(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 119 731 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
11.09.2024 Bulletin 2024/37

(21) Application number: **22184195.0**

(22) Date of filing: **11.07.2022**

(51) International Patent Classification (IPC):
E02F 9/22 *(2006.01)* ***E02F 9/20*** *(2006.01)*
F15B 7/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E02F 9/2282; E02F 9/207; E02F 9/2228;
F15B 21/087; F15B 2211/20515; F15B 2211/20538;
F15B 2211/3116; F15B 2211/327; F15B 2211/329;
F15B 2211/45; F15B 2211/50518;
F15B 2211/50554; F15B 2211/5156;
F15B 2211/555; F15B 2211/6309; (Cont.)

(54) **ELECTRO-HYDRAULIC CONTROL CIRCUIT OF A HYDRAULIC ACTUATOR FOR AN ELECTRIFIED WORK VEHICLE**

ELEKTROHYDRAULISCHE STEUERSCHALTUNG EINES HYDRAULISCHEN AKTUATORS FÜR EIN ELEKTRIFIZIERTES ARBEITSFAHRZEUG

CIRCUIT DE COMMANDE ÉLECTROHYDRAULIQUE D'UN ACTIONNEUR HYDRAULIQUE POUR UN VÉHICULE DE TRAVAIL ÉLECTRIFIÉ

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **16.07.2021 IT 202100018941**

(43) Date of publication of application:
18.01.2023 Bulletin 2023/03

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Processed by Luminess, 75001 PARIS (FR)

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(52) Cooperative Patent Classification (CPC): (Cont.)
F15B 2211/6346; F15B 2211/6355;
F15B 2211/6651; F15B 2211/88

Description

Field of the invention

[0001] The present invention relates to the field of electrified work vehicles, and in particular of the type comprising an electro-hydraulic circuit for the actuation of at least one hydraulic member, including an arm and/or a bucket.

State of the art

[0002] In the field of work and agricultural vehicles, the operation of members, such as arms and related tools, is carried out by means of a hydraulic circuit.

[0003] The hydraulic circuit is powered by a hydraulic pump driven in rotation by a prime mover, very often an internal combustion engine.

[0004] The hydraulic actuators implemented for moving the members are of the double chamber type, that is to say a movable piston divides two closed chambers that can be fed alternately by the hydraulic pump.

[0005] There are different types of valves for controlling hydraulic circuits. Those that are most implemented are the directional ones with open center. These valves, in relation to the position of the relative movable spool, divide the hydraulic oil fluid pumped by the hydraulic pump into a first flow destined for one of the hydraulic actuator chambers, while the second, remaining flow is sent to a collection tank, where the hydraulic pump draws the hydraulic oil to recirculate it.

[0006] In particular, when the spool is in the rest position, all the pump flow is sent to the tank, during the adjustment phase, the flow of the hydraulic pump is divided between the actuator and the tank. When the spool is in the maximum opening position, all the pump flow is sent to the actuator. The position of the movable spool is generally controlled by the operator using a joystick placed in the vehicle's cockpit.

[0007] The progressive technological development of battery power systems makes it possible to design electric work vehicles.

[0008] The fundamental problem of the electrification of work vehicles consists in the fact that the hydraulic control circuits of arms, shovels, etc., are very well tested and reliable, therefore, electric vehicles continue to include a hydraulic circuit for actuating at least one hydraulic actuator enslaved to the movement of a working hydraulic organ.

[0009] The term "work hydraulic organ" means one of those distinct and separate components from those inherent to the movement of the work vehicle, such as transmissions, braking systems, etc. Hereinafter, for convenience, reference is made to a "hydraulic organ" meaning a "working hydraulic organ".

[0010] The electrification of a work vehicle involves the elimination of the internal combustion engine in favor of at least one electric motor.

[0011] For example, it is possible to provide a first electric motor used exclusively to drive the hydraulic pump for feeding at least one hydraulic working member in rotation. A second electric motor can be provided for moving the vehicle.

[0012] There are many differences between internal combustion engines and electric motors. In addition to the substantial different source of energy, the internal combustion engine, when active, has a minimum rotation speed, which is essential for its operation, while an electric motor starts rotating as soon as it is electrically powered.

[0013] All of this has repercussions on the operation of the hydraulic pump driven by the first electric motor.

[0014] A minimum rotation speed of the electric motor implies a consumption of electricity not necessary for the intrinsic operation of the same.

[0015] Saving electricity is essential to allow the spread of electrified vehicles, replacing traditional work vehicles equipped with internal combustion engines.

[0016] 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.

[0017] EP1291467A1 discloses an excavator having an electro-hydraulic circuit with the features of the preamble of claim 1.

Summary of the invention

[0018] The purpose of the present invention as defined in claims 1 and 8 is to propose a method and system for saving electric energy in an electrified work vehicle. In particular for those work vehicles completely without an internal combustion engine.

[0019] The purpose of the present invention is to modify the hydraulic circuit and the behavior of the electric motor, which drives a fixed displacement hydraulic pump in rotation, when an directional open center control electro-valve of the hydraulic supply circuit of a hydraulic member is in the closed condition, ie released, so that the replacement of the internal combustion engine with the electric motor does not alter the functionality of the entire hydraulic circuit.

[0020] The basic idea is to deactivate the electric motor when the control lever of the directional electro-valve is released, that is, when the directional open center control electro-valve is in the released condition. This results in significant energy savings. However, this fact can lead to a depressurization of the portion of the hydraulic circuit between the fixed displacement hydraulic pump and the open center control directional electro-valve, therefore, when the control lever is operated again, there is a risk that the hydraulic organ behaves in an uncontrolled way. According to the present invention, an overpressure valve is arranged on the "neutral" line of the directional open center electro-valve, which connects the electro-valve with the hydraulic oil recovery tank, configured to

open when a first predetermined pressure threshold is exceeded.

[0021] When the control lever is inclined to cause an actuation, the hydraulic circuit is pressurized to a pressure greater than or equal to the aforementioned first predetermined pressure threshold.

[0022] This is because when the position of the movable spool is in the "adjustment" range, the hydraulic oil is directed by the hydraulic pump partly to the actuators and partly to the recovery tank through the overpressure valve, while when the spool is in the maximum opening all the pump flow is sent to the actuator, therefore, the portion of the circuit between the hydraulic pump and the electro-control valve is pressurized at a pressure level greater than or equal to the aforementioned first predetermined threshold of pressure. When the control lever is released, the hydraulic pump is activated cyclically to keep this portion of the hydraulic circuit pressurized at a pressure level slightly below the opening threshold of the overpressure valve.

[0023] This ensures that a power supply circuit for the solenoid valve actuation, branched from the portion of the circuit between the hydraulic pump and the control electro-valve, always has the minimum pressure sufficient for the actuation of the solenoid valve itself.

[0024] Preferably, the power supply circuit is connected to the aforementioned portion of the circuit between the hydraulic pump and the electro-valve, by means of a pressure relief valve. Advantageously, the power supply circuit of the electro-valve can operate at a pressure much lower than the pressure generated by the hydraulic pump.

[0025] In other words, both the high pressure circuit intended to power the hydraulic actuator, and the low pressure circuit, which activates the electro-valve, are powered by the same hydraulic pump.

[0026] Such pump, is the sole pump connected to the hydraulic circuit.

[0027] At the same time, on the portion of the hydraulic circuit comprised between the hydraulic pump and the electro-valve there is a pressure sensor configured to activate the electric motor when the measured pressure is lower than a second predetermined pressure threshold and deactivate it when the measured pressure is higher than a third predetermined pressure threshold greater than the second predetermined pressure threshold and less than or equal to the first predetermined pressure threshold, when the control lever of the directional electro-valve is released. Advantageously, the overpressure valve, in addition to always guaranteeing the minimum pressure necessary to operate the control electro-valve, allows to close the portion of the hydraulic circuit between the hydraulic pump and the directional open center control electro-valve, generating a closed volume of oil which, in order to be pressurized, requires few non-continuous activations of the electric motor, useful only to compensate for oil leaks through the pump. This involves significant energy savings because otherwise, the electric motor should always be active, albeit at a relatively low rotation speed, to keep the portion of the hydraulic circuit between the hydraulic pump and the control electro-valve pressurized. Advantageously, the hydraulic circuit is always well pressurized and uncontrolled behavior is not observed when the operator intervenes on the actuator control lever.

[0028] The dependent claims describe preferred variants of the invention, forming an integral part of this description.

Brief description of the figures

[0029] 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 attached drawings given purely for explanatory and non-limiting purposes, in which:

Figure 1 shows an example of an electro-hydraulic circuit according to the present invention;
Figure 2 shows a work vehicle implementing the present invention.

[0030] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0031] It should also be noted that the terms "first", "second", "third", "upper", "lower" and the like can be used as labels 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.

[0032] 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

[0033] Figure 1 shows an example of an electro-hydraulic circuit HC according to the present invention.

[0034] This circuit comprises three directional open center control electro-valves V1, V2, V3 arranged to control the BOOM, BUCKET and AUX double acting actuators respectively. Obviously, the electro-hydraulic circuit can comprise any number of control electro-valves with respective hydraulic actuators.

[0035] Each electro-valve comprises a central drawer which provides for the closure of the opposite chambers of the respective actuator, while the fixed displacement hydraulic pump P is operatively connected to the recovery tank T.

[0036] Each electro-valve includes a lateral drawer, left and right, according to which an actuator chamber is operationally connected to the hydraulic pump while the opposite chamber is operationally connected to the recovery tank T of the hydraulic oil.

[0037] When a side drawer is active, one actuator chamber expands due to the pressure of the hydraulic oil, while the opposite one contracts, discharging the previously accumulated oil into the recovery tank.

[0038] In a mechanical shovel, this fact results, for example, in the lifting or lowering of the arm or in the forward or backward rotation of the bucket.

[0039] According to the present invention, an overpressure valve SV is arranged between the outlet door of the central drawer and the recovery tank T. This valve is calibrated to open when a first pressure threshold Th1 is exceeded.

[0040] The outlet ports of the side drawers of the electro-valve are connected directly to the recovery tank T.

[0041] Each electro-valve is of the proportional type, in order to perform a partialization of the hydraulic oil directed to the actuator and that sent directly to the recovery tank T according to the inclination of the control lever. Preferably, this function is proportional.

[0042] A pressure sensor PS is associated with the portion of the hydraulic circuit comprised between the hydraulic pump P and the electro-hydraulic valve.

[0043] For convenience, "electro-hydraulic valve" or "electro-valve" means the "open center electro-hydraulic directional control valve" mentioned above.

[0044] This sensor is designed to activate the electric motor M associated with the hydraulic pump P, so as to keep the hydraulic circuit pressurized between a second Th2 and a third pressure threshold Th3.

[0045] This band Th2 - Th3 is selected:

- in order to guarantee predictable behavior of the hydraulic circuit,
- in relation to the pressure sufficient to control the actuation of the electro-valve itself,
- in order to avoid an excessively frequent activation of the electric motor.

[0046] The relationship between the pressure thresholds is as follows: $Th1 \leq Th3 < Th2$.

[0047] This relationship makes it possible to avoid wasting electricity by draining hydraulic oil into the recovery tank.

[0048] This connection diagram ensures that the portion of the hydraulic circuit between the hydraulic pump and the electro-valve is well pressurized even if the electric motor M is generally kept off when the JOYSTICK control lever is released.

[0049] According to the example in Figure 1, the AC drive circuit of the electro-valve works at a lower pressure than the remaining HC hydraulic circuit, so that a reducing valve RV, operatively connected to the hydraulic pump P, supplies the AC drive circuit.

[0050] In the same diagram, it is noted that the electrovalves are electrically connected with the CONTROL UNIT block which represents a processing unit arranged to control the position of the movable spool of each electro-valve, but also to supervise the operation of the hydraulic pump P by means of the relative electric motor M. The processing unit is also operationally connected to the control lever JOYSTICK and to the pressure sensor PS.

[0051] Advantageously, the fact of ensuring constant pressurization of the portion of the hydraulic circuit between the hydraulic pump P and the electro-valve, allows to ensure sufficient pressurization of the drive circuit AC of the same electro-valve, so that a double benefit is obtained:

- the possibility of deactivating the electric motor without emptying the portion of the hydraulic circuit between the hydraulic pump and the electro-valve,
- the fact of having an approximately constant pressure source for controlling the actuation of the electro-valve. Generally, the control lever is defined by a joystick arranged in the cockpit of the work or agricultural vehicle.

[0052] Figure 2 shows a work vehicle WL, a mechanical shovel, with an arm B and the relative hydraulic actuator "BOOM" and a shovel T with the relative BUCKET actuator.

[0053] The vehicle WL is equipped with a battery pack BAT and an electric motor M with at least one electro-hydraulic circuit similar to that of figure 1, fixed to a relative frame F.

[0054] From an operational point of view, the present invention also includes a method of operation of an electro-hydraulic circuit HC as described above, comprising

- deactivation of the electric motor when the electrovalve is in the closed condition,
- maintaining a pressurization of a portion of the hydraulic circuit between the hydraulic pump (P) and the electro-valve, by means of intermittent activation of the electric motor.

[0055] 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.

[0056] 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.

[0057] 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. Electro-hydraulic circuit (HC) comprising

   - a fixed displacement hydraulic pump (P) and an electric motor arranged to drive the hydraulic pump in rotation,
   - a recovery tank (T) arranged to collect hydraulic oil,
   - a hydraulic actuator (BUCKET, BOOM, AUX) arranged to move a work member (B, T) and/or an auxiliary device and to be powered by the hydraulic circuit,
   - a directional open center electro-valve (V1, V2, V3) operatively interposed between said fixed displacement hydraulic pump and said actuator and comprising a released condition in which it isolates the hydraulic actuator by hydraulically connecting the hydraulic pump with the recovery tank,
   - wherein the electric motor (M) is configured to deactivate when the electro-valve is in released condition,

   characterised in that the electro-hydraulic circuit further comprises an overpressure valve (SV) interposed between the electro-valve and the recovery tank and configured to open when a first predetermined pressure threshold is exceeded and a pressure sensor (PS) associated with a portion of the hydraulic circuit comprised between the hydraulic pump and the electro-valve and wherein the pressure sensor is configured, when the electro-valve is in the closed condition, to activate the electric motor when the measured pressure is lower than a second predetermined pressure threshold (Th2) and subsequently deactivate it when the measured pressure is higher than a third predetermined pressure threshold (Th3) greater than the second predetermined pressure threshold, less than or equal as the first predetermined pressure threshold.

2. Circuit according to claim 1, further comprising a supply circuit (AC) for the actuation of the electro-valve, and in which said supply circuit is supplied by said hydraulic pump by means of a pressure limiting valve (RV).

3. Circuit according to claim 2, in which said pressure limiting valve is operatively connected to said portion of the hydraulic circuit comprised between the hydraulic pump and the electro-valve.

4. Circuit according to claim 3, in which a pressurization of the supply circuit (AC) is a function of the pressurization of the portion of the hydraulic circuit between the hydraulic pump and the electro-valve.

5. Circuit according to any one of the preceding claims, in which said hydraulic actuator is enslaved to a hydraulic work member such as an arm and/or a bucket or an auxiliary device.

6. Work vehicle comprising a hydraulic circuit according to any one of the preceding claims.

7. Work vehicle according to claim 6, wherein said hydraulic work member does not pertain to the movement of the vehicle.

8. Method of operation of an electro-hydraulic circuit (HC) according to any one of the preceding claims comprising

   - deactivation of the electric motor when the electro-valve is in the closed condition,
   - maintaining a pressurization of a portion of the hydraulic circuit between the hydraulic pump (P) and the electro-valve, through intermittent activation of the electric motor.

Patentansprüche

1. Elektro-hydraulischer Kreislauf (HC) mit

   - einer Hydraulikpumpe (P) mit fester Verdrängung und einem elektrischen Motor, der dazu eingerichtet ist, die Hydraulikpumpe in Rotation zu versetzen,
   - einem Rückgewinnungsbehälter (T), der dazu eingerichtet ist, Hydrauliköl zu sammeln,
   - einer hydraulischen Betätigungseinrichtung (BUCKET, BOOM, AUX), die dazu eingerichtet ist, ein Arbeitselement (B, T) und/oder ein Hilfsgerät zu bewegen und von dem hydraulischen Kreislauf angetrieben zu werden,
   - ein elektronisches Wegeventil mit offenem Zentrum (V1, V2, V3), das zwischen der Hydraulikpumpe mit fester Verdrängung und der Betätigungseinrichtung wirkend angeordnet ist und einen Freigabezustand aufweist, in welchem es die hydraulische Betätigungseinrichtung durch ein hydraulisches Verbinden der Hydraulikpumpe mit dem Rückgewinnungsbehälter isoliert, wobei der elektrische Motor (M) dazu eingerichtet ist, sich zu deaktivieren, wenn sich das elektronische Ventil in dem Freigabezustand befindet,

   dadurch gekennzeichnet, dass der elektrohydraulische Kreislauf des Weiteren umfasst ein Überdruckventil (SV), das zwischen dem elektronischen Ventil und dem Rückgewinnungsbehälter angeordnet ist und dazu eingerichtet ist, sich zu öffnen, wenn ein erster vorbestimmter Druckgrenzwert überschritten wird,

und
einen Drucksensor (PS), der mit einem Teil des hydraulischen Kreislaufs verknüpft ist, der zwischen der Hydraulikpumpe und dem elektronischen Ventil umfasst ist, und wobei, wenn sich das elektronische Ventil in dem geschlossenen Zustand befindet, der Drucksensor dazu eingerichtet ist, den elektrischen Motor zu aktivieren, wenn der gemessene Druck kleiner ist als ein zweiter vorbestimmter Druckgrenzwert (Th2) und ihn anschließend zu deaktivieren, wenn der gemessene Druck höher ist als ein dritter vorbestimmter Druckgrenzwert (Th3), der größer ist als der zweite vorbestimmte Druckgrenzwert, kleiner oder gleich dem ersten vorbestimmten Druckgrenzwert.

2. Kreislauf nach Anspruch 1, des Weiteren einen Versorgungskreislauf (AC) zum Betätigen des elektronischen Ventils umfassend und wobei der Versorgungskreislauf von der Hydraulikpumpe mittels eines druckbegrenzenden Ventils (RV) versorgt wird.

3. Kreislauf nach Anspruch 2, wobei das druckbegrenzende Ventil mit dem Teil des hydraulischen Kreislaufs wirkend verbunden ist, der zwischen der Hydraulikpumpe und dem elektronischen Ventil angeordnet ist.

4. Kreislauf nach Anspruch 3, wobei eine Druckbeaufschlagung des Versorgungskreislauf (AC) in Abhängigkeit von der Druckbeaufschlagung des Teils des hydraulischen Kreislaufs zwischen der Hydraulikpumpe und dem elektronischen Ventil erfolgt.

5. Kreislauf nach einem der vorhergehenden Ansprüche, wobei die hydraulische Betätigungseinrichtung mit einem hydraulischen Arbeitselement, wie einem Arm und/oder einer Schaufel, oder einem Hilfsgerät gekoppelt ist.

6. Nutzfahrzeug mit einem hydraulischen Kreislauf nach einem der vorhergehenden Ansprüche.

7. Nutzfahrzeug nach Anspruch 6, wobei das hydraulische Arbeitselement nicht die Bewegung des Fahrzeugs betrifft.

8. Verfahren zum Betreiben eines elektro-hydraulischen Kreislaufs (HC) nach einem der vorhergehenden Ansprüche umfassend

- das Deaktivieren des elektrischen Motors, wenn das elektronische Ventil sich in dem geschlossenen Zustand befindet,
- das Beibehalten einer Druckbeaufschlagung eines Teils des hydraulischen Kreislaufs zwischen der Hydraulikpumpe (P) und dem elektronischen Ventil durch intermittierendes Aktivieren des elektrischen Motors.

Revendications

1. Circuit électrohydraulique (HC) comprenant

- une pompe hydraulique à cylindrée constante (P) et un moteur électrique agencé pour entraîner la pompe hydraulique en rotation,
- un réservoir d'expansion (T) agencé pour recueillir l'huile hydraulique,
- un actionneur hydraulique (BUCKET, BOOM, AUX) agencé pour déplacer un élément de travail (B, T) et/ou un dispositif auxiliaire et être alimenté par le circuit hydraulique,
- une valve à actionnement électrique directionnelle et à centre ouvert (V1, V2, V3) interposée fonctionnellement entre ladite pompe hydraulique à cylindrée constante (P) et ledit actionneur et comprenant une condition de déverrouillage dans laquelle elle isole l'actionneur hydraulique en raccordant hydrauliquement la pompe hydraulique au réservoir d'expansion,
- dans lequel le moteur électrique (M) est configuré pour se désactiver lorsque la valve à actionnement électrique est en condition de déverrouillage,

caractérisé en ce que le circuit électrohydraulique comprend en outre
une vanne de surpression (SV) interposée entre la valve à actionnement électrique et le réservoir d'expansion et configurée pour s'ouvrir lorsqu'un premier seuil de pression prédéterminé est dépassé et
un capteur de pression (PS) associé à une partie du circuit hydraulique compris entre la pompe hydraulique et la valve à actionnement électrique et dans lequel le capteur de pression est configuré, lorsque la valve à actionnement électrique est à l'état fermé, pour activer le moteur électrique lorsque la pression mesurée est inférieure à un deuxième seuil de pression prédéterminé (Th2) et la désactiver ensuite lorsque la pression mesurée est supérieure à un troisième seuil de pression prédéterminé (Th3) supérieur au deuxième seuil de pression prédéterminé, inférieur ou égal au premier seuil de pression prédéterminé.

2. Circuit selon la revendication 1, comprenant en outre un circuit d'alimentation (AC) pour l'actionnement de la valve à actionnement électrique, et dans lequel ledit circuit d'alimentation est alimenté par ladite pompe hydraulique au moyen d'une valve de limitation de pression (RV).

3. Circuit selon la revendication 2, dans lequel ladite valve de limitation de pression est fonctionnellement reliée à ladite partie du circuit hydraulique comprise entre la pompe hydraulique et la valve à actionnement électrique.

4. Circuit selon la revendication 3, dans lequel une pressurisation du circuit d'alimentation (AC) est fonction de la pressurisation de la partie du circuit hydraulique comprise entre la pompe hydraulique et la valve à actionnement électrique.

5. Circuit selon l'une quelconque des revendications précédentes, dans lequel ledit actionneur hydraulique est asservi à un élément de travail hydraulique comme un bras et/ou un godet ou un dispositif auxiliaire.

6. Véhicule agricole comprenant un circuit hydraulique selon l'une quelconque des revendications précédentes.

7. Véhicule de travail selon la revendication 6, dans lequel ledit élément de travail hydraulique ne concerne pas le mouvement du véhicule.

8. Procédé de fonctionnement d'un circuit électrohydraulique (HC) selon l'une quelconque des revendications précédentes comprenant

- la désactivation du moteur électrique lorsque la valve à actionnement électrique est à l'état fermé,
- le maintien d'une pressurisation d'une partie du circuit hydraulique entre la pompe hydraulique (P) et la valve à actionnement électrique, par activation intermittente du moteur électrique.

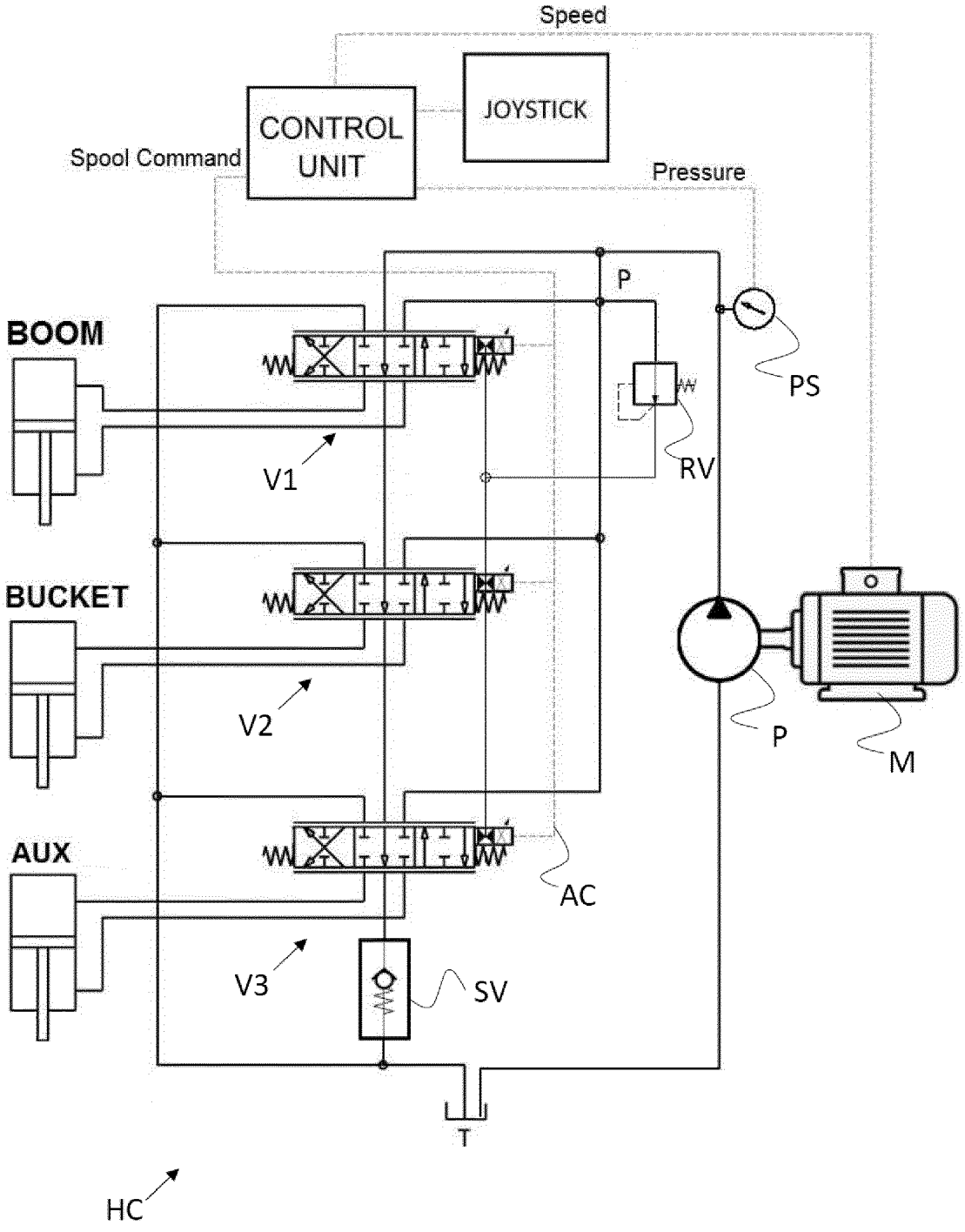
Speed
JOYSTICK
CONTROL UNIT
Spool Command
Pressure
P
BOOM
PS
V1
RV
BUCKET
V2
P
M
AUX
AC
V3
SV
T
HC

Fig. 1

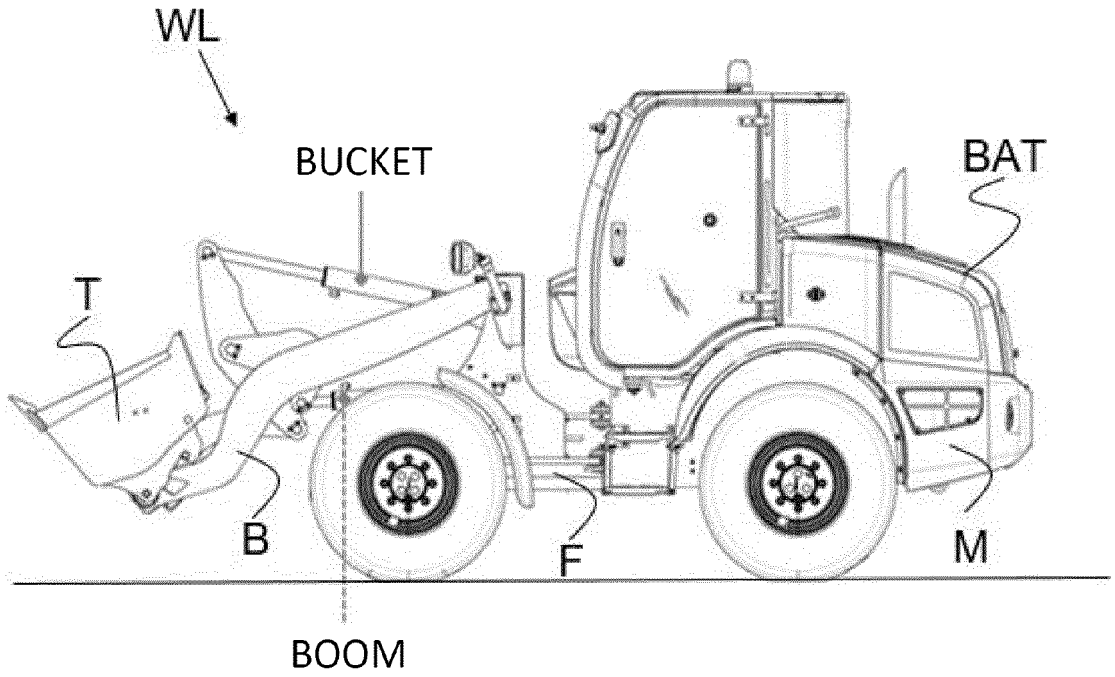

Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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