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(54) METHOD FOR OPERATING A HYDRAULIC CIRCUIT OF A WORK VEHICLE, CORRESPONDING PROCESSING UNIT AND WORK VEHICLE

(57) Method for managing a hydraulic circuit (HC) of a work vehicle, comprising a first operating mode, called "accelerator-base", in which a rotation speed (ES) of the prime mover (E) is directly proportional to a deflection of an accelerator lever (AP) and in which a speed (VS) of the vehicle and the rotation speed of the prime mover are approximately directly proportional to each other and a second operating mode, called "tool-base", in which in a first continuous range of joystick lever deflection (LJK), the prime mover is operated at a predetermined approximately fixed rotational speed, and an opening of the open-center directional valve is proportional to the deflection of the joystick lever (LJK), in a second continuous joystick lever deflection (LJK) range distinct and separate from said first deflection range, the prime mover is operated at a rotational speed proportional to said joystick lever deflection (LJK) and the open center directional valve opening is fixed at a maximum opening value.

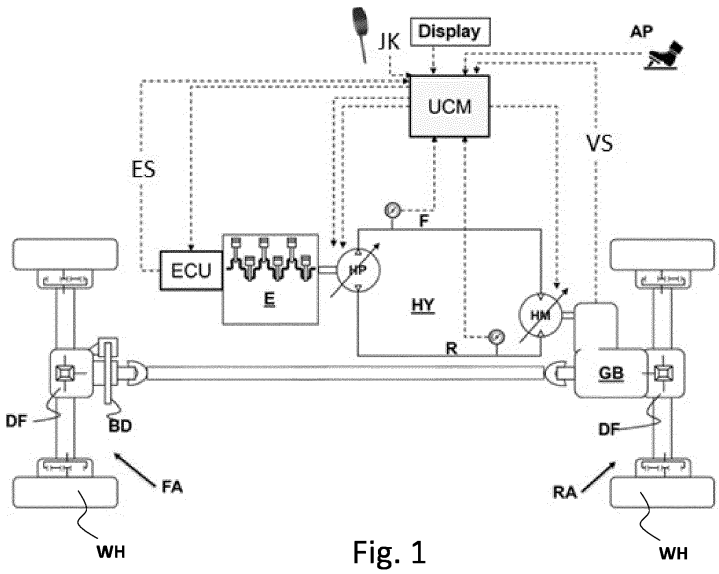

Fig. 1

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Description

Field of the invention

[0001] The present invention relates to the field of work vehicles, including the so-called Wheel Loaders, and agricultural vehicles.

State of the art

[0002] Compact Wheel Loaders and Wheel Loaders are work vehicles equipped with a mechanical arm to which a bucket is connected for moving material or for earthmoving.

[0003] In the context of work vehicles, the operation organs, such as arms and related tools, is achieved via a hydraulic circuit.

[0004] The hydraulic circuit is powered by a first hydraulic pump driven in rotation by a prime mover, most often an internal combustion engine.

[0005] In work vehicles, the most well-known and implemented organs are the arms equipped with buckets or forks or other devices connected to the arm.

[0006] The lifting and lowering of the arm and the rollback and unload of the bucket or forks are carried out using at least one double-action hydraulic actuator. It includes a pair of opposing chambers which fill and empty alternately to raise or lower the arm and rollback and unload the bucket or forks.

[0007] The valve for controlling a hydraulic actuator is generally controlled by the operator using a joystick located in the cockpit of the vehicle.

[0008] The electrical signal generated by the joystick is acquired by a processing unit, which processes it to control the directional control valve configured to control the corresponding hydraulic actuator. The directional control valve is evidently of the electro-hydraulic type.

[0009] The most common electro-hydraulic valves are open center. They are characterized by the fact of splitting a flow of hydraulic oil, pumped by the corresponding first hydraulic pump, into a first flow intended for an actuator, and a second flow intended for a collection tank. When the joystick lever is released, the entire oil flow is sent to the collection tank, while when the joystick lever is fully deflected, the entire oil flow is sent to the hydraulic actuator. Between these two extreme configurations there are intermediate positions proportional to the deviation/position of the Joystick lever, in which a first portion of the oil flow is sent to the hydraulic actuator, while a second portion of the oil flow is sent to the collection tank.

[0010] In work and agricultural vehicles, the transmission to transfer the motion of the prime mover to the wheels is hydraulic. Generally, the transmission defines a series configuration, in which the internal combustion prime mover drives a second hydraulic pump with variable displacement, which, in turn, drives a hydraulic motor, which can have both fixed and variable displacement.

[0011] The second pump and the hydraulic motor are interconnected in a known way to form a hydrostat, by means of a so-called high pressure hydraulic line or "forward" line and a low pressure hydraulic line or "return" line of the hydraulic oil towards the hydraulic pump.

[0012] A gearbox with discrete ratios is often, but not always, located between the hydraulic motor and the wheels. Very often there are just two gears, to facilitate the autonomous movement of the vehicle from one workplace to another. Generally, the rotation speed of the prime mover is directly proportional to the position of the accelerator lever and the displacement of the second hydraulic pump is proportional to the rotation speed of the prime mover according to a predetermined mapping, while the displacement of the hydraulic motor is inversely proportional to the speed of the vehicle.

[0013] Therefore, to obtain a higher vehicle speed it is necessary to increase the rotation speed of the prime mover.

[0014] However, a greater rotation speed of the prime mover also affects the actuation of the hydraulic components. In fact, the first hydraulic pump, having a fixed displacement, pumps a greater oil flow as it increases the corresponding rotation speed. Therefore, when the transmission is in neutral, the operator can exploit this effect by acting on the accelerator lever to regulate the flow of oil that reaches the hydraulic actuators via the respective control valves.

[0015] Unless 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

[0016] The aim of the present invention is to provide a method of managing a hydraulic circuit of a work vehicle equipped with an internal combustion engine which allows to increase productivity.

[0017] The basic idea of the present invention is to introduce an operating mode in which the rotation speed of the prime mover is entirely controlled through the joystick lever responsible for controlling a hydraulic organ, while the accelerator lever acts exclusively on the configuration of the hydrostat.

[0018] More in detail, according to the present invention, the joystick excursion is divided into three bands:

- A first band, named as dead band, optional, in which the signal generated by the joystick is ignored, i.e. it does not involve any modification in the operating parameters of the prime mover and of the hydraulic organ controlled by the joystick,
- A second band, proportional, in which a deflection of the joystick lever results in a proportional adjustment of the opening of the control valve while the prime mover is maintained at a first predetermined rotation speed value, named as lower limit, for the entire

second band,

- A third band, in which the valve is brought fully open so that the entire flow of hydraulic oil is sent to the corresponding hydraulic actuator and the deflection of the joystick lever involves a proportional adjustment of the rotation speed of the prime mover from the aforementioned minimum limit up to a second predetermined speed value greater than the first, named as upper limit.

[0019] Both the lower limit and the upper limit are approximately fixed, although they can be changed manually via a human/machine interface.

[0020] In the second band of the joystick lever, an action on the accelerator lever causes a variation in the rotation speed of the prime mover up to the lower limit speed.

[0021] In the second band of the joystick lever, an action on the accelerator lever does not involve a variation in the rotation speed of the prime mover which is fixed at the lower limit speed, but involves a variation in the transmission ratio of the hydrostat allowing the operator to control the speed of the vehicle regardless of whether the prime mover is operated at constant speed.

[0022] In the third band of the joystick lever, an action on the accelerator lever does not lead to a variation in the rotation speed of the prime mover which instead depends exclusively on the deflection of the joystick lever, however if the accelerator lever is kept fixed and the deflection of the joystick lever varies in said third band, then the system proceeds to compensate the variations in speed of the prime mover with a different transmission ratio, so that the speed of the vehicle is not affected by the variation in speed of the prime mover.

[0023] In other words, the system automatically compensates for variations in the speed of the prime mover by ensuring that only the accelerator lever indicates the speed that the vehicle must assume.

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

Brief description of the figures

[0025] Further objects and advantages of the present invention will be clear from the following detailed description of an example of its implementation (and its variants) and from the attached drawings given purely for explanatory and non-limiting purposes, in which:

- Fig. 1 schematically shows a propulsion system for a work vehicle comprising a prime mover arranged to drive a hydraulic pump of a hydrostat in rotation;
- Fig. 2 shows an example of a joystick for controlling a work tool;
- Fig. 3 shows an electro-hydraulic circuit for the actuation of a vehicle work tool;
- Fig. 4 discloses a diagram of deflection intervals of the joystick lever of Fig. 2,
- Fig. 5 discloses a work vehicle according to the present invention.

[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", "higher", "lower" and the like may 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 characteristics illustrated in the different preferred embodiments, including the drawings, can be combined with each other without departing from the scope of protection of the present application as described below.

Detailed description

[0029] Fig. 1 shows a diagram of the propulsion system of a work or agricultural vehicle.

[0030] The propulsion system includes a prime mover E, generally an internal combustion engine, for example Diesel or spark ignited.

[0031] The prime mover is configured to drive a variable geometry hydraulic pump HP in rotation, which powers a hydraulic motor HM, for vehicular propulsion, via a forward or highpressure hydraulic line F and a return or low-pressure line R.

[0032] Preferably, the prime mover is connected to the vehicular wheels only through the hydrostat.

[0033] The hydraulic motor has a shaft operationally associated with a driving axle RA of the vehicle.

[0034] Preferably, this association is achieved by means of a discrete ratio gearbox GB. Generally, the secondary shaft of the gearbox GB rotates a port of a differential DF, to rotate the two axle shafts of the driving axle RA. The configuration shown in figure 1 is four-wheel drive, so there is a rear driving axle RA and a front driving axle FA. The configuration shown is itself known.

[0035] According to the present invention, the displacement of the hydraulic pump can be controlled independently of the rotation speed of the prime mover which drives the rotation of the hydraulic pump itself. More preferably, the hydraulic motor has variable displacement and can be controlled independently of the hydraulic pump by means of respective electro-hydraulic valves, not shown.

[0036] An engine control processing unit ECU controls the operation of the prime mover.

[0037] A UCM vehicle processing unit interfaces with the ECU engine control processing unit and controls the hydraulic transmission HY as well as monitors the position of levers, buttons and human/machine interface controls, both in relation to the movement of the vehicle and in relation to the operation of hydraulic tools, such as

an arm, a bucket and auxiliary parts connected to the vehicle.

[0038] LJK indicates, in Fig. 2, the control lever of a joystick JK for controlling a vehicle work tool, such as an arm. The buttons L1 - L3 and the roller RL can be programmed to perform certain functionality in relation to the current mission.

[0039] AP indicates, in Fig. 1, the accelerator pedal.

[0040] The existence of two distinct processing units is entirely optional. A single processing unit can control both the prime mover and all the other functions of the vehicle and monitor the activation of commands by the operator.

[0041] The present invention is preferably implemented in the vehicular processing unit UCM, but there is nothing to prevent it from being implemented in the ECU.

[0042] The speed ES of the engine can be measured in any way, for example by means of the so-called phonic wheel associated with the crankshaft (not shown).

[0043] In accelerator-bas mode, the throttle lever AP directly controls the rotational speed of the prime mover E. Furthermore, as the vehicle speed VS increases, the displacement of the hydraulic pump increases, while the displacement of the hydraulic motor reduces.

[0044] The inverse proportionality between the value of the displacement of the hydraulic pump and the value of the displacement of the hydraulic motor can be tabulated according to a pre-ordained strategy.

[0045] Fig. 3 shows an example of an electro-hydraulic circuit implemented in the vehicle covered by the present invention.

[0046] The prime mover E rotates the hydraulic pump P arranged to power at least one hydraulic actuator BM, BKT, AUX.

[0047] Fig. 5 shows a work vehicle CWL, for example a so-called "compact wheel loader".

[0048] This comprises an arm BM and a BKT bucket, wherein the arm has a first end hinged to a vehicular frame F and a second end, opposite to the first, arranged to rotatably support a bucket BKT.

[0049] The lifting of the arm is achieved via the actuator BM shown in Fig. 3, while a rotation of the bucket with respect to the arm is achieved via the actuator BKT. Additional actuators may be present in the vehicle electro-hydraulic circuit HC.

[0050] Each hydraulic actuator corresponds to an open center directional valve V1, V2, V3.

[0051] The open center direction valve, hereinafter simply referred to as the "valve", has the task of directing the hydraulic oil to the corresponding actuator or to the collection tank T.

[0052] When the valve is completely closed, which generally corresponds to the complete release of the joystick lever, the entire oil pumped by the hydraulic pump P is directed to the collection tank T. Conversely, when the valve is completely open, which generally corresponds to the complete deflection of the joystick lever, the entire hydraulic oil flow is sent to the actuator.

[0053] This operating mode is for convenience called "accelerator_base" mode, in which, that is, the rotation speed ES of the prime mover E is directly proportional to the deflection of the accelerator lever AP and in which the speed VS of the vehicle and the rotation speed of the prime mover are approximately directly proportional to each other. It is important to remember that the accelerator lever and the joystick lever are distinct and separate devices as well as independently operable by the human operator.

[0054] According to the present invention, a second operating mode is provided, named as "tool-base" for convenience, in which

+ in a first continuous interval R1 of deflection of the joystick lever LJK, the prime mover is operated at a predetermined approximately fixed rotation speed, and an opening of the valve V1 - V3 is proportional to the deflection of the joystick lever LJK,
+ in a second continuous interval R2 of the joystick lever LJK deflection, distinct and separate from the first deflection interval, the prime mover is operated at a rotational speed proportional to the joystick lever deflection LJK and the opening of the open center directional valve is fixed at a maximum opening value.

[0055] The fixed speed of the first interval R1 is for example 1400 rpm.

[0056] In any case it can be set manually by the operator via a human/machine interface, for example a touchscreen display.

[0057] Fig. 4 shows a diagram of the intervals R0, R1, R2 for operating the joystick lever in a predetermined direction.

[0058] It can be seen that the intervals R1 (T1, T2) and R2 (T2, TMax) are continuous and non-degenerate, meaning they are not empty.

[0059] Preferably, they are also contiguous to each other. The symbol TMax indicates the maximum deflection of the joystick lever, while T0 indicates the release position and therefore R0 (T0, T1).

[0060] In the "accelerator-bas" operating mode, the condition of maximum deflection of the joystick lever corresponds to the maximum opening of valve V1 - V3.

[0061] According to the " tool-base " operating mode, the valve has an approximately linear increasing trend in the R1 interval, while in the R2 interval, the valve is constantly open to its maximum value.

[0062] The trend in the R1 and R2 intervals can be for example:

- discontinuous: the valve opens linearly between T1 and T2, and then jumps to 100% of the opening in T2;
- continuous: the valve opens linearly between T1 and T3, where T3 is intermediate between T1 and T2, and then reaches the maximum in T2 value through another linear or non-linear trend, for example a

parabolic trend; however, the two trends are continuous with each other.

[0063] The selection of said first or second operating mode is achieved by means of a further human/machine interface device different from said accelerator lever and said joystick lever. It can be, for example, a button located on the dashboard or a virtual menu of the touchscreen instrument panel.

[0064] Advantageously, the interval R1 allows the operator to finely control the operated actuator, while the R2 interval allows reducing losses due to hydraulic oil lamination through the V1 - V3 valve.

[0065] In the range R2, the oil flow reaching the hydraulic actuator is controlled exclusively by varying the rotation speed of the prime mover. That is, indirect control of the hydraulic oil flow rate that reaches the actuator is obtained by controlling the rotation speed of the prime mover.

[0066] The range R0 is completely optional and represents the so-called dead band in which a deflection of the joystick lever does not cause anything. The deadband R0 is between a position of complete release of the joystick lever and the threshold T1. When indicating the release of the joystick lever, it can implicitly refer to the deadband, which is implemented in any application.

[0067] For example, T1 may be 5 - 10% of the maximum joystick lever deflection, while T2 may be 25% - 35% of the maximum deflection.

[0068] It is worth highlighting that the electrical signals generated by the joystick lever and the accelerator lever are sent to the UCM processing unit, which, in relation to the strategies implemented, controls the prime mover and the hydrostat HY, i.e. the displacement of the HP hydraulic pump and/or HM hydraulic motor.

[0069] In the second operating mode, when the joystick lever is in the first deflection range, the deflection of the accelerator lever impacts the rotation speed of the prime mover up to the lower speed limit of the prime mover, once this value is exceeded an action on the accelerator lever determines exclusively a variation of the hydrostat transmission ratio, without any influence on the rotation speed of the prime mover, as happens when the joystick lever is in the second deflection range.

[0070] Preferably, the vehicle object of the present invention has a series type propulsion system, i.e. in which the prime mover is connected to the wheels WH exclusively through the hydrostat.

[0071] Preferably, when the joystick lever is in the third deflection range, the processing unit is configured to compensate for changes in rotational speed of the prime mover controlled exclusively by the joystick lever, by controlling the displacement of the HP hydraulic pump. In this way, the speed of the vehicle is immune to variations in the rotation speed of the prime mover, apparently being exclusively a function of the deflection of the accelerator lever.

[0072] The present invention can advantageously be carried out by means of a computer program which includes coding means for carrying out one or more steps of the method, when this program is executed on a computer. It is therefore understood 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.

[0073] Constructive variations to the non-limiting example described are possible, without 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.

[0074] 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 of operating a hydraulic circuit (HC) of a work vehicle, including the work vehicle

- a hydraulic work tool (BM, BKT) and a joystick (JK) for controlling the hydraulic work tool,
- an internal combustion prime mover (E),
- a first hydraulic pump (HP), with variable displacement, defining a hydrostat (HY) arranged to drive at least one propulsion wheel (WH),
- a second hydraulic pump (P), with fixed displacement, arranged to supply the hydraulic circuit (HC), in which the hydraulic circuit includes at least one hydraulic actuator configured to move said work tool (BM, BKT) and at least one open center directional valve (V1) arranged to control a flow of hydraulic oil intended for said actuator,
- a joystick lever for controlling said at least one hydraulic actuator (LJK),

the first and second hydraulic pumps being stably connected to the prime mover to be driven in rotation by the prime mover (E),
the method includes

- a first operating mode, named as " accelerator-base ", in which a rotation speed (ES) of the prime mover (E) is directly proportional to a deflection of an accelerator lever (AP) and in which a speed (VS) of the vehicle and the rotation speed of the prime mover are approximately directly proportional to each other and
- a second operating mode, called " toolbase", in which

+ in a first continuous interval (T1, T2) of joystick lever deflection (LJK), the

prime mover is operated at a predetermined approximately fixed rotation speed, and an opening of the open-center directional valve is proportional to the deflection of the joystick lever (LJK),
+ in a second continuous interval (T2, TMax) of joystick lever deflection (LJK) distinct and separate from said first deflection interval, the prime mover is operated at a rotation speed proportional to said joystick lever deflection (LJK) and the opening of the open center directional valve is fixed at a maximum opening value.

2. The method of claim 1, wherein in said second operating mode, in said first deflection range, the deflection of the joystick is less than the deflection of said second deflection range.

3. The method of claim 1 or 2, wherein said first and second deflection intervals are contiguous.

4. A method according to any one of the preceding claims, wherein, in a third continuous range of deflection including a joystick lever release position, said open center directional valve (V1) is closed and the prime mover is operated at idle (low idle).

5. The method of claim 4, wherein said third interval is contiguous with said first deflection interval and wherein said first interval is intermediate between said third and second deflection intervals.

6. Method according to any one of the preceding claims, wherein, in said first joystick deflection interval (T1, T2) of said second operating mode, a deflection of the accelerator lever impacts exclusively on a vehicle speed.

7. The method of claim 6 wherein said throttle lever deflection controls a hydrostat gear ratio.

8. Method according to claim 6, wherein in said second joystick deflection interval (T2, TMax) of said second operating mode, said vehicle speed is an exclusive function of the position of the accelerator lever automatically compensating for any variation in the rotation speed of the prime mover.

9. The method according to any of the preceding claims 1-8, wherein said second throttle lever deflection interval is contiguous with said first throttle lever deflection interval.

10. Method according to any of the previous claims 1 - 9, wherein a selection of said first or second operating mode is achieved by means of a further human/machine interface device other than said accelerator lever and said joystick lever.

11. Processing unit (UCM) of a work vehicle comprising

- a hydraulic work tool (BM, BKT) and a joystick (JK) for controlling the hydraulic work tool,
- an internal combustion prime mover (E),
- a first hydraulic pump (HP), with variable displacement, defining a hydrostat (HY) arranged to drive at least one propulsion wheel (WH),
- a second hydraulic pump (P), with fixed displacement, arranged to supply the hydraulic circuit (HC), in which the hydraulic circuit includes at least one hydraulic actuator configured to move said work tool (AM, BK) and at least one directional valve open center (V1) arranged to control a flow of hydraulic oil intended for said actuator,
- a joystick lever for controlling said at least one hydraulic actuator (LJK),

the first and second hydraulic pumps being stably connected to the prime mover to be driven in rotation by the prime mover (E),
the processing unit being configured to receive as input a signal generated by an accelerator lever (AP) and implement

- a first operating mode, named as " accelerator-base ", in which it controls the rotation speed (ES) of the prime mover (E) in a manner directly proportional to a deflection of the accelerator lever (AP), so that a speed (VS) of the vehicle and the rotation speed of the prime mover are approximately directly proportional to each other and
- a second operating mode, named as "toolbase", in which

+ in a first continuous range of joystick lever deflection (LJK), the processing unit is configured to operate the prime mover at a predetermined approximately fixed rotational speed, and control an opening of the open-center directional valve proportionally to joystick lever deflection (LJK),
+ in a second continuous joystick lever deflection interval (LJK) distinct and separate from said first deflection interval, the processing unit is configured to operate the prime mover at a rotational speed proportional to said joystick lever deflection (LJK) and to force the opening of the open center directional valve to a maximum opening value.

12. A computer program comprising instructions for causing the processing unit of claim 11 to implement the method model of claim 1.

13. A computer readable medium having stored the program of claim 12.

14. Work vehicle incuding

- a hydraulic work tool (BM, BKT),
- an internal combustion prime mover (E),
- a first hydraulic pump (HP), with variable displacement, defining a hydrostat (HY) arranged to drive at least one propulsion wheel (WH),
- a second hydraulic pump (P), with fixed displacement, arranged to supply the hydraulic circuit (HC), in which the hydraulic circuit includes at least one hydraulic actuator configured to move said work tool (AM, BK) and at least one directional valve open center (V1) arranged to control a flow of hydraulic oil intended for said actuator,
- a joystick lever for controlling said at least one hydraulic actuator (LJK),

the first and second hydraulic pumps being stably connected to the prime mover to be driven in rotation by the prime mover (E),

- a processing unit (UCM) according to claim 11.

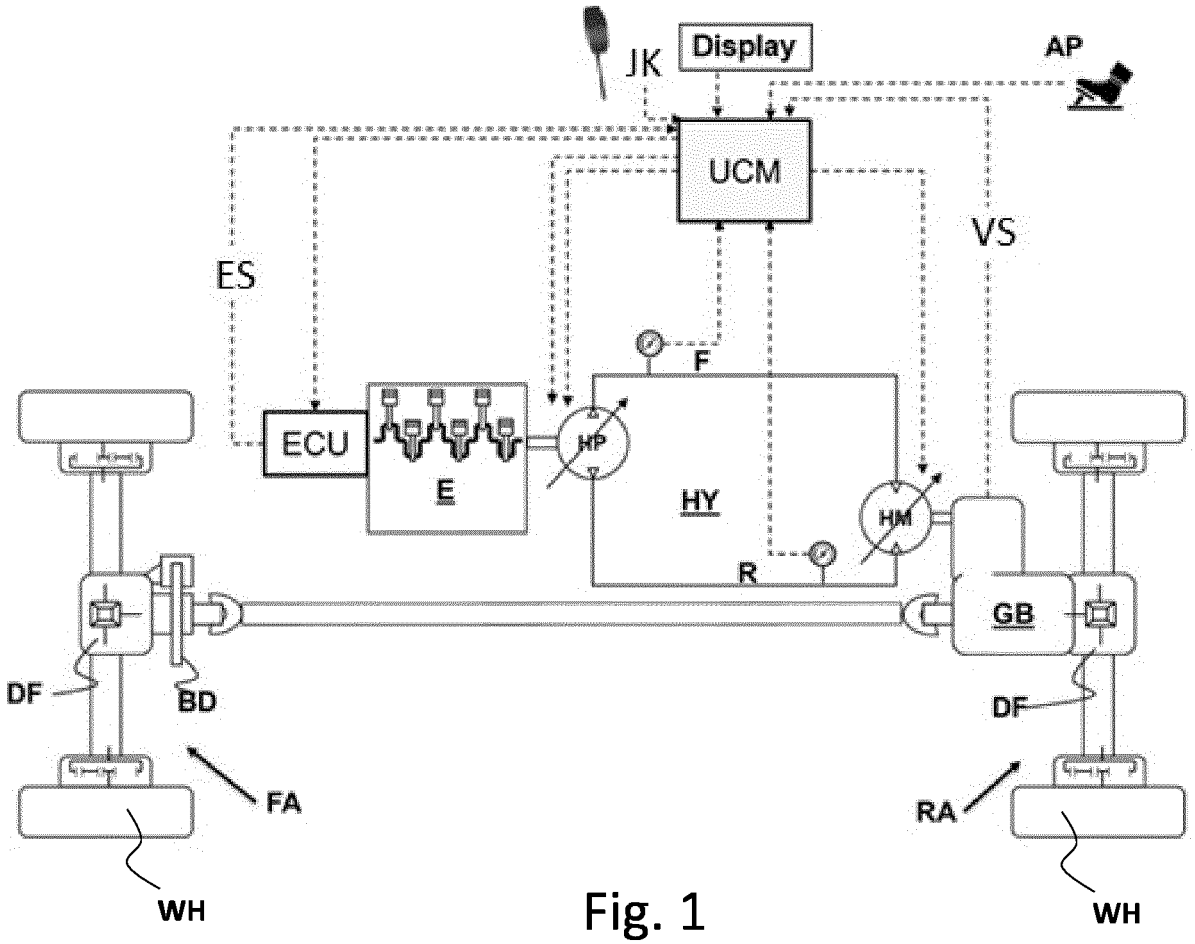

Fig. 1

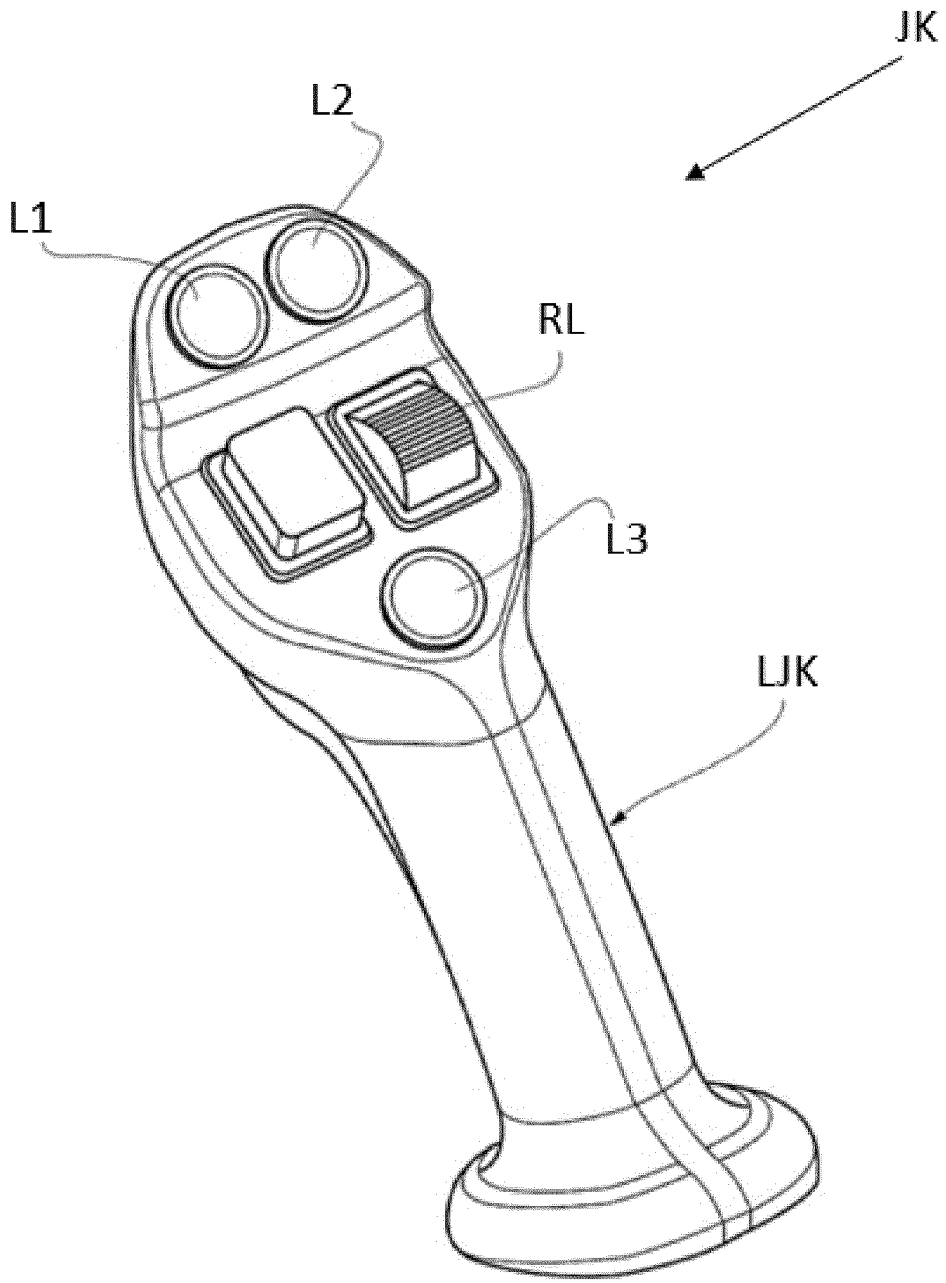

Fig. 2

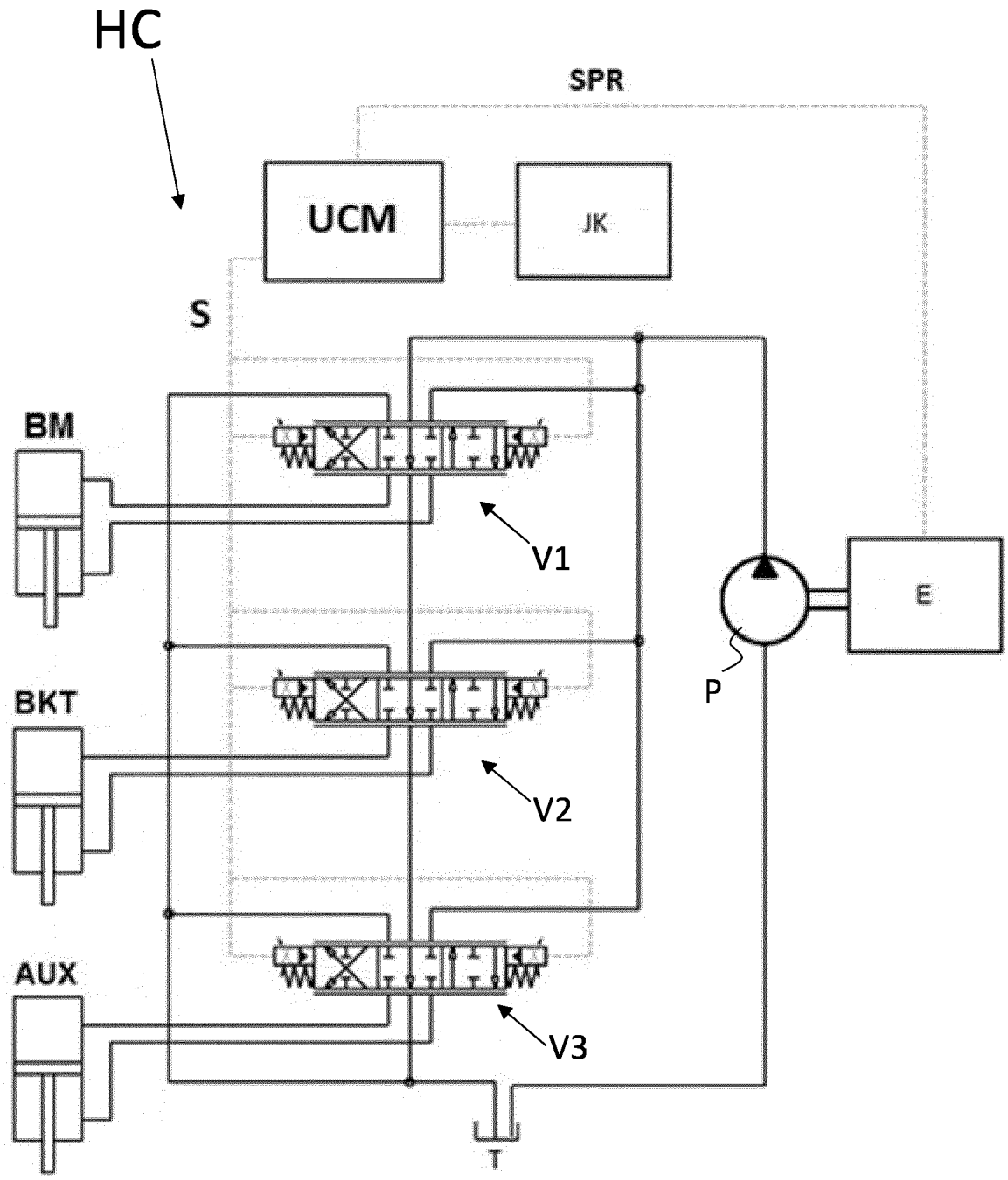

Fig. 3

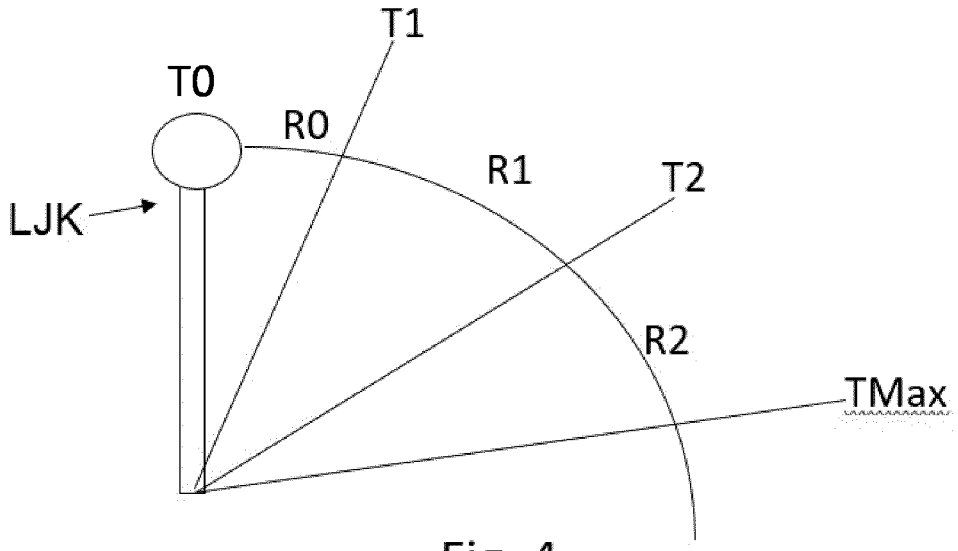

Fig. 4

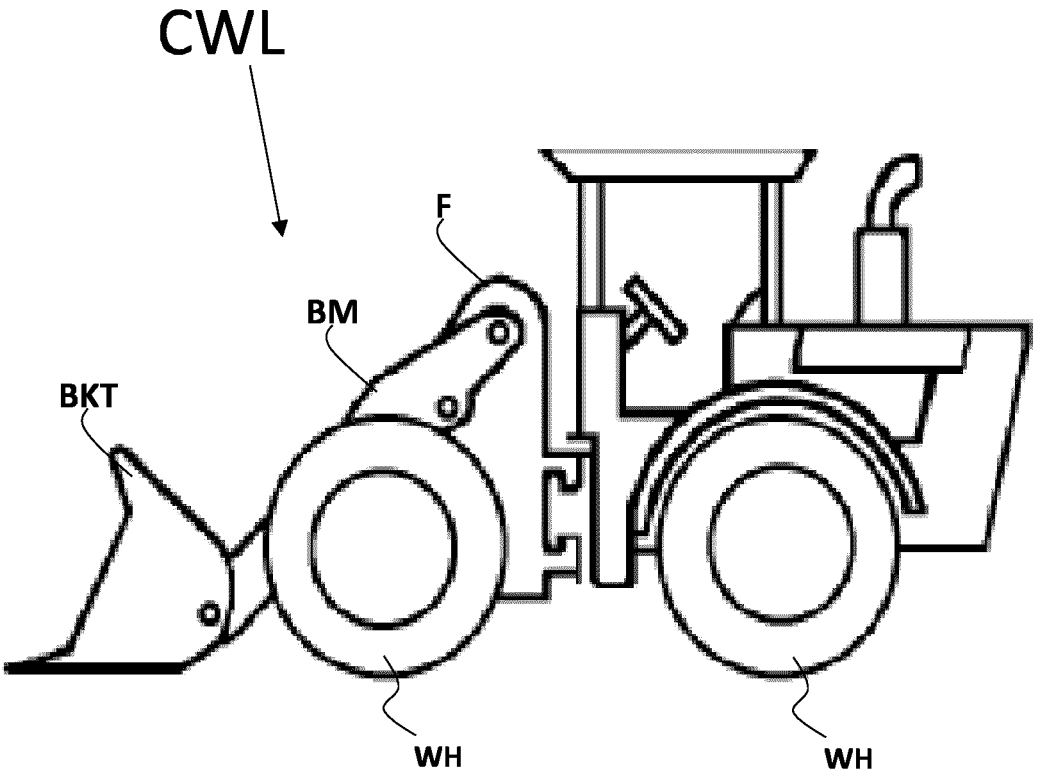

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 24 22 0531

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 3 660 226 A1 (HITACHI CONSTRUCTION MACH CO [JP]) 3 June 2020 (2020-06-03) * paragraphs [0027], [0032], [0047] - [0054]; figures 1,4 * -----	1-14	INV. E02F9/22
			TECHNICAL FIELDS SEARCHED (IPC) E02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 April 2025	Dreyer, Christoph

CATEGORY OF CITED DOCUMENTS

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