustion engine of the wheel loader.

25 A significant part of the work performed by the lift cylinder on a wheel loader or a boom cylinder on an excavator is used to lift the bucket and loading unit. Furthermore, significant energy losses occur as energy stored in the lift cylinder is dumped to the hydraulic reservoir when the bucket is lowered.

30

Accordingly in applications where a hydraulic cylinder is used for repetitive lifting, it is advantageous to compensate for the dead weight of the lift arrangement and the bucket in order to increase the efficiency of the lifting cylinder and for reducing losses in the hydraulic system.

5 A solution for balancing the weight of the lift arrangement is suggested by US2007/0068754 which discloses a gas biased lift cylinder integrated in the lift cylinder as an additional inner piston biased by a pressurized gas within the cylinder assembly. The gas biased lift cylinder according to US2007/0068754 is biased to balance the weight of the lift arm and the tool
10 connected to the arm.

However an integrated gas biased lift cylinder involves restrictions with regard to the configuration of the lift cylinder and thereby to the weight compensating function.

15 Summary of the Invention

Accordingly, it is an object of the present invention to provide an improved lift arrangement for a working machine reducing the losses in such a lift arrangement compared to prior art solutions.

The object is achieved by a lift arrangement for a working machine
20 according to claim 1.

The present invention is based on the realization that by using a separately arranged balance actuator actuated by a closed volume of pressurized gas providing a lift force on the arm, the efficiency of the lift arrangement can be improved through reduced losses in the lift actuator.
25 Furthermore, the size, and thereby the weight, of the lift cylinder may be reduced, resulting in additional efficiency improvements. Moreover, a separately arranged balance actuator offers flexibility in the arrangement of the actuator not possible for an actuator integrated in the lift cylinder. Thereby, various geometries of the lift arrangement may be accommodated
30 by selecting the position of the balance actuator.

Furthermore, as the main cylinders may be downsized, the rest of the hydraulic system such as pumps and valves may also be downsized since the required hydraulic flow will decrease given the same speed requirement.

The hydraulic lift actuator may typically be a hydraulic lift cylinder. The
5 hydraulic lift cylinder acts to pivot the arm of the lift arrangement about the pivot axis defined by the connection of the arm to the working machine.

According to one embodiment of the invention, the balance actuator may advantageously be configured and arranged to provide a lift force on the lift arm resulting in a counteracting torque about the pivot axis of the lift arm
10 substantially equal in magnitude to a torque resulting from the dead weight of the lift arrangement.

A large part of the work performed by a lift cylinder in a conventional lift arrangement is used to lift the dead weight of the lift arrangement and of a tool, such as a bucket, attached to the lift arrangement. Such a lift
15 arrangement incurs substantial losses as stored energy of the lift cylinder is dumped to tank when the arm is lowered. In the present embodiment of the invention, by arranging a balance cylinder providing a torque in the opposite direction of the torque resulting from the weight of the lift arrangement, the lift arrangement is substantially balanced by the balance actuator, meaning that
20 that the lift arrangement appears as nearly weightless to the lift cylinder. The torque resulting from the dead weight of the lift arrangement is the product of the force vector in the vertical direction and the length of the lever arm. Accordingly, to balance the weight of the lift arrangement it is desirable that the torque resulting from the balance actuator varies with the position of the
25 arm. Such variation can be achieved by tailoring the characteristics of the balance actuator and the geometry and position of the balance actuator in relation to arm of the lift arrangement. Thereby, the size of the lift cylinder can be reduced and losses in the lift cylinder when lowering the arm may also be reduced. A counteracting torque here refers to a torque around the pivot axis
30 acting in a direction opposite that of the torque resulting from the dead weight

of the lift arrangement. Thus, counteracting refers to the direction of the torque as opposed to the magnitude.

In one embodiment of the invention, the counteracting torque may preferably be smaller than the torque resulting from the dead weight of the lift arrangement. By providing a counteracting torque from the balance actuator which is smaller in magnitude than the torque resulting from the dead weight, the lift arrangement may be lowered through its' own weight when no lift force is applied by the lift cylinder. In comparison, if the counteracting torque was to be equal to or larger than the torque resulting from the dead weight, an external force would be required to lower the lift arrangement, something which may be undesirable in some applications.

According to one embodiment of the invention, the balance actuator may be a gas cylinder. Furthermore, the closed volume of pressurized gas may be included in the gas cylinder. Moreover, the gas cylinder may advantageously have a controllable preload gas pressure which is controlled based on a weight of said lift arrangement. Thereby, the balance actuator can be controlled to provide balance for lift arrangements and tools of different weight. In particular, a gas cylinder having a controllable preload pressure may advantageously be used in a lift arrangement having a replaceable tool, thus enabling easy modification of the gas accumulator to accommodate balancing of the arm for tools of different weight.

In one embodiment of the invention, the balance actuator may be a hydraulic cylinder pressurized by a hydraulic accumulator including the closed volume of pressurized gas. Similarly to the discussion above relating to a gas cylinder, the hydraulic accumulator may advantageously have a controllable pressure which is selected based on a weight of the lift arrangement. The preload pressure of the balance actuator determines the force provided by the actuator in the fully extended position. The force from the balance actuator is lowest when the actuator is fully extended and highest when the actuator is fully retracted.

Furthermore, the characteristics of the balance actuator may be controlled by selecting the relation between the piston stroke volume of the actuator and the total volume of a gas reservoir.

In applications when the available space for the balance actuator is limited, it may be advantageous to use a balance actuator in the form of a hydraulic actuator hydraulically connected to a gas accumulator positioned elsewhere in the working machine.

According to one embodiment of the invention, the balance actuator is arranged essentially perpendicular to the lift actuator. In a typical lift arrangement, the lift actuator is often arranged so that the highest torque for lifting a load is provided when the arm is in its lowest position. By providing the highest torque at the lowest position of the arm, a high breakout force is achieved. A high breakout force may be required when lifting a load which is attached to the ground, thus requiring a force higher than the weight of the load for lifting the load from the ground. On the other hand, the balance actuator preferably provides a force such that the resulting torque about the pivot axis of the lift arm is essentially zero. Therefore, a different arrangement of the balance actuator is required compared to the lift actuator. The desired characteristics of a balance actuator may be achieved by arranging the balance actuator essentially perpendicular to the lift actuator.

In one embodiment of the invention, the balance actuator may be connected to the arm at a point closer to the working machine than the point where the lift actuator is connected to the arm, and wherein the balance actuator is configured to be connected to the working machine at a point in front of a point where the lift actuator is to be connected to the working machine so that the longitudinal axis of the balance actuator and the longitudinal axis of the lift actuator intersect each other.

There is further provided a working machine comprising a lift arrangement according to any one of the abovementioned embodiments.

Furthermore, in one embodiment of the invention there is provided a working machine comprising a lift arrangement, wherein the balance actuator

is connected to the arm at a point closer to the working machine than the point where the lift actuator is connected to the arm, and wherein the balance actuator is connected to the working machine at a point in front of a point where the lift actuator is connected to the working machine so that the
5 longitudinal axis of the balance actuator and the longitudinal axis of the lift actuator intersect each other.

Brief Description of the Drawings

These and other aspects of the present invention will now be described
10 in more detail with reference to the appended drawings showing example embodiments of the invention, wherein:

Fig. 1 schematically illustrates a working machine comprising a lift arrangement according to an embodiment of the invention;

Figs. 2a and 2b schematically illustrate lift arrangements according to
15 embodiments of the invention;

Fig. 3 is a schematic illustration of a hydraulic system for a lift arrangement according to an embodiment of the invention; and

Fig. 4 schematically illustrates lever arms of the lift arrangement of Fig. 2b.

20

Detailed Description of Preferred Embodiments of the Invention

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be
25 embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person. Like reference characters refer to like elements throughout.

An embodiment of a lift arrangement according to the present invention will mainly be discussed with reference to a lift arrangement for a wheel loader.

Figure 1 illustrates a working machine 1 in the form of a wheel loader.

5 The wheel loader 1 is to be considered as an example of a working machine onto which a lift arrangement according to the invention can be attached. The wheel loader has a forward machine part 8 and a rear machine part 9. Each of these machine parts comprises a frame and wheels 12 arranged on an axle. The rear machine part 9 comprises a cab 10 for an operator of the
10 wheel loader 1. The machine parts 8, 9 are connected to each other in such a way that they can pivot relative to each other about a vertical axis by means of two hydraulic cylinders (steering cylinders) 7a, 7b which are arranged between the machine parts 8, 9 and attached thereto. The hydraulic cylinders 7a, 7b are thus arranged one on each side of a centre line extending in the
15 longitudinal direction of the working machine 1 in order to turn or steer the wheel loader by means of the hydraulic cylinders. In other words, the wheel loader 1 is a so called frame-steered 5 working machine.

The wheel loader comprises a lift arrangement 2 for handling different loads, such as objects or material. The lift arrangement 2 comprises a lift arm
20 5 in a first end pivotably connected to the forward machine part 8 in order to achieve a lift motion of the arm 5. The lift arm 5 may also be referred to as a boom.

The lift arrangement 2 further comprises a tool 3 in the shape of a bucket which is pivotably connected to a second end of the lift arm 5 in order
25 to achieve a tilt motion of the bucket for example for emptying a load.

The lift arrangement 2 can be raised and lowered relative to the forward machine part 8 of the vehicle by means of a hydraulic actuator, here a hydraulic cylinder (lift cylinder) 17. The hydraulic cylinder 17 is at a first end coupled to the forward machine part 8 and at the second end to the lift arm 4.
30 The bucket 3 can be tilted relative to the lift arm 4 by means of a further

hydraulic cylinder (tilt cylinder), which at a first end is coupled to the lift arm 5 and at second end is coupled to the bucket 3.

The wheel loader further comprises a drive line (not illustrated) which includes an engine, such as an internal combustion engine, torque converter, gear box etc. The engine can be arranged to supply power to the drive line for driving the wheels 12 and for driving hydraulic machines (pumps) in the hydraulic system by means of a power take off (PTO) which can be arranged at the drive line between the engine and the torque converter.

A balance actuator 20, in the form of a gas cylinder or a hydraulic cylinder powered by a gas accumulator, is connected between the forward machine part 8 and the lift arm 5.

Figures 2a and 2b schematically illustrate two alternative arrangements of the balance actuator 20 where the force from the balance actuator 20 on the arm 5 results in a torque at the pivot axis counteracting the torque from the weight of the lift arrangement 2. In Figs. 2a and 2b, the joint where the balance actuator 20 is attached to the lift arm 5 is illustrated as being below the lift arm 5. However, the joint may equally well be positioned above the lift arm 5.

Fig. 3 schematically illustrates the hydraulic system comprising the balance actuator 20 powered by a gas accumulator 32 containing pressurized gas. The lift cylinder 17 is connected to a hydraulic pump 36 which in turn is connected to a motor 38 powered by an energy generator 40. The energy generator 40 may be the internal combustion engine of the working machine. In some embodiments, energy may also be provided to the motor from a battery or a fuel cell.

As is readily realized by the person skilled in the art, many different positions of the balance actuator and geometries of the lift arrangement are possible for achieving the desired effect.

With reference to Fig. 4, the torque resulting from the weight of the lift arrangement, T_w , as a function of the position of the lift arm 5 can be calculated as $T_w = m * g * k * c$ where m is the mass of the lift arrangement 2, g is

the gravitational constant and, k is the factor between 0 and 1 corresponding to the portion of the force perpendicular to the arm and c is the distance between the pivot axis and the center of gravity, i.e. the lever arm, of the lift arrangement 2. The factor k times the lever arm may be seen as the resulting lever arm for a given position of the lift arm 5. Correspondingly, the torque lifting the arm, T_L , can be calculated as $T_L = F_L * a + p * A * b$ where F_L is the force of the lift cylinder 17, a is the resulting lever arm of the lift cylinder, p is the pressure of the pressurized gas of the balance actuator 20, A is the area of the piston of the balance actuator and b is the resulting lever arm of the balance actuator. Accordingly, the desired counteracting torque from the balance actuator 20 can be determined by solving $m * g * c = p * A * b$. As resulting lever arms and pressure vary with the position of the arm 5, the above equation should be solved for all positions of the arm, or at least for a selected sub-range of positions. For example, the balance actuator 20 may be configured so that a torque contribution corresponding to the weight of the lift arrangement is only provided for arm positions above a certain elevation percentage as the lift cylinder 17 is weakest at higher elevations. Thus, the balance actuator 20 may be configured to relieve the lift cylinder 17 for some selected positions of the arm 5. It should also be noted that the torque resulting from the weight of the lift arrangement 2 depends on the geometry of the lift arrangement. Thus, the optimum position and characteristics of the balance actuator 20 varies with varying geometries.

Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. A lift arrangement for a working machine, comprising:
5 a lift arm in one end pivotably connectable to the body of a working machine;
a hydraulic lift actuator connected to said arm for pivoting said arm about a pivot axis relative to the body of a working machine;
a balance actuator connected to said arm and configured to provide a
10 lift force on said lift arm;
c h a r a c t e r i z e d i n that said balance actuator is arranged separately from said hydraulic lift actuator, said balance actuator being actuated by a closed volume of pressurized gas for creating said lift force.
- 15 2. The lift arrangement according to claim 1, wherein said balance actuator is configured and arranged to provide a lift force on said lift arm resulting in a counteracting torque about the pivot axis of said lift arm substantially equal in magnitude to a torque resulting from the dead weight of said lift arrangement.
- 20 3. The lift arrangement according to claim 1, wherein said balance actuator is configured and arranged to provide a lift force on said lift arm resulting in a counteracting torque about the pivot axis of said lift arm smaller in magnitude than a torque resulting from the dead weight of said lift
25 arrangement.
4. The lift arrangement according to any one of the preceding claims, wherein said balance actuator is a gas cylinder.
- 30 5. The lift arrangement according to claim 4, wherein said closed volume of pressurized gas is included in the gas cylinder.

6. The lift arrangement according to claim 4 or 5, wherein said gas cylinder has a controllable preload gas pressure.

5 7. The lift arrangement according to claim 6, wherein said gas pressure is controlled based on a weight of said lift arrangement.

8. The lift arrangement according to any one of claims 1 to 3, wherein said balance actuator is a hydraulic cylinder pressurized by a
10 hydraulic accumulator including said closed volume of pressurized gas.

9. The lift arrangement according to claim 8, wherein said hydraulic accumulator has a controllable pressure.

15 10. The lift arrangement according to claim 9, wherein said pressure is selected based on a weight of said lift arrangement.

11. The lift arrangement according to any one of the preceding claims, wherein said balance actuator is arranged essentially perpendicular to
20 said lift actuator.

12. The lift arrangement according to any one of the preceding claims, wherein said balance actuator is connected to said arm at a point closer to said working machine than the point where said lift actuator is
25 connected to said arm, and wherein said balance actuator is configured to be connected to said working machine at a point in front of a point where said lift actuator is to be connected to said working machine so that the longitudinal axis of said balance actuator and the longitudinal axis of said lift actuator intersect each other.

13. A working machine comprising a lift arrangement according to any one of claims 1 to 12.

14. A working machine comprising a lift arrangement according to
5 claim 1,

wherein said balance actuator is connected to said arm at a point closer to said working machine than the point where said lift actuator is connected to said arm, and wherein said balance actuator is connected to said working machine at a point in front of a point where said lift actuator is
10 connected to said working machine so that the longitudinal axis of said balance actuator and the longitudinal axis of said lift actuator intersect each other.

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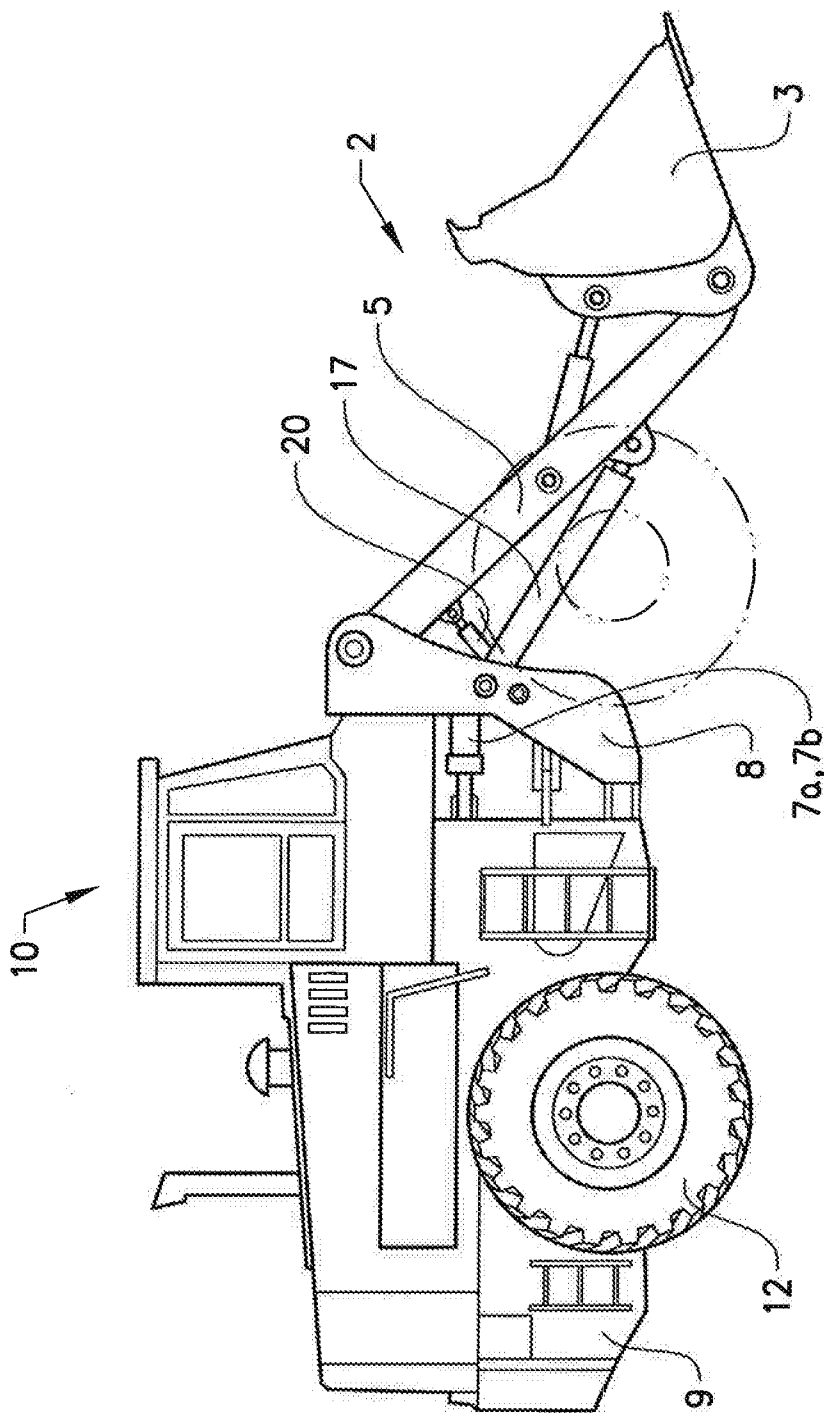


FIG. 1

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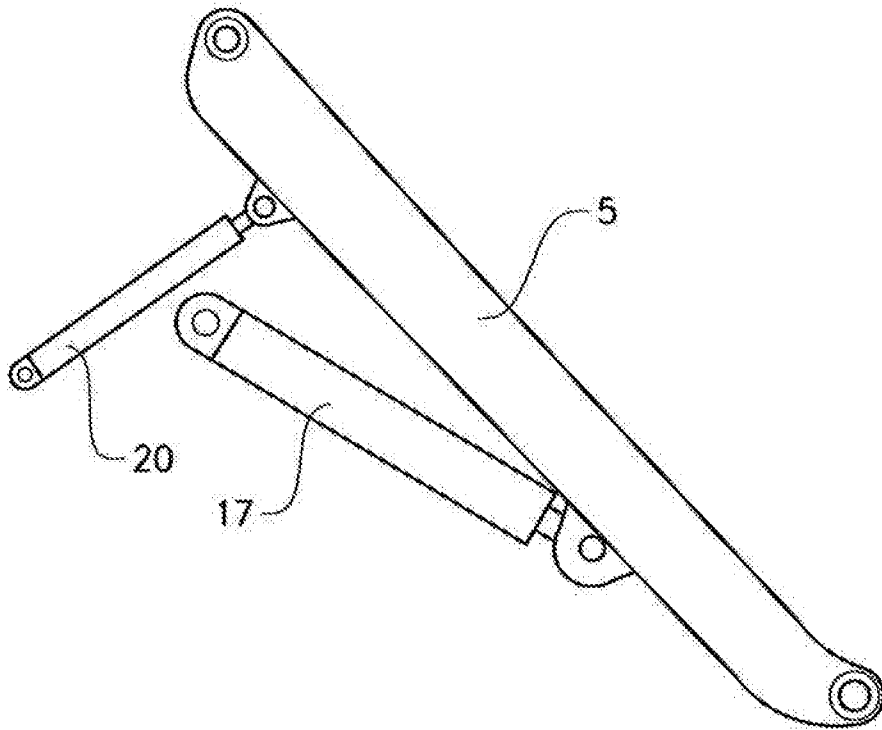


FIG. 2a

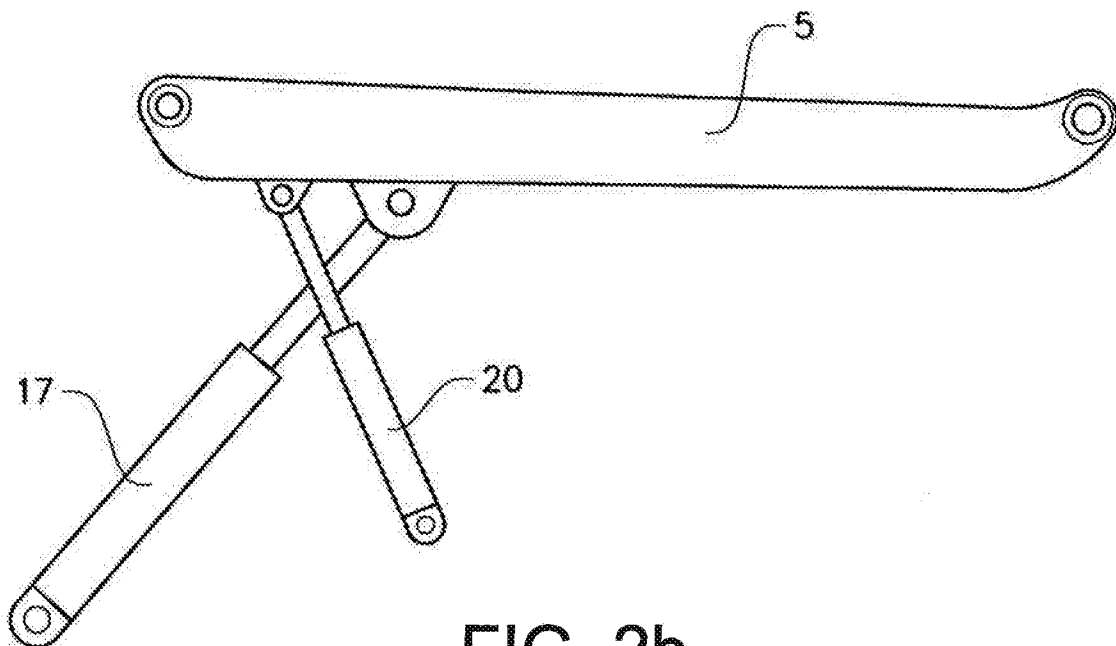


FIG. 2b

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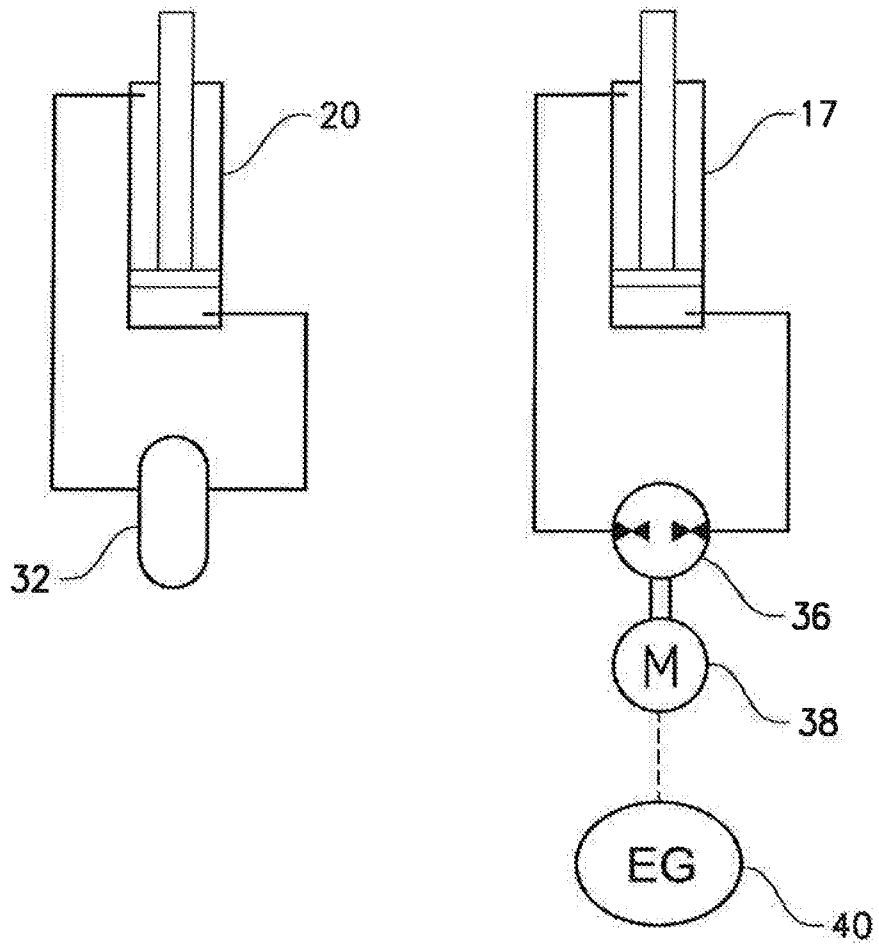


FIG. 3

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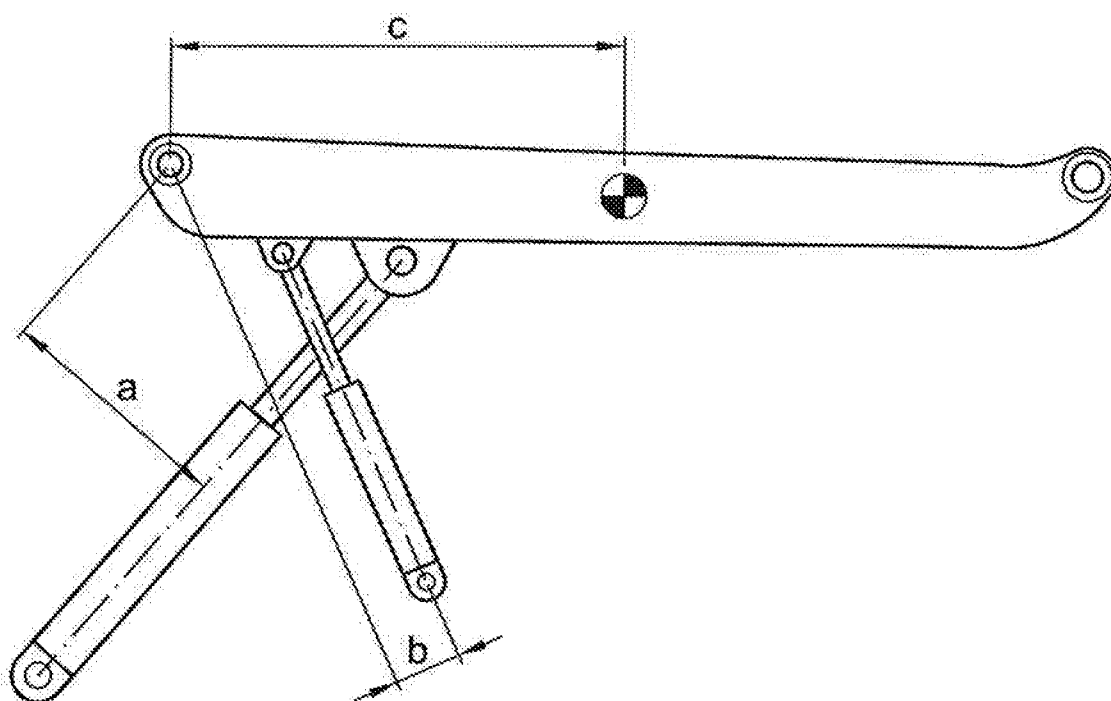


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: E02F, F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	AU 443718 B2 (PACIFIC CAR AND FOUNDRY COMPANY), 12 December 1973 (1973-12-12); page 7, paragraph [0003] - page 9, paragraph [0001]; figures --	1-7, 11-14
X	GB 1432124 A (POCLAIN SA), 14 April 1976 (1976-04-14); page 1, line 25 - line 48; page 2, line 41 - line 89; figures --	1-3, 8-14
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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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Patent- och registreringsverket

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INTERNATIONAL SEARCH REPORT

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Continuation of: second sheet
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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