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(54) METHOD FOR CONTROLLING THE ACTUATION OF AT LEAST ONE HYDRAULIC ORGAN OF A WORK OR AGRICULTURAL VEHICLE

(57) Method for controlling the actuation of at least one hydraulic actuator (A1, A2) of an organ (B, T) of a work or agricultural vehicle (WL), such as an arm (B) and/or a tool (T), the work or agricultural vehicle comprising a prime mover (E) and a second hydraulic pump (P) configured to be driven in rotation by the prime mover so as to generate a flow of hydraulic oil proportional to the speed of the vehicle, and wherein said actuator hydraulic is controlled hydraulically by means of a hydraulic circuit fed by the second hydraulic pump (P) and by a hydraulic valve (V1) comprising a movable shuttle arranged to be electrically operated so that a relative position is proportional to a control lever (Joystick) position, the method comprising (Step 1) Acquisition of the vehicle speed (Step 2) and Application of a first limiting factor of an actuation speed of said mobile shuttle and/or of a second limiting factor of a relative stroke of the movable shuttle.

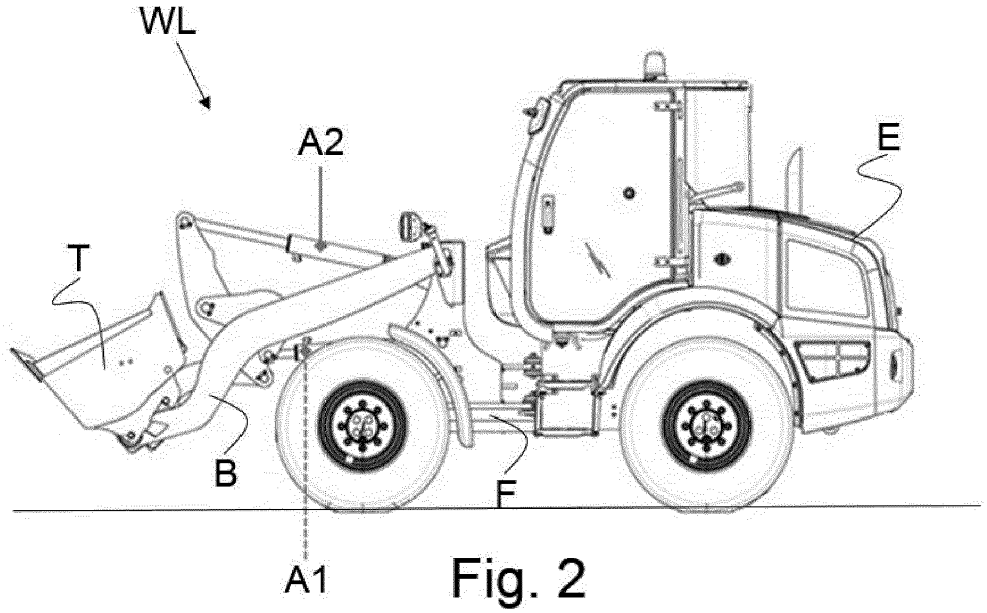

Fig. 2

EP 4 067 581 A1

Description

Field of the invention

[0001] The present invention relates to the field of electro-hydraulic controls and in particular to a method for controlling the actuation of a hydraulic organ of a work or agricultural vehicle.

State of the art

[0002] Motorized agricultural or work vehicles are well known for handling materials and performing specific heavy tasks. They are often equipped with a hydraulically operated lift arm to move a shovel or bucket.

[0003] A wheel loader is a heavy machine used in construction to move earth or materials such as asphalt, demolition debris, snow, feed, gravel, logs, raw minerals, recycled material, rock, sand, wood chips, etc.. into or on top of another type of machinery (such as a dump truck, conveyor belt, feed hopper, or rail car). There are many types of mechanical loaders, which, depending on the design and application, are called by various names, including bucket loader, front loader, front loader, loader, pallet, shovel, skip loader, wheel loader or shovel compact (skid-steer). In the remainder of the present description, vehicle and machine are terms that are interchangeable with each other.

[0004] In work and agricultural vehicles, the transmission to transfer the motion of a prime mover to the wheels is of the hydraulic type. Very often, the transmission defines a series configuration, in which the prime mover drives a variable displacement hydraulic pump, which, in turn, drives a hydraulic motor which can have either fixed or variable displacement.

[0005] The pump and the hydraulic motor are interconnected in a per se known manner by means of a so-called hydraulic delivery line and a hydraulic return line.

[0006] Between the hydraulic motor and the wheels, there is often, but not always, a gearbox with discrete ratios. Very often, there are just two relationships, to facilitate the autonomous movement of the vehicle from one workplace to another workplace.

[0007] Generally, the rotation speed of the prime mover is directly proportional to the position of the accelerator lever and the displacement of the pump is proportional to the rotational speed of the prime mover, while the displacement of the hydraulic motor is inversely proportional to the speed of the vehicle.

[0008] Consequently, the speed of the vehicle and the rotation speed of the prime mover are approximately directly proportional to each other. This first operation mode is for convenience defined as "accelerator-base", since the rotation speed of the prime mover is approximately directly proportional to the position of the accelerator lever and the speed of the vehicle depends on the rotational speed of the prime mover.

[0009] The term "about" shows that the control is in open loop, therefore an increase in the slope causes the vehicle and also the prime mover to slow down.

[0010] This fact is very advantageous when the vehicle is in operation because the driver can manage with the accelerator lever the generation of hydraulic fluid necessary to operate the various on-board devices functional to the operation.

[0011] The movement of the arm and bucket is controlled by the user via a joystick placed inside the operator's (human) cabin of the work vehicle.

[0012] Each hydraulic actuator includes a hydraulic cylinder operatively connected to the arm and to the tool or blade respectively, which uses the hydraulic power of a working fluid to allow mechanical operation.

[0013] Each valve in the circuit is able to guarantee a predetermined pressure to the relative actuator or user, while the flow generated by the hydraulic pump is shared by the various users. This guarantees an efficient combined operation of several actuators or users.

[0014] The speed of actuation of the hydraulic actuator depends on the electrical signal generated by the joystick, as the signal increases, the speed of actuation increases.

[0015] The hydraulic flow rate of the working fluid necessary to operate the arm and the tool is produced by a second hydraulic pump, which is driven by the prime mover, being it an internal combustion engine or an electric drive. The same prime mover drives, albeit indirectly, the propulsion wheels of the work vehicle and all the actuators. Therefore, the speed of movement of the arm and of the tool also depends on the rotation speed of the prime mover, as the speed of rotation of the motor increases, the speed of actuation increases.

[0016] Additionally, with an open center valve, when the prime mover is running at a high rotational speed, minimal joystick movement by the user is required to perform one arm and/or implement movement. Conversely, when the prime mover is running at low rotational speed or idle, a large movement of the joystick by the user is required.

[0017] For the (human) operator, in certain circumstances, it is difficult to take into account the fact that the speed of actuation depends not only on the position of the joystick lever but also on the rotation speed of the prime mover.

[0018] If not specifically excluded in the detailed description that follows, what is described in this chapter is to be considered as an integral part of the detailed description.

Summary of the invention

[0019] The object of the present invention is to make it easier and more convenient for an operator to control a work or agricultural vehicle.

[0020] The basic idea of the present invention is to make the operation of the arm and/or bucket less sudden while the vehicle is moving along a path so as not to

require excessive attention from the operator during work activities.

[0021] More specifically, the idea is to limit the speed of the movements of the arm and/or bucket, the more the greater the vehicle speed.

[0022] This fact is particularly advantageous because when the vehicle moves along a path, for example carrying a load, the prime mover is brought to a relatively high rotation speed. This fact leads to a corresponding increase in the flow of oil pumped by the hydraulic pump. When the operator operates the arm or bucket while the vehicle is moving, in the absence of the present invention, the movements of these organs are sudden and even dangerous. Therefore, in the absence of the present invention, the operator is forced to pay strong attention to the operation of the arm or bucket while directing the vehicle at high speed. In other words, the fact of having to carefully dose the joystick takes the operator's attention away from driving the vehicle with risk for himself and for others.

[0023] Thanks to the present invention, the behavior of the arm or bucket is at least partially independent of the speed of the vehicle or, even, it can be obtained that, when the vehicle is in dynamic conditions, the speed of actuation of the arm or bucket is slower than when the vehicle is in static or quasi-static conditions.

[0024] The dependent claims describe preferred variants of the invention, forming an integral part of this description.

Brief description of the figures

[0025] Further objects and advantages of the present invention will become clear from the following detailed description of an example of its embodiment (and its variants) and from the annexed drawings given purely by way of non-limiting explanation, in which:

Figure 1 shows an example of a propulsion scheme of a work or agricultural vehicle in which the present invention is implemented;

Figure 2 shows an example of a work or agricultural vehicle to which the present invention applies;

Figure 3 shows an example of a hydraulic diagram of an actuator of the vehicle of Figure 1.

[0026] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0027] It should also be noted that the terms "first", "second", "third", "upper", "lower" and the like can be used here to distinguish various elements. These terms do not imply a spatial, sequential or hierarchical order for the modified elements unless specifically indicated or inferred from the text.

[0028] The elements and features illustrated in the various preferred embodiments, including the drawings, can be combined with each other without however departing from the scope of this application as described below.

Detailed description of examplary embodiments

[0029] With reference to Figure 1, a prime mover E, generally an internal combustion, drives a variable displacement hydraulic pump HP in rotation, which powers a hydraulic motor HM, which can have either fixed or variable displacement, operatively connected to the hydraulic pump by defining a so-called hydrostat HY, in which a delivery hydraulic line F and a return hydraulic line R interconnect the hydraulic pump with the hydraulic motor. The displacement of the hydraulic pump is proportional to the rotation speed of the prime mover.

[0030] The prime mover also drives a second hydraulic pump in rotation, intended to power one or more hydraulic members A1, A2, shown in figure 2.

[0031] According to the present invention, a work vehicle WL such as a mechanical shovel, preferably wheel loader comprises a frame F, the prime mover E which rotates the second hydraulic pump which allows to pressurize a hydraulic circuit which allows to control one or more hydraulic actuators A1, A2 for moving respectively an arm B, having a first end hinged to the frame and a second end to support a tool T, and the tool T such as a shovel or forks, etc. Figure 3 shows an example of a simplified electro-hydraulic layout for controlling arm B using the actuator A1.

[0032] The hydraulic actuator A1, also called hydraulic cylinder, includes two opposing chambers labelled with the labels "Lift up" and "Lift down".

[0033] When the arm is raised, the "Lift up" chamber is operationally powered by the second hydraulic pump indicated with the "P" symbol, while the Lift down chamber is connected to the collection tank T of the hydraulic liquid to discharge the excess liquid due to the contraction of the same chamber Lift down.

[0034] The valve VI, preferably an open center directional, provides a rest mode corresponding to the central spool V1_2 of figure 3, in which both the Lift up and Lift down chambers are closed and isolated from the remaining hydraulic circuit. In such conditions, the arm or tool remains stationary in its position.

[0035] The side spools V1_1 and V1_3 connect a chamber, for example Lift up, to the hydraulic pump P and the opposite chamber, for example Lift down, to the recovery tank T of the hydraulic oil and vice versa.

[0036] The valve is of the proportional type with a movable shuttle which slides in a relative valve body, opening/closing the openings in a per se known manner.

[0037] A processing unit UCM is operationally connected with the valve V1 and with a control lever Joystick arranged in the vehicle cabin to be operated by a human operator.

[0038] The processing unit is arranged to receive an electrical input signal generated by the control lever Joystick and to control, consequently, the position of the movable shuttle of the valve VI.

[0039] Obviously, the diagram of figure 3 is considered to be replicated for each of the actuators on board the vehicle. According to the present invention, the processing unit is configured to acquire a vehicle's current speed value VEHICLE SPEED and to apply

- A first limitation of the speed of movement of the movable shuttle inside the relative valve body and/or
- A second limitation of a stroke of the movable shuttle inside the relative valve body.

[0040] The first limiting factor prevents the controlled hydraulic organ from starting to move suddenly, while the second limiting factor limits the speed of movement of the organ in steady state conditions, that is, when it is already in dynamic conditions.

[0041] In other words, both factors impact on the response of the actuated organ, but while the first impacts on the organ in transient conditions and more specifically in static/dynamic switching, the second limiting factor only affects the dynamic behaviour of the actuated organ, thus limiting the speed with which, for example, the arm is raised or lowered. For convenience, below it is said that the limiting factors impact on different stages of actuation in relation to what is described here.

[0042] According to the present invention, at least one of the first or second limiting factor has a variable value in a way that is directly proportional to the speed of the vehicle, so as to decorrelate an actuation response of the hydraulic actuator from the increase of the speed of the vehicle at least in one point or in a sub-range of the entire vehicle speed range.

[0043] In other words, the decorrelation term excludes the direct proportionality between vehicle speed, in the entire vehicle speed range, and the actuation response of the hydraulic actuator by applying a limiting factor as a function of increasing speeds, be it linear, piecewise linear or discrete.

[0044] Preferably, during a slowdown of the vehicle, an inverse strategy is applied in the control of the actuator, with a faster response as the speed decreases.

[0045] It is worth noting that according to the present invention, at least one limiting factor is applied. The concept of limitation explicitly indicates that the actuator response is reduced compared to the response that would occur without any limitation.

[0046] In other words, according to the present invention, the relationship between the response of the actuator and the flow of hydraulic oil generated by the second hydraulic pump is interrupted.

[0047] This does not mean that the response cannot have a minimum correlation with the vehicle speed, but rather that the approximately proportional link that exists according to the known art throughout the entire vehicle speed range is now broken.

[0048] For example, if one envisages the application of discrete limiting factors with gradually increasing values as the vehicle speed increases, in the speed range dominated by one of the values of a limiting factor, the response of the actuator is still proportional to the speed of the vehicle. However, for the operator, this can be considered irrelevant by benefiting from a general decorrelation between the response of the actuator with respect to the vehicle speed and in general to the rotation speed of the prime mover. Therefore, the concept of "decorrelation" according to the present invention is in the sense that it passes from a direct and constant proportionality between the speed of the vehicle and the response of the actuator to only partial proportionality in the entire speed range of the vehicle which can also be indirect or there may be no proportionality at al making the behavior of the actuator completely decorrelated from the speed of the vehicle. Thanks to the present invention, at high speed of rotation of the first motor, the flow of hydraulic oil generated by the second hydraulic pump is correspondingly high, but this does not involve, as according to the known art, a too reactive behavior of the at least one hydraulic actuator. According to a first variant of the invention, the operation of the hydraulic organ is immune to variations in vehicle speed. According to another preferred variant of the invention, the limiting factors are chosen so that the response speed of the hydraulically operated organ is lower when the vehicle is in motion than when the vehicle is stationary.

[0049] In other words, according to this preferred variant of the invention it is possible to obtain an opposite behavior with respect to the ordinary behavior described above.

[0050] According to a preferred variant of the invention, which combines with any of the previous variants, at least one of the limiting factors can vary continuously as a function of the vehicle speed, can vary in a discrete and tabulated manner and can be selected automatically and/or manually.

[0051] For example, the operator can choose to keep the behaviour of the hydraulic organs unchanged with respect to ordinary behaviour, that is, without applying any limitation function of the vehicle speed.

[0052] The operator can select fixed limit values that apply at exceeding a predetermined vehicle speed threshold.

[0053] The operator can select discretely variable limiting factor values that apply at exceeding predetermined vehicle speed thresholds.

[0054] Furthermore, the operator can vary the proportionality ratio between the limiting factors and the vehicle speed. For example, it may decide to have limiting factors, which vary with a first predetermined proportion with the vehicle speed below a first vehicle speed threshold and with a second predetermined proportion above the first vehicle speed threshold.

[0055] According to a preferred variant of the invention, at least one of the limiting factors is a continuous function in at least two ranges of vehicle speed values and in which a first proportionality coefficient of a first range is different from a second proportionality coefficient of a

second interval of the at least two intervals and in which each of the proportionality coefficients identifies a relationship between the relative limiting factor and the speed of the vehicle in the relative interval.

[0056] According to another preferred variant of the invention, at least one of the limiting factors varies so that a behavior of said at least one actuator is invariable with respect to the speed of the vehicle.

[0057] It is clear that since the two factors impact on different phases of the actuator implementation, the invariability can refer to one, the other or both aspects.

[0058] According to another preferred variant of the invention, at least one of said limiting factors can be manually selected by means of a man/machine interface and preferably, at least one of the two limiting factors can be canceled by means of the man/machine interface so as to obtain a behaviour of the hydraulic member as a function of a position of the control lever and the speed of the vehicle. That is to say, in a similar way to the known art in relation to one of the two stages of implementation.

[0059] It is worth highlighting that the two limiting factors can be applied with a common logic, i.e. both according to any of the variants described above or they can be applied following different logics, i.e. according to different variants described above.

[0060] For example, one limiting factor is fixed and the other is continuously variable with the speed of the vehicle. For example, one varies continuously and the other discreetly.

[0061] For example, one varies with a constant proportionality factor and the other with variable proportionality factors depending on the speed range in which the current vehicle speed falls.

[0062] The present invention can be advantageously carried out by means of a computer program, which comprises coding means for carrying out one or more steps of the method, when this program is executed on a computer. Therefore, it is intended that the scope of protection extends to said computer program and further to computer readable means comprising a recorded message, said computer readable means comprising program coding means for carrying out one or more steps of the method. , when said program is run on a computer. Implementation variants of the described non-limiting example are possible, without however departing from the scope of protection of the present invention, including all the equivalent embodiments for a person skilled in the art, to the content of the claims.

[0063] From the above description, the person skilled in the art is able to realize the object of the invention without introducing further construction details.

Claims

1. Method for controlling the actuation of at least one hydraulic actuator of an organ (B, T) of a work or agricultural vehicle (WL), such as an arm (B) and/or a tool (T), the work vehicle or agricultural including a prime mover (E) and

- a first variable displacement hydraulic pump (HP) configured to be driven in rotation by the prime mover and wherein a relative displacement is directly proportional to a rotational speed of the prime mover so that a vehicle speed and the rotation speed (Engine Speed) of the prime mover are approximately directly proportional to each other,
- a second hydraulic pump (P) configured to be driven in rotation by the prime mover so as to generate a flow of hydraulic oil proportional to the speed of the vehicle,

and wherein said hydraulic actuator (A1, A2) is controlled hydraulically by means of a hydraulic circuit fed by the second hydraulic pump (P) and by a hydraulic valve (VI) comprising a movable shuttle arranged to be electrically operated so that a relative position is proportional to a control lever (Joystick) position,

the method including the following steps:

- (Step 1) Acquisition of the vehicle speed (Vehicle Speed),
- (Step 2) Application of a first limiting factor of an actuation speed of said movable shuttle and/or of a second limiting factor of a relative stroke of the movable shuttle, wherein at least one of said first or second limiting factor has a variable value directly proportional to the speed of the vehicle, so as to at least partially decorrelate an actuation response of the hydraulic actuator from the vehicle speed increase.

2. Method according to claim 1, wherein said first limiting factor and said second limiting factor are applied simultaneously.

3. Method according to claim 1 or 2, wherein said value of the at least one limiting factor is variable continuously or discretely depending on the speed of the vehicle.

4. Method according to claim 1 or 2, wherein at least one of said limiting factors has a fixed value and automatically activated when a predetermined vehicle speed threshold is exceeded.

5. Method according to claim 1 or 2, wherein at least one of said limiting factors is a continuous function in at least two ranges of vehicle speed values and wherein a first proportionality coefficient of a first range is different from a second proportionality coefficient of a second interval of said at least two ranges and wherein each of said proportionality coeffi-

cients identifies a relationship between the relative limiting factor and the speed of the vehicle in the relative range.

6. Method according to any one of claims 1 - 3, wherein at least one of said limiting factors varies so that a behaviour of said at least one actuator is invariable with respect to the vehicle speed.

7. Method according to any one of claims 1 - 5, wherein at least one of said limiting factors is manually selectable by means of a man/machine interface.

8. Method according to claim 7, wherein at least one of said limiting factors can be cancelled by means of said man/machine interface so as to obtain a behaviour of the at least one hydraulic member as a function of a position of the control lever and of the speed of the vehicle.

9. Computer program comprising program coding means adapted to carry out all the steps of any one of claims 1 to 8, when said program is run on a computer.

10. Computer readable means comprising a recorded program, said computer readable means comprising program coding means adapted to perform all steps of any one of claims 1 to 8, when said program is run on a computer.

11. Work or agricultural vehicle (WL) comprising

- at least one hydraulic actuator of a member (B, T) such as an arm (B) and/or a tool (T),
- a prime mover (E),
- a first variable displacement hydraulic pump (HP) configured to be driven in rotation by the prime mover and wherein a relative displacement is directly proportional to a rotational speed of the prime mover so that a vehicle speed and the rotation speed (Engine Speed) of the prime mover are approximately directly proportional to each other,
- a second hydraulic pump (P) configured to be driven in rotation by the prime mover so as to generate a flow of hydraulic oil proportional to the speed of the vehicle,
- a hydraulic circuit fed by the second hydraulic pump (P) and by a hydraulic valve (VI) arranged to control said hydraulic actuator (B, T), wherein the valve comprises a movable shuttle arranged to be electrically operated so that a relative position is proportional to a control lever (Joystick) of the vehicle,
- processing means (ECU) configured to acquire the vehicle speed (Vehicle Speed), and to apply a first limiting factor of an actuation speed of said movable shuttle and/or of a second limiting factor of a relative stroke of the movable shuttle,

wherein at least one of said first or second limiting factor is directly proportional to the vehicle speed, so as to at least partially decorrelate an actuation response of the hydraulic actuator from the vehicle speed increase.

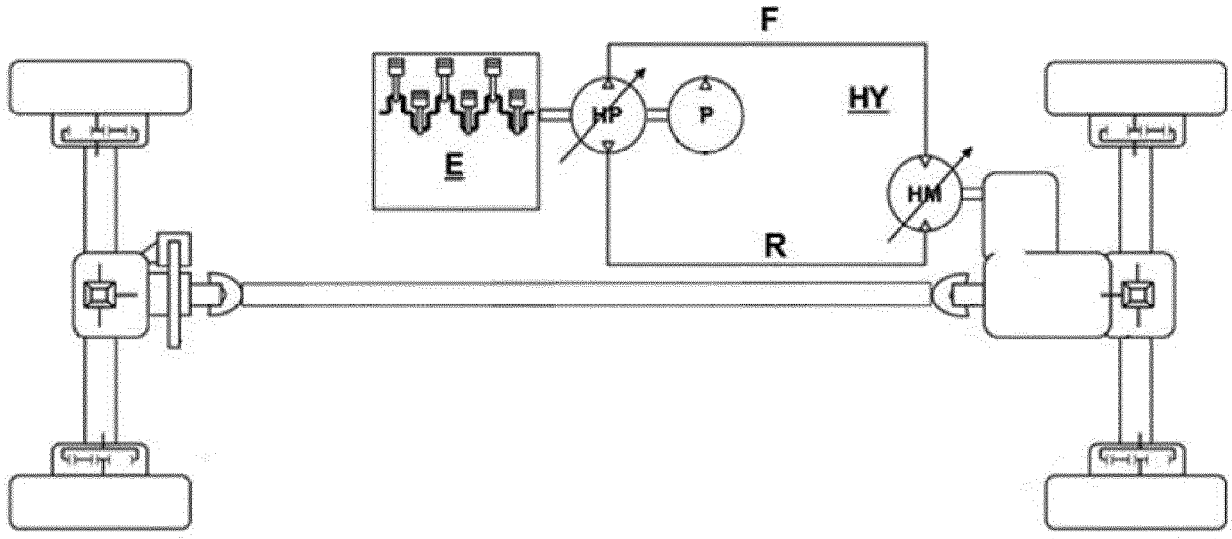

Fig. 1

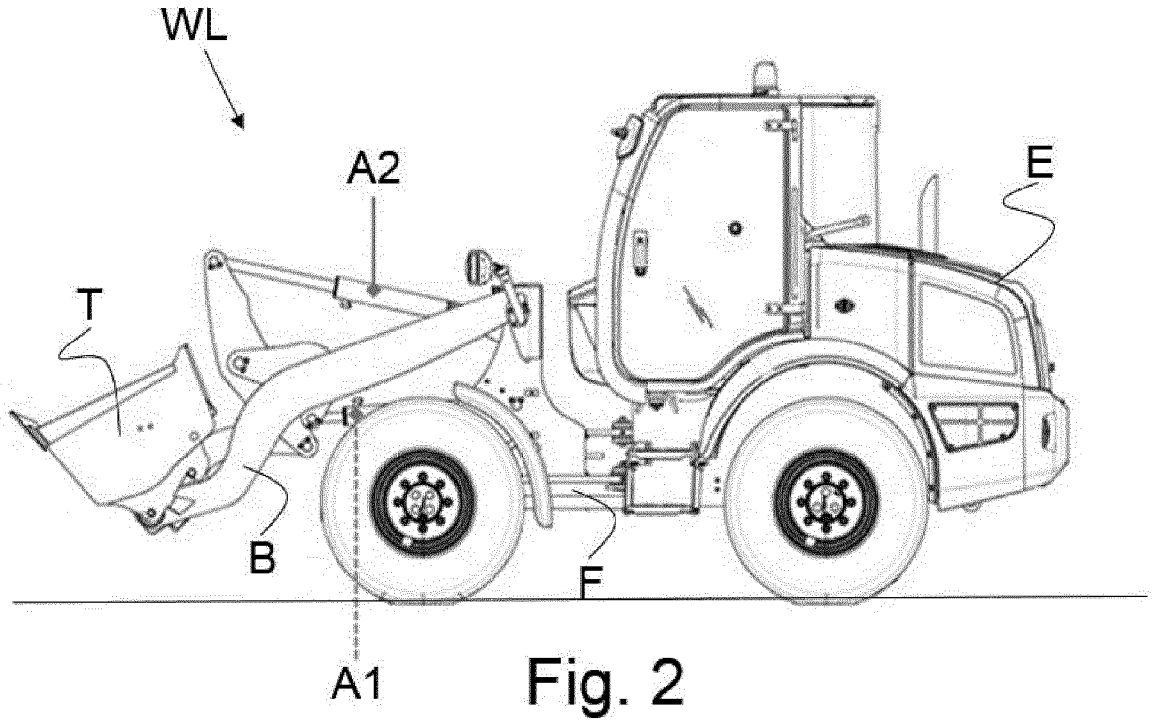

Fig. 2

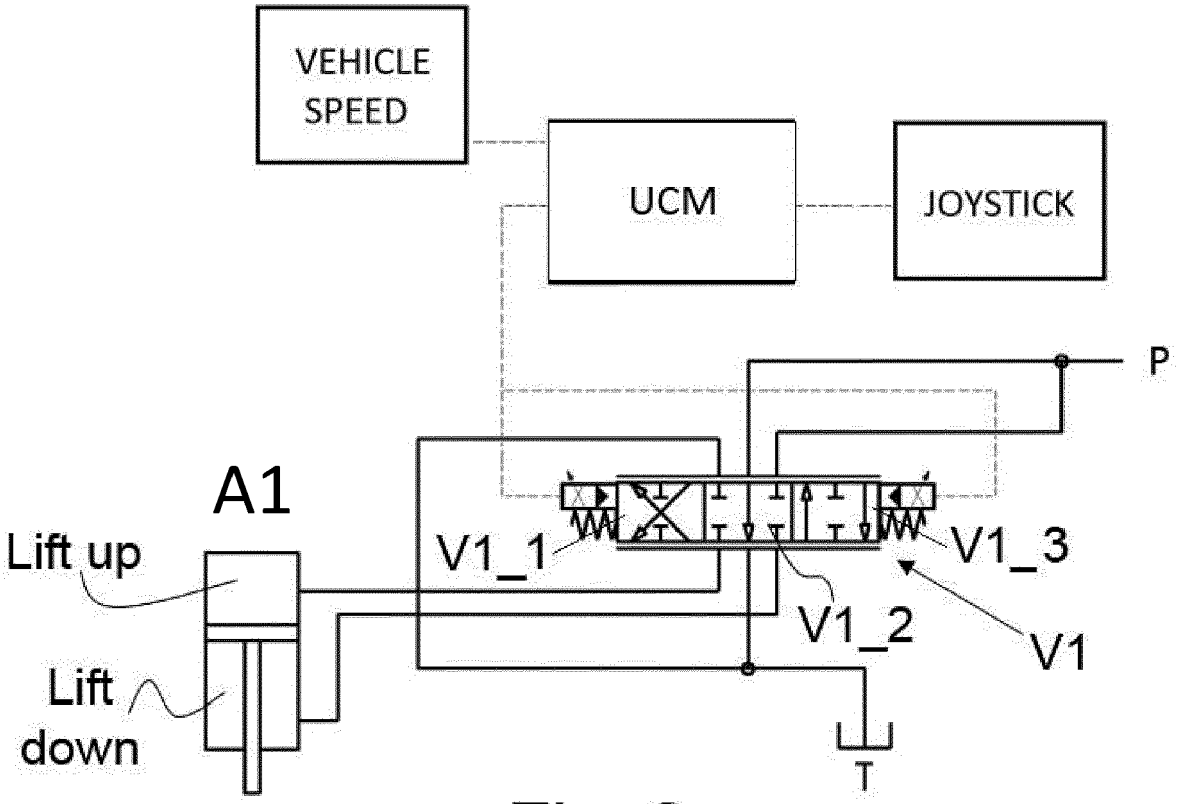
VEHICLE SPEED
UCM
JOYSTICK
P
A1
Lift up
Lift down
V1_1
V1_2
V1_3
V1
T

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 5605

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TECHNICAL FIELDS SEARCHED (IPC)

E02F
F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 July 2022	Clarke, Alister

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