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(72) Inventors:
• **GARRAMONE, Adriano**
73100 Lecce (IT)
• **GRAVILI, Andrea**
73100 Lecce (IT)
• **LIBERTI, Stefano**
73100 Lecce (IT)

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(74) Representative: **CNH Industrial IP Department**
Leon Claeyssstraat 3A
8210 Zedelgem (BE)

(71) Applicant: **CNH Industrial Italia S.p.A.**
10156 Torino (IT)

(54) **METHOD AND CONTROL SYSTEM OF A HYDRAULIC CIRCUIT OF A WORK VEHICLE**

(57) Control system of a hydraulic circuit (HB) of a work vehicle (CWL), the hydraulic circuit comprising a hydraulic pump (P) and an electric motor (M) operatively connected to the hydraulic pump to drive it in rotation, two or more actuators hydraulic (BOOM, BUCKET,...) and corresponding two or more directional valves (V1, V2,...) with open center and corresponding two or more control levers (JOYSTICK) and a processing unit (CONTROL UNIT). The processing unit is configured to set a

rotation speed of the electric motor proportional to a sum of the deflections of the two or more control levers, and to calculate, for each of said two or more directional valves (V1, V2, ...) , an opening value of the valve according to a function of the value of the corresponding deflection and the values of the deflections of the remaining one or more control levers, and subsequently to set said calculated opening value.

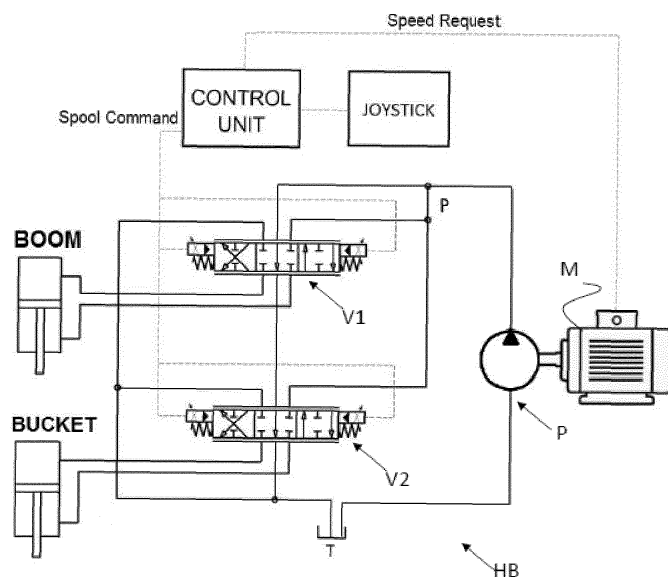


Fig.3

Description**Field of the invention**

5 **[0001]** The present invention relates to the field of methods and control systems for hydraulic circuits of work vehicles and in particular of electrified work vehicles, in which the hydraulic circuit is powered exclusively by an electro-pump.

State of the art

10 **[0002]** In the field of work and agricultural vehicles, the organs or 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. However, the progressive technological development of battery power systems makes it possible to design work vehicles with electric propulsion and/or with a hydraulic system powered by an electric motor that drives a hydraulic pump in rotation, such as an actuation hydraulic circuit for at least one hydraulic actuator enslaved to the movement of a hydraulic work member.

15 **[0004]** By "work hydraulic member" it is meant one of those components such as arms, buckets, etc .. distinct and separate from those inherent to the propulsion of the work vehicle, such as for example transmissions, braking systems, etc. Hereinafter, for convenience, reference is made to a "hydraulic member" meaning a "work hydraulic member".

20 **[0005]** In work machines, the most well known and implemented members are the arms equipped with bucket or forks or other devices.

[0006] The lifting and lowering of the arm, as well as the opening and closing of the bucket or forks, are carried out using at least one double-acting linear hydraulic actuator. It includes a pair of opposing chambers that are filled and emptied alternately to raise or lower the arm.

25 **[0007]** There are different types of valves for controlling hydraulic actuators. The most implemented are the open center directional valves. 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 and remaining flow, is sent to a collecting tank, from where the hydraulic pump draws on the the hydraulic oil to recirculate it.

30 **[0008]** In particular, when the spool is in the rest (or released) position, all the pumped flow from the pump 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.

[0009] The position of the movable spool is generally controlled by the operator using a joystick placed in the vehicle's cockpit.

35 **[0010]** The electrical signal generated by the joystick is acquired by a processing unit, which processes it to proportionally control the directional control valve. In other words, the greater the deflection of the control lever, the greater the oil sent to the corresponding hydraulic actuator. The directional control valve is evidently of the electro-hydraulic type.

[0011] When two or more hydraulic members are activated simultaneously, the flow of oil generated by the hydraulic pump is divided between the corresponding two or more actuators and the recovery tank. In addition, the oil flow, with the same opening of the mobile spool, will be greater towards the actuator which has the lowest hydraulic load.

40 **[0012]** In electrified vehicles, the rotation speed of the electric motor enslaved to the hydraulic circuit for supplying the work members can be controlled independently from other subsystems. In fact, while, in vehicles equipped with an internal combustion engine, the rotation speed of the hydraulic pumps depends on the rotation speed of the internal combustion engine, in electrified vehicles this dependency is lacking.

45 **[0013]** The present applicant, in a non-disclosed prototype, has implemented a control strategy of the electric motor, according to which the rotation speed is controlled so as to be proportional to the sum of the deflections of the control levers of the different hydraulic actuators. However, the behavior of the hydraulic members was found to be different from that expected and sometimes difficult to control. However, the fact of controlling the rotation speed of the electric motor proportionally to the activation of the hydraulic members is essential to minimize the consumption of electricity in order to extend the activity time of the electrified work vehicle.

50 **[0014]** It is evident that it is indifferent to talk about the sum of the deflections, obviously calculated with respect to a release position of the same levers, or to talk about the opening degree of the corresponding valves or the degree of activation of the same hydraulic organs.

[0015] 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

55 **[0016]** The purpose of the present invention is to improve the responsiveness of the working parts. In particular, when

the control of the electric motor that drives the hydraulic pump that feeds the control circuit of the work members is proportional to the sum of the deflections of the control levers of the hydraulic members.

[0017] The basic idea of the present invention is to generate a hydraulic flow proportional to the sum of the control signals generated by the control levers that can be operated by the operator, to calculate a nominal opening degree of each directional valve as a function of the corresponding control signal generated by the corresponding control lever and to correct the opening control signal of each control valve according to a valve opening reduction table, which takes into account the simultaneous activation of all the directional valves of the hydraulic circuit.

[0018] Thanks to this limitation table, there is such a behaviour that the behaviour of the hydraulic members is the desired one.

Brief description of the figures

[0019] 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 by way of non-limiting explanation, in which:

Figure 1 shows a work machine and in particular a mechanical shovel comprising two or more hydraulic work members;

Figure 2 shows a control diagram of the rotation speed of the electric pump, which feeds the hydraulic circuit of the work machine in figure 1, as a function of the deflection of a single control lever of a hydraulic actuator;

Figure 3 shows an example of a hydraulic control circuit of two hydraulic actuators enslaved to the control of an arm of the work machine of Figure 1;

Figure 4 shows a control flow diagram of two hydraulic members activated at the same time.

[0020] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0021] 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.

[0022] 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 examples of realization

[0023] Figure 1 shows an example of a work machine CWL equipped with hydraulic work members B, TO and in particular an arm B and a bucket TO.

[0024] The arm is operated by a per se known double action hydraulic actuator A1.

[0025] The bucket is operated by a per se known double action hydraulic actuator A2.

[0026] Both actuators are powered by the same hydraulic circuit HB, see figure 3, equipped with a hydraulic pump P operatively connected to an electric motor M to be driven in rotation exclusively by it.

[0027] The electric motor is powered by a source of electrical energy.

[0028] Figure 2 shows a diagram that relates to a deflection of the "Joystick Axis" control lever of one of the actuators and the rotation speed of the "Motor Speed" electric motor, when only one actuator is activated at a time.

[0029] It is noted that the trend is linear with an intersection with the abscissa axis as a so-called guard band is expected, within which the deflection of the control lever is neglected.

[0030] Furthermore, when only one actuator is activated, the opening degree of the relative directional valve follows another control strategy, for example, it can be decided to leads to the maximum opening degree, by adjusting the oil flow on the basis of the electric motor control.

[0031] The control lever is indicated in figure 3 as "JOYSTICK".

[0032] A joystick is generally used to control the arm and the bucket as it can be operated along two mutually perpendicular axes.

[0033] In the following, reference will be made to a "control lever" or "command lever", bearing in mind that the man-machine interfaces for the control of hydraulic work components can have any nature and shape.

[0034] According to a first aspect of the present invention, the rotation speed of the electric motor is equal to the sum of the speeds, each calculated as a function of the deflection of the corresponding control lever available to the operator.

[0035] Since the joystick lever can be tilted in two directions perpendicular to each other, it is suitable for controlling the arm in a first Y direction and the bucket in a second X direction perpendicular to the first.

[0036] With reference to Figure 3, it can be seen that each BOOM and BUCKET actuator is powered by means of an open center directional solenoid valve V1 and V2, respectively.

[0037] As described above, when the movable spool of each valve is in the adjustment position, a first portion of the flow is sent to the actuator, while a second portion is sent to the recovery tank T, from which the hydraulic pump P draws. According to the present invention, the processing unit CONTROL UNIT is arranged to acquire the signals, generated by the control levers, representative of the relative deflections and to control the electric motor M which drives the hydraulic pump P in rotation and to control the degree or, equivalently, the position of the movable spool inside each directional valve.

[0038] According to the acquired signals, the processing unit generates the control signals of the valves V1 and V2 and the control signal of the electric motor M.

[0039] According to the present invention, when the processing unit detects that two or more control levers are controlled simultaneously, it performs the following steps:

- Controlling of the electric motor so as to reach a rotation speed proportional to the sum of the deflection values of the two or more control levers,
- Calculation of a degree of opening of each directional valve proportional to the deflection of the corresponding control lever,
- Reduction of the opening degree of each valve according to the deflection value of all the control levers.

[0040] The following table shows an example of application of the reduction in the degree of opening of the valves which respectively supply the two actuators BOOM and BUCKET which control respectively the position of the arm B with respect to the vehicle frame and of the bucket TO with respect to the arm.

	0	20	40	60	80	100	Boom Command % Lowering (Y>0)
0	0	0	0	0	0	0	Boom Command Derating* %
20	0	50	58	62	63	64	
40	0	50	58	62	63	64	
60	0	50	58	62	63	64	
80	0	50	58	62	63	64	
100	0	50	58	62	63	64	
Bucket Command % Rollback (x>0)	* Load on Bucket Rollback > Load on Boom Lowering						

[0041] The first line indicates a percentage deflection value "Boom Command%" with respect to the maximum deflection of the control lever in the direction Y > 0 which controls the "Lowering" of boom B: 0, 20, 40, 60, 80, 100 %.

[0042] The first column indicates a percentage value of deflection "Bucket Command%" with respect to the maximum deflection of the control lever in the direction X > 0 which controls the "Rollback" recall of the bucket TO: 0, 20, 40, 60, 80, 100%. Since the hydraulic load to recall the "Load on Bucket Rollback" is greater than the hydraulic load to lower the "Load on Boom Lowering" arm, when these two movements are activated at the same time, only the degree of opening of the valve V1 which supplies the "lowering of the boom" to a percentage value "Boom Command Derating%" such as to have about the same hydraulic load on the lowering of the boom compared to the rollback of the bucket.

[0043] The hydraulic load, as known, is the pressure perceived by each valve immediately upstream of the relative movable spool. In which "upstream" takes into account the direction of circulation of the hydraulic oil.

[0044] For example, when the nominal signal for controlling the lowering of the arm is equal to 60% of the maximum signal, then there is an attenuation of this signal equal to 62%, so that the signal actually used to control the relative valve V1 is equal to $60\% \times 0.62 = 37.2\%$ for each value of the nominal bucket rollback control signal (20, 40, 60, 80, 100%) .

[0045] In other words, the opening degree of the valve V1 is reduced by 62% from the nominal opening degree when the control lever of the valve V2 is activated to rollback the bucket, regardless of its deflection degree.

[0046] Therefore, thanks to the present invention it is possible not only to compensate the increase in flow rate due to the summative control of the rotation speed of the electric motor but it is also possible to differentiate the response of the individual actuators when two or more of them are activated simultaneously so that the relative behaviour remains similar to the case in which they are activated individually.

[0047] Each hydraulic component can move in two opposite directions, for example the arm can raise Y < 0 and lower Y > 0, while the bucket can be retracted X > 0, i.e. rotate backwards (load or rollback), or can be overturned X < 0, or rotate forward (discharge).

[0048] Four combinations are therefore identified. For each of these combinations, a table for reducing the degree of opening of the directional valves can be provided.

[0049] It is worth highlighting that the present invention can also be applied to solutions, which provide for the concomitant activation of three or more hydraulic actuators. It is clear that in this case, the reduction table has a dimensionality equal to the number of hydraulic actuators.

[0050] According to the present invention, the processing unit is configured to perform the following steps in succession:

- (Step i) Acquisition of an electrical signal representative of a deflection of each of said two or more control levers, and then
- (Step ii) Calculation of a rotation speed of the electric motor proportional to a sum of the deflections of the two or more control levers, and
- (Step iii) calculation, for each of said two or more directional valves (V1, V2), of a valve opening value as a function of
 - + a value of the corresponding deflection and
 - + values of the deflections of the remaining one or more control levers, in order to obtain a common hydraulic load on all active valves, and subsequently
- (Step iv) setting of said calculated opening value.

[0051] While it is clear that the first acquisition step must precede all the other steps, the setting of the rotation speed of the electric motor, step ii, can be simultaneous to the setting of the outflow section of the directional valves, step iv.

[0052] In other words, step ii and steps iii and iv can be performed in parallel by means of two parallel "tasks".

[0053] 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.

[0054] 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. Control system of a hydraulic circuit (HB) of a work vehicle (CWL), including the hydraulic circuit

- a hydraulic pump (P) and an electric motor (M) operatively connected to the hydraulic pump to drive it in rotation,
- two or more hydraulic actuators (BOOM, BUCKET,...) and corresponding
- two or more open center directional valves (V1, V2,...) and corresponding
- two or more control levers (JOYSTICK) of the hydraulic actuators
- a processing unit (CONTROL UNIT) operationally connected with

. the two or more control levers to acquire a relating signal representative of a deflection of the two or more control levers,

. the two or more directional valves (V1, V2, ...)

. the electric motor (M),

the processing unit being configured to set a rotation speed of the electric motor proportional to a sum of the deflections of the two or more control levers, and to calculate, for each of said two or more directional valves (V1, V2, ...), a valve opening value is a function of

- a value of the corresponding deflection and
- values of the deflections of the remaining one or more control levers, and subsequently to set said calculated opening value, to obtain circa a common hydraulic load on the two or more active valves.

2. System according to claim 1, wherein said opening value of each valve as a function of the deflection value of the corresponding control lever is a linear function of the deflection value.

3. System according to claim 1 or 2, wherein said opening function comprises a look up table arranged to reduce the opening value of each valve as a function of the opening value of the remaining valves so as to obtain a diversified

reduction of the opening of each valve to obtain said circa common hydraulic load on all active valves.

4. Work vehicle (CWL) including a hydraulic circuit for the actuation of two or more hydraulic parts (B, TO, ...), the circuit comprising

- a hydraulic pump (P) and an electric motor (M) operatively connected to the hydraulic pump to drive it in rotation,
- two or more hydraulic actuators (BOOM, BUCKET, ...) and corresponding,
- two or more open center directional valves (V1, V2, ...) and corresponding,
- two or more control levers (JOYSTICK) of the hydraulic actuators,
- a processing unit (CONTROL UNIT) operationally connected with

- . the two or more control levers to acquire a relating signal representative of a deflection of the two or more control levers,

- . the two or more directional valves (V1, V2, ...)

- . the electric motor (M),

wherein the processing unit is configured in accordance with the control system according to any one of claims 1 to 3.

5. Control method of a hydraulic circuit (HB) of a work vehicle (CWL), the hydraulic circuit comprising

- a hydraulic pump (P) and an electric motor (M) operatively connected to the hydraulic pump to drive it in rotation,
- two or more hydraulic actuators (BOOM, BUCKET,...) and corresponding
- two or more open center directional valves (V1, V2,...) and corresponding
- two or more control levers (JOYSTICK) of the hydraulic actuators
- a processing unit (CONTROL UNIT) operationally connected with

- . the two or more control levers to acquire a relative signal representative of a deflection of the two or more control levers,

- . the two or more directional valves (V1, V2, ...)

- . the electric motor (M);

said method including

- (Step i) Acquisition of an electrical signal representative of a deflection of each of said two or more control levers, and then

- (Step ii) Calculation of a rotation speed of the electric motor proportional to a sum of the deflections of the two or more control levers, and

- (Step iii) calculation, for each of said two or more directional valves (V1, V2, ...), of a valve opening value as a function of

- + a value of the corresponding deflection and

- + values of the deflections of the remaining one or more control levers, and subsequently to obtain a circa common hydraulic load on the two or more active valves,

- (Step iv) setting of said calculated opening value.

6. Computer program comprising program coding means suitable for carrying out all steps (i - iv) of claim 5, when said program is run on a processing unit of a control system according to claim 1.

7. Computer readable means comprising a recorded program, said computer readable means comprising program coding means adapted to perform all steps (i - iv) of claim 5, when said program is run on a processing unit of a control system according to claim 1.

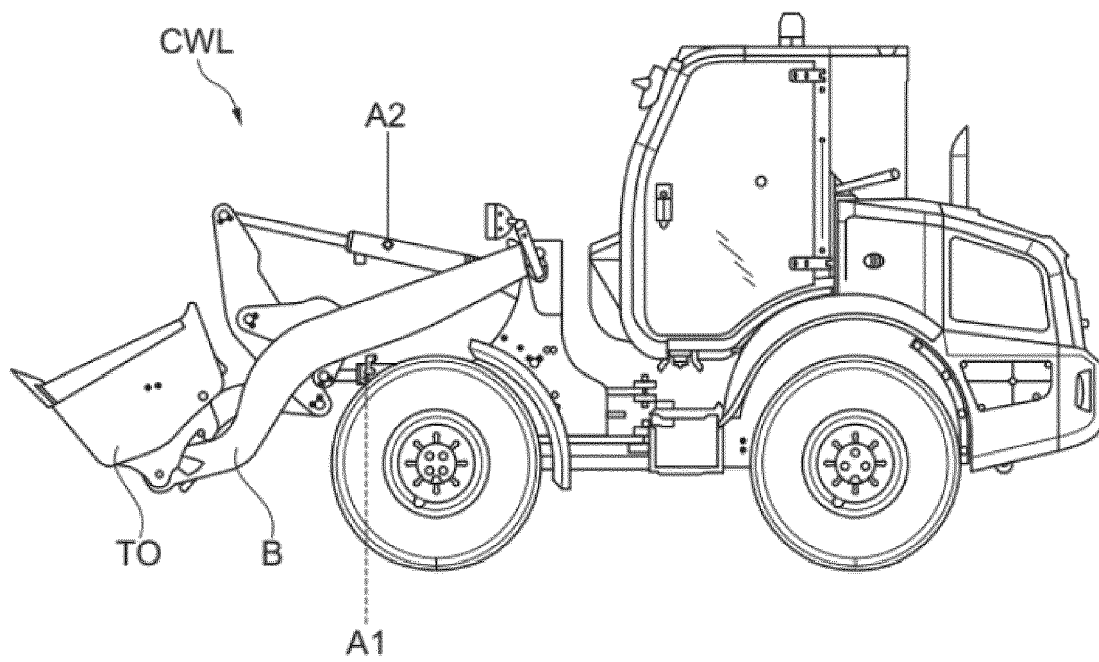


Fig. 1

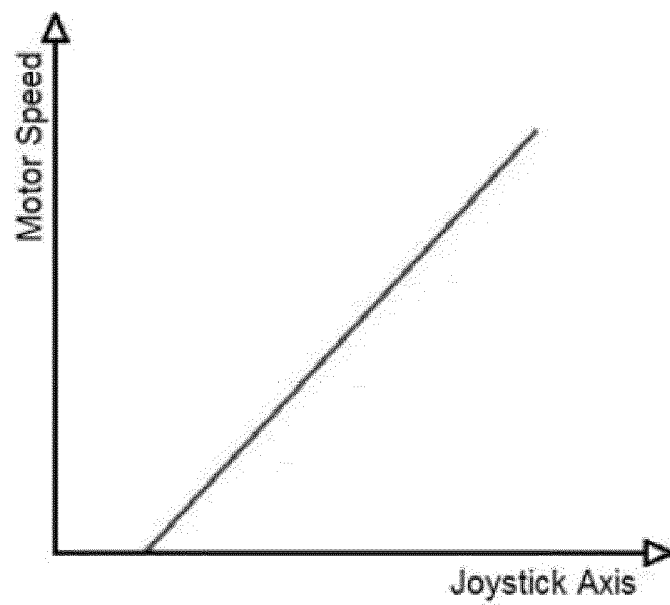


Fig.2

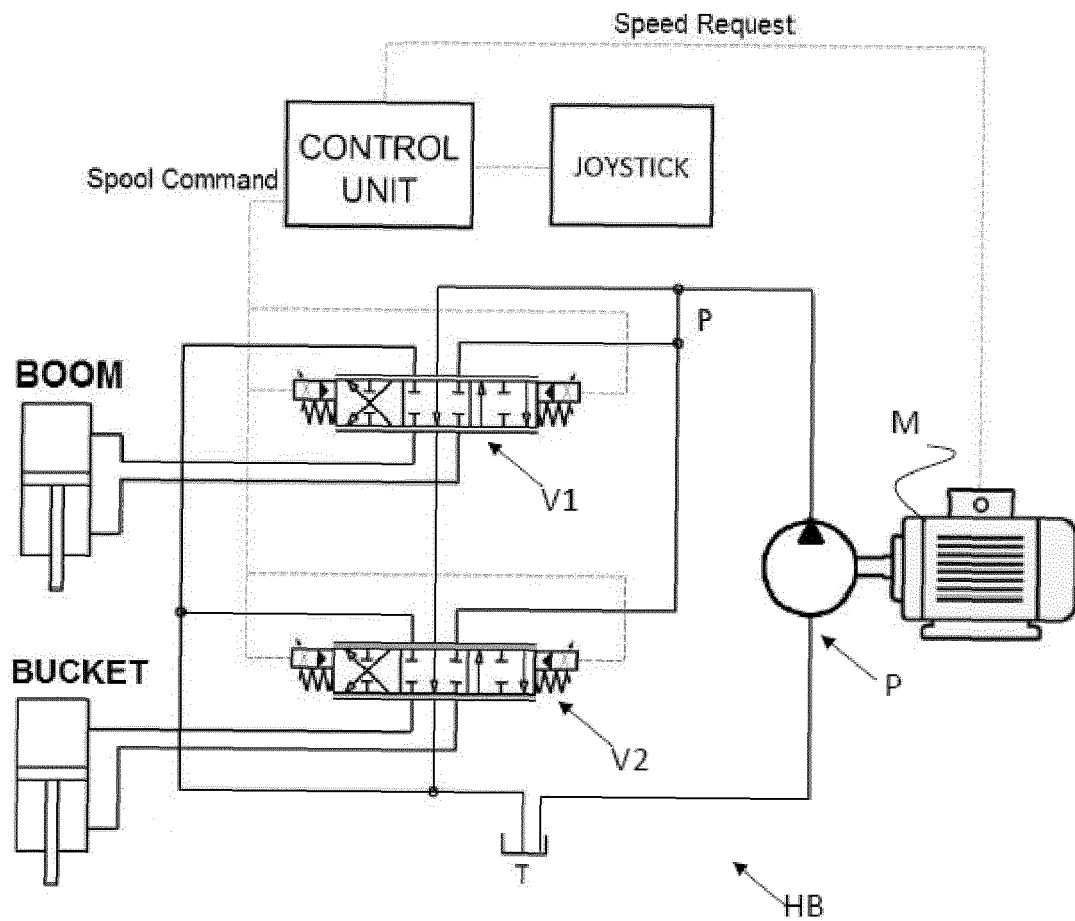


Fig.3

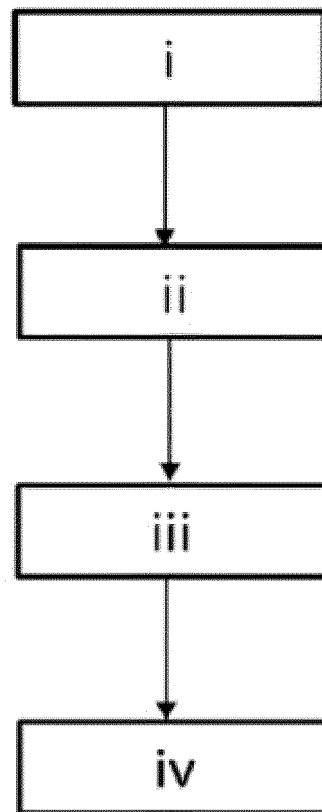


Fig.4



EUROPEAN SEARCH REPORT

Application Number

EP 22 21 0368

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EPO FORM 1503 03:82 (P04C01)

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 1 455 439 A1 (KOBELCO CONSTR MACHINERY LTD [JP]) 8 September 2004 (2004-09-08) * paragraph [0024] - paragraph [0029]; figures 2,3 *	1-7	INV. E02F9/22 E02F9/20
A	EP 1 291 467 A1 (KOBELCO CONSTR MACHINERY LTD [JP]) 12 March 2003 (2003-03-12) * paragraph [0026] - paragraph [0038]; figures 2,4 *	1-7	
A	EP 3 849 047 A1 (HITACHI CONSTRUCTION MACHINERY TIERRA CO LTD [JP]) 14 July 2021 (2021-07-14) * paragraph [0031] - paragraph [0042]; figure 3 *	1-7	
A	US 5 560 387 A (DEVIER LONNIE J [US] ET AL) 1 October 1996 (1996-10-01) * column 2, line 19 - column 3, line 6; figure 1 *	1-7	
			TECHNICAL FIELDS SEARCHED (IPC)
			E02F F15B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 20 March 2023	Examiner Clarke, Alister
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EP 22 21 0368

5

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1455439 A1	08-09-2004	EP 1455439 A1	08-09-2004
		JP 3969068 B2	29-08-2007
		JP 2003155760 A	30-05-2003
		US 2005001567 A1	06-01-2005
		WO 03044940 A1	30-05-2003
EP 1291467 A1	12-03-2003	AT 455907 T	15-02-2010
		AT 495312 T	15-01-2011
		EP 1291467 A1	12-03-2003
		EP 1995385 A2	26-11-2008
		KR 20030036186 A	09-05-2003
		US 2003132729 A1	17-07-2003
		WO 0190490 A1	29-11-2001
EP 3849047 A1	14-07-2021	CN 111869040 A	30-10-2020
		EP 3849047 A1	14-07-2021
		JP 6944426 B2	06-10-2021
		JP 2020039239 A	12-03-2020
		KR 20200106548 A	14-09-2020
		US 2021025132 A1	28-01-2021
		WO 2020049805 A1	12-03-2020
US 5560387 A	01-10-1996	CA 2179818 A1	13-06-1996
		CN 1139978 A	08-01-1997
		DE 19581494 T1	27-02-1997
		JP H09509243 A	16-09-1997
		US 5560387 A	01-10-1996
		WO 9618042 A1	13-06-1996