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(54) **METHOD AND CONTROL SYSTEM OF AN ACTUATOR OF AN ARM OF AN AGRICULTURAL OR WORK VEHICLE**

(57) Control method of an actuator of an arm of an agricultural or work vehicle subject to a load, in which the arm (B) comprises at least one element (AR, TL) directly or indirectly hinged to a vehicle frame (F) and a double action actuator (A1, A2) comprising a lifting chamber (CH1) and a lowering chamber (CH2) opposite the lifting chamber and a directional valve (V1, V2), the method comprising a first step (ST1) of calculate a flow value of hydraulic oil directed to the lowering chamber (CH2) from

the directional valve and a corresponding first flow value (F1) of hydraulic oil destined to be discharged from the lifting chamber (CH1), a second step (ST2) of detecting a second flow value (F2) of hydraulic oil actually discharged from the lifting chamber due to the load and a third step (ST3) of adjusting the directional valve (V1, V2) so as to force said second value to equate the first flow value, when the second value exceeds the first (CK = Yes).

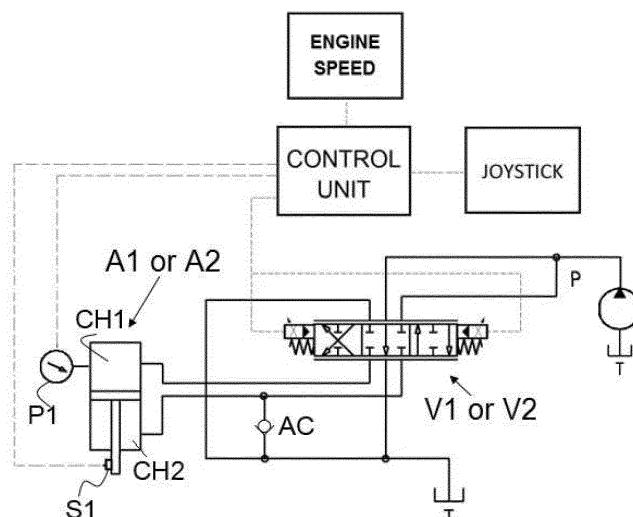


Fig. 2

Description

Field of the invention

[0001] The present invention relates to the field of control methods and systems for an actuator of an arm of an agricultural or work vehicle.

State of the art

[0002] The problem of dragged or uncontrolled load is known in the context of hydraulic circuits with control valve.

[0003] The actuator normally implemented is of the double-acting type, ie it includes two opposing chambers:

- a first chamber, called lifting chamber, fed by a source of hydraulic oil to cause the lifting of an arm, e
- a second lowering chamber, opposite to the first, fed by the source of hydraulic oil to cause the lowering of the boom.

[0004] When one of the chambers is powered by the hydraulic oil source, the other is connected to a hydraulic oil recovery tank, where the hydraulic oil is collected.

[0005] The problem of the dragged load is a condition in which a double-acting hydraulic actuator, during the lowering of the arm, sees the chamber responsible for lifting the arm, discharging more oil than the oil filling the chamber responsible for lowering the arm.

[0006] In these conditions, therefore, the phenomenon of cavitation occurs with damage for the hydraulic circuit and danger to things and people due to a sudden lowering of the arm.

[0007] In the absence of any system for limiting the effects of uncontrolled load, the operator controlling the arm can only act on the lever that controls the arm, trying to limit the effects of the dragged load, obtaining sudden stops and restarts of the arm, which can represent a danger to the vehicle itself and the vehicle operator.

[0008] As soon as the control lever of the arm returns to command its lowering, the aforementioned sudden phenomenon occurs again until the end of the stroke of the arm.

[0009] The known technique has solved this problem by means of the so-called "Counterbalance" or "Over-center" valves.

[0010] Examples of such solutions are given in WO2013081213A1 US2003141132A1.

[0011] These solutions both have a control valve arranged to simultaneously control both chambers of a double-acting hydraulic actuator according to at least three configurations:

- Lifting: in which the lifting chamber fills with hydraulic oil, while the lowering chamber discharges its content into a recovery tank;
- Lowering: in which the lowering chamber fills with

hydraulic oil, while the lifting chamber discharges its content into the recovery tank;

- stop position, in which both the lifting and lowering chambers are closed and disconnected by the oil source.

[0012] The oil filling is carried out by means of a hydraulic pump driven in rotation by a prime mover, generally of the internal combustion type.

[0013] A throttle valve prevents a flow of hydraulic oil greater than that required by the control valve and which would cause a lowering with a speed greater than that required and cavitation in the lowering chamber.

[0014] These valves have been widely used but represent a cost and a complication of the hydraulic circuit. However, they are the reference standard in the hydraulic control circuits of articulated arms of agricultural and work vehicles.

[0015] In modern vehicles, the arm control lever generates a first electrical signal, which is processed by a processing unit. The latter generates a second control signal, which controls the spool of the electro-hydraulic directional control valve, in proportion to the first electrical signal.

[0016] If not specifically excluded in the detailed description below, what is described in this chapter is to be considered as an integral part of the detailed description.

Summary of the invention

[0017] The purpose of the present invention is to identify an at least alternative solution with respect to the use of a valve to limit the flow of oil.

[0018] The basic idea of the present invention is to consider that there is a proportion between the oil entering one chamber and the oil that is discharged from the other chamber of the same double-acting actuator.

[0019] Downstream of this observation, the idea is to exploit the presence of a control unit to manipulate the signal generated by the actuator control lever, in order to limit the second control signal, so that, during the arm lowering, the oil flow actually discharged into the recovery tank from the actuator lifting chamber is never greater than the corresponding proportional oil flow entering the lowering chamber.

[0020] The limitation of the control signal of the directional control valve of the actuator implies that the relative movable spool progressively throttles the ports of the lowering chamber and simultaneously of the lifting chamber, moving towards the stop condition.

[0021] In other words, depending on the signal generated by the actuator control lever, the control signal actually sent to the directional control valve is limited taking into account the effect of the uncontrolled load, without implementing any valve to limit the flow discharged from the actuator lift chamber.

[0022] Advantageously, the present strategy does not require the use of auxiliary valves such as overcenter or

counterbalance valves of the known art.

[0023] This guarantees a lowering speed never greater than that required and that the phenomenon of cavitation in the lowering chamber is avoided.

[0024] The flow generated by the hydraulic pump is a function of the rotation speed of the prime mover, which drives the hydraulic pump into rotation. While the flow of oil sent to the lowering chamber depends on the flow generated by the pump and the position of the spool of the actuator directional control valve.

[0025] The directional control valve simultaneously controls the oil sent to the lowering chamber and the flow of the oil discharged from the lifting chamber into the recovery tank, therefore, the position of the movable spool of the valve is controlled in such a way as to ensure, independently of the first signal generated by the arm control lever, that the flow of oil discharged from the lifting chamber is never greater than the proportional flow of oil reaching the lowering chamber.

[0026] In other words, the directional valve is adjusted so that the oil that flows from an actuator never exceeds the oil discharged by the actuator when it is under "not dragged" load conditions.

[0027] According to a preferred variant of the invention, between the recovery tank and the port of the lowering chamber there is a check valve arranged so as to allow a flow of oil from the recovery tank to the lowering chamber.

[0028] This fact is very useful, because when the opening limitation of the directional control valve intervenes, the lacking oil sent to the lowering chamber is compensated by the oil flowing through the check valve, avoiding cavitation of the lowering chamber.

[0029] Indeed, it should be borne in mind that the control is "tracking" control, in the sense that the limitation intervenes as soon as there is an excessive discharge of oil from the lifting chamber, and therefore, even a minimal lack of oil in the lowering chamber is immediately compensated by means of the check valve.

[0030] According to a first preferred variant of the invention, the flow of oil discharged is "detected", in dynamic conditions of the arm, by means of a position sensor associated with the hydraulic actuator. In particular, by detecting the change in the position of the actuator over time, it is possible to calculate the flow of oil discharged into the recovery tank since the characteristics of the actuator are known.

[0031] At the same time, the "expected" flow of oil discharged from the lifting chamber is proportional to the oil sent to the lowering chamber and can be calculated, being known the construction characteristics of the actuator and pump, as a function of the rotation speed of the prime mover (and therefore of the pump) and the position of the spool which depends on the signal generated by the control lever of the arm.

[0032] From an operational point of view, it is ensured that the "expected" discharged oil flow is always greater than or equate to the "detected" discharged oil flow, by

means of a look up table stored in the processing unit, which allows to limit the second control signal depending on the load conditions. This is equivalent to an adjustment curve of the position of the movable spool as a function of the "expected" flow of oil discharged by the actuator and the "detected" flow of oil discharged by the actuator.

[0033] According to another preferred variant of the invention, the flow of oil discharged is "estimated", in static conditions of the arm, by means of a pressure sensor associated with the lifting chamber of the hydraulic actuator. In particular, by detecting the pressure generated by the load in the lifting chamber, it is possible to calculate the flow of oil that will be discharged as soon as the control lever commands the lowering of the arm.

[0034] At the same time, the "expected" flow of oil discharged is calculated, given the construction characteristics of the actuator and pump, as a function of the rotation speed of the prime mover (and therefore of the pump) and the position of the spool from the signal generated by the arm control lever.

[0035] From an operational point of view, when the control lever will command the lowering of the arm, in order to avoid cavitation in the lowering chamber of the actuator and a sudden lowering of the arm, it is guaranteed that the flow of the "expected" oil discharged is greater than or equal to the "estimated" discharged oil flow, by means of a look up table stored in the processing unit which allows to limit the second control signal according to the load conditions. This is equivalent to an adjustment curve of the position of the movable spool as a function of the "expected" flow of oil discharged from the actuator and the "estimated" flow of oil discharged from the actuator.

[0036] The dependent claims describe preferred variants of the invention, forming an integral part of this description.

Brief description of the figures

[0037] 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 vehicle equipped with a hydraulically actuated mobile arm;

Figure 2 shows an example of an electro-hydraulic circuit for actuating the arm of the vehicle of Figure 1, which shows a directional control valve, proportional to an activation signal, an actuator equipped with a lifting chamber, and a lowering chamber, a position sensor associated with the actuator, an optional check valve, and an optional pressure sensor associated with the lifting chamber;

Figure 3 shows an exemplary flow chart of the method object of the present invention.

[0038] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0039] 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 it is specifically indicated or inferred from the text.

[0040] The elements and features illustrated in the various preferred embodiments, including drawings, can be combined with each other without however departing from the scope of this application as described below.

Detailed description of exemplary embodiments

[0041] The present invention relates to the control of an actuator of an arm of an agricultural or work vehicle subjected to a load as exemplified in figure 1.

[0042] The arm B comprises at least one element AR directly and/or a tool T indirectly hinged to a vehicular frame F and a double action actuator A1, A2 comprising a lifting chamber CH1 and a lowering chamber CH2 opposite the lifting chamber. The electro-hydraulic control circuit of at least one of the components AR and/or TL is exemplified in Figure 2.

[0043] A directional valve V1, V2 is arranged to connect

- the lifting chamber CH1 with a recovery tank T of hydraulic oil e
- the lowering chamber CH2 with a source of hydraulic oil P, in a first operating configuration for lowering the arm and vice versa in a second operating configuration for lifting the arm and a third stop configuration for the arm, in which both chambers are closed and are disconnected from both the recovery tank or the source of hydraulic oil.

[0044] The directional valve is represented as a proportional valve with a central rest spool corresponding to the aforementioned third operating condition, a left spool corresponding to the second operating condition for lifting the arm, and a right spool corresponding to the first operating condition for lowering the arm.

[0045] Since it is a proportional valve, the amount of opening in raising or lowering is adjustable.

[0046] In addition, each spool simultaneously controls both ports of the actuator, ie both the port of the first chamber CH1 and the second chamber CH2, providing for the aforementioned connections or disconnections in the event of the arm stop. Generally, the source of hydraulic oil is defined by a hydraulic pump P driven in rotation by a prime mover, typically an internal combustion engine.

[0047] According to the present invention, in dynamic conditions of lowering of the arm, the following steps are carried out:

- a first step ST1 of calculating a flow value of hydraulic oil directed to the lowering chamber CH2 by the directional valve and a corresponding first flow value F1 of hydraulic oil intended to be discharged from the lifting chamber CH1,
- a second step ST2 of detecting a second flow value F2 of hydraulic oil actually discharged from the lifting chamber due to the load and
- a third step ST3 to adjust the directional valve V1, V2 so as to force said second value to equate the first flow value, when the second value exceeds the first (CK = Yes). Otherwise (CK = No), obviously, it is not necessary to intervene.

[0048] With reference to Figure 3, it is evident that the method object of the present invention is carried out continuously and recursively, dynamically correcting the regulation of the position of the movable spool of the directional valve by "tracking" the aforementioned equality.

[0049] This implies, starting from a condition imposed by the control operated by the user and the system, in real time, is able to detect whether the "measured" flow of discharged hydraulic oil, measured indirectly by monitoring the actuator excursion over time, exceeds the "expected" oil flow, calculated on the basis of the oil directed to the lowering chamber and to force the directional control valve to throttle to obtain that the "measured" flow does not exceed the "expected" flow of oil discharged from the lifting chamber CH1.

[0050] It is evident that the oil sent to the actuator is specifically sent to the relative CH2 lowering chamber, while the oil discharged from the actuator is discharged from the relative CH1 lifting chamber.

[0051] The flow directed to the lowering chamber CH2 is functional

- of the oil flow generated by the hydraulic pump P e
- from the position of the movable spool of the directional valve V1, V2.

[0052] The oil flow generated by the hydraulic pump P, in turn, is a function of the rotation speed of the prime mover.

[0053] The measured hydraulic oil flow, on the other hand, is calculated by associating a position sensor S1 with the hydraulic actuator A1, A2, so that, once the geometry of the actuator and in particular of the lifting chamber is known, the oil can be calculated. actually relieved as the actuator stem moves.

[0054] The position of the movable shuttle of the directional valve depends at least on the position of a control lever of the arm located in the passenger compartment of the vehicle. Generally, this lever is in the form of a joystick. The electrical signal generated by the activation of the lever is sent to a processing unit, generally the vehicle control unit (Control Unit) which conditions this signal to control the operation of the directional valve.

[0055] In the specific case, the processing unit is con-

figured to manipulate and adapt this signal not only on the basis of the position of the joystick lever, but also on the basis of the detection of an uncontrolled/dragged load.

[0056] The rotation speed of the pump can be obtained by means of the so-called phonic wheel associated with the drive shaft of the prime mover.

[0057] Since the transmission ratio and the displacement of the hydraulic pump are known, it is possible to easily calculate the flow rate generated by it.

[0058] In fact, in modern vehicles, the control variables and operating parameters of the vehicle devices are published on a CAN data network.

[0059] Since the same control criterion can be used for any of the elements of an open kinematic chain, then, it is clear that it can be applied both to the first component of the arm AR and to the blade or tool TL connected to the first component of the arm.

[0060] According to a preferred variant of the invention, an estimate of the load associated with arm B is made when it is still in static conditions.

[0061] Thanks to this information, knowing the geometric characteristics of the actuator it is possible to estimate the oil that will actually be discharged according to the position of the directional valve spool. This is achieved by means of a pressure sensor P1 associated, directly or indirectly, with the lifting chamber CH1. This fact is advantageous because it allows to adopt, before the lowering of the arm is commanded, a limitation or saturation curve, of the control of the movable spool. In this way, the dynamic control described above is engaged in a more favorable operating condition, which is not decided solely by the position of the joystick lever.

[0062] According to a further preferred variant of the invention, between the recovery tank and the port of the lowering chamber CH2 there is a check valve AC arranged so as to allow a flow of oil from the tank to the lowering chamber. This fact is very useful, because when the opening limitation of the directional control valve intervenes, any oil defect previously sent to the lowering chamber is compensated by the oil flowing through the check valve, avoiding cavitation of the lowering chamber. In fact, in these operating conditions, the lowering chamber is simultaneously fed by the directional valve and the collection tank.

[0063] It must in fact be kept in mind that when the control is "pure tracking", in the sense that the limitation intervenes as soon as there is an excessive discharge of oil from the lifting chamber, even a minimal lack of oil in the lowering chamber is immediately compensated by the check valve. This situation, when the arm is lowered, can be compensated for by the measurement strategy in static conditions of the load described above. In any case, it is possible to combine the implementation of the check valve with the pre-calculation strategy in static conditions, of the hydraulic oil that will actually be discharged by the actuator in order to promptly intervene on the control of the directional valve. The present invention can be

advantageously implemented 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. 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

- Control method of an actuator of an arm of an agricultural or work vehicle subject to a load, in which the arm (B) comprises at least one element (AR, TL) directly or indirectly hinged to a vehicle frame (F) and a double action actuator (A1, A2) comprising a lifting chamber (CH1) and a lowering chamber (CH2) opposite the lifting chamber and a directional valve (V1, V2), arranged to connect
 - the lifting chamber with a recovery tank (T) of hydraulic oil e
 - the lowering chamber with a source of hydraulic oil (P), in a first operating configuration of lowering the arm and vice versa in a second operating configuration of lifting the arm and a third stop configuration of the arm in which both chambers are closed and disconnected from the reservoir and the source of hydraulic oil,
 the method, in dynamic conditions of lowering of the arm, including
 - a first step (ST1) of calculating a flow value of hydraulic oil directed to the lowering chamber (CH2) from the directional valve and a corresponding first flow value (F1) of hydraulic oil destined to be discharged from the lifting chamber (CH1),
 - a second step (ST2) of detecting a second flow value (F2) of hydraulic oil actually discharged from the lifting chamber due to the load and
 - a third step (ST3) of adjusting the directional valve (V1, V2) so as to force said second value to equate the first flow value, when the second value exceeds the first (CK = Yes) .
- Method according to claim 1, carried out in such a way to obtain, in real time, a throttling of the opening during arm lowering of the directional valve (V1, V2).

3. Method according to any one of claims 1 or 2, wherein said first flow (F1) is calculated as a function of a third flow generated by the hydraulic source (P) and of an opening position of a movable spool of the valve (V1, V2) directional. 5
4. Method according to claim 3, wherein said position of the movable shuttle is a function of a position of an arm control lever. 10
5. Method according to any of the preceding claims, in which the detection of said second flow value (F2) is carried out by monitoring the variation of an actuator excursion (A1, A2) over time. 15
6. Method according to any one of the preceding claims, wherein said third adjustment step comprises a limitation of a control signal generated by a human-machine interface device. 20
7. Method according to claim 6, wherein said man-machine interface device coincides with said control lever according to claim 4.
8. Method according to any one of the preceding claims, wherein said arm comprises said first element (AR) having a first end directly hinged to the vehicle frame (F) and a tool (TL) hinged to a second end of the first element, opposite to the first end, and in which the tool comprises an actuator (A2) controlled in accordance with the actuator (A1) of the first element. 25 30
9. Method according to any one of the preceding claims, comprising a preliminary step, carried out in static conditions of the arm, comprising estimating said second flow by measuring a pressure in the lifting chamber (CH1). 35
10. A computer program comprising program coding means suitable for carrying out all steps (ST1 - ST3) of any one of claims 1 to 9, when said program is run on a computer. 40
11. Computer readable means comprising a recorded program, said computer readable means comprising program coding means adapted to perform all steps (ST1 - ST3) of any one of claims 1 to 9, when said program is run on a computer. 45 50
12. Control system of an actuator of an arm of an agricultural or work vehicle subject to a load, in which the arm (B) includes at least one element (AR, TL) directly or indirectly hinged to a vehicle frame (F) and a double action actuator (A1, A2) comprising a lifting chamber (CH1) and a lowering chamber (CH2) opposite the lifting chamber and a directional valve (V1, V2), arranged to connect 55
 - the lifting chamber with a recovery tank (T) of hydraulic oil e
 - the lowering chamber with a source of hydraulic oil (P), in a first operating configuration of lowering the arm and vice versa in a second operating configuration of lifting the arm and a third stop configuration of the arm in which both chambers are closed and disconnected from the reservoir and the source of hydraulic oil,

the system comprising processing means configured to calculate (ST1), during a dynamic arm lowering condition, a hydraulic oil flow value addressed to the lowering chamber (CH2) from the directional valve and a corresponding first hydraulic oil flow value intended to be discharged from the lifting chamber (CH1), to detect (ST2) a second flow value of hydraulic oil actually discharged from the lifting chamber due to the load and consequently to regulate (ST3) the directional valve (V1, V2) in so as to force said second value to equate the first flow value, when the second value exceeds the first (CK = Yes).
13. A system according to claim 12, further comprising a check valve (AC) arranged to allow the lowering chamber to suck a flow of oil from the collecting tank.

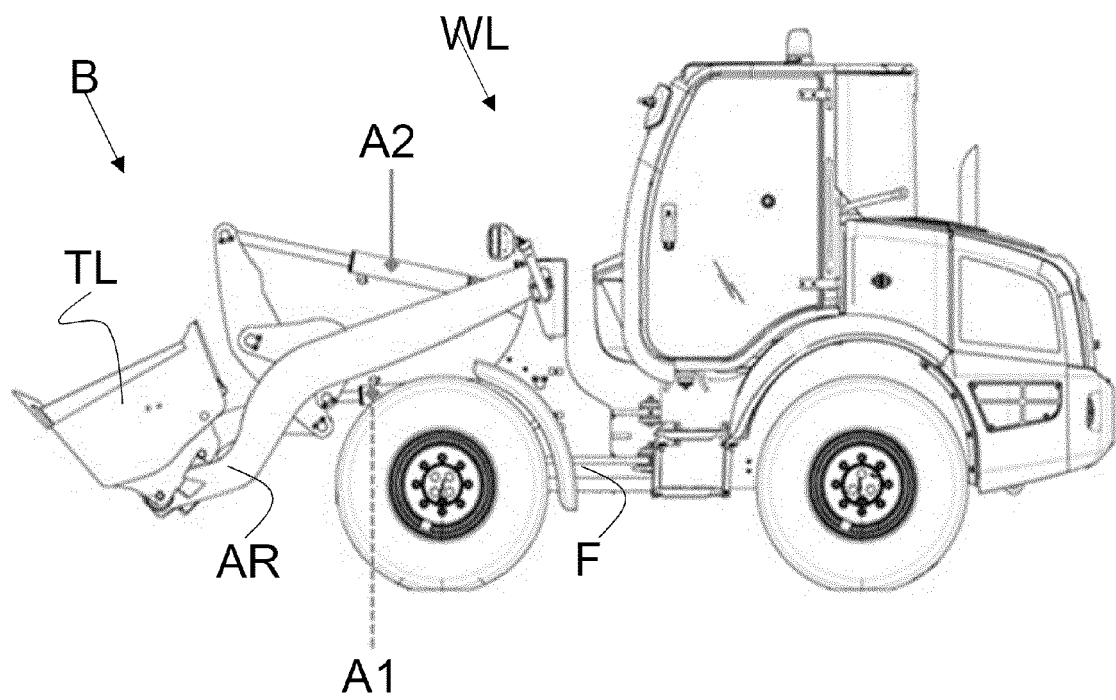


Fig. 1

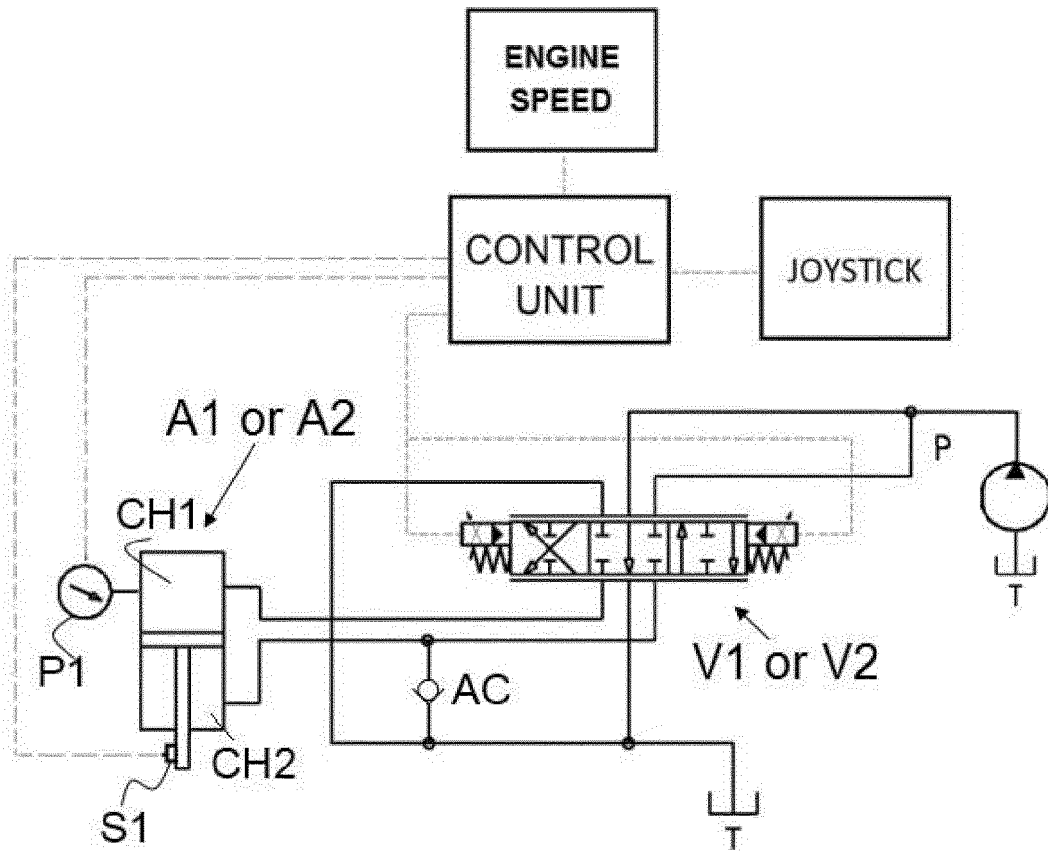


Fig. 2

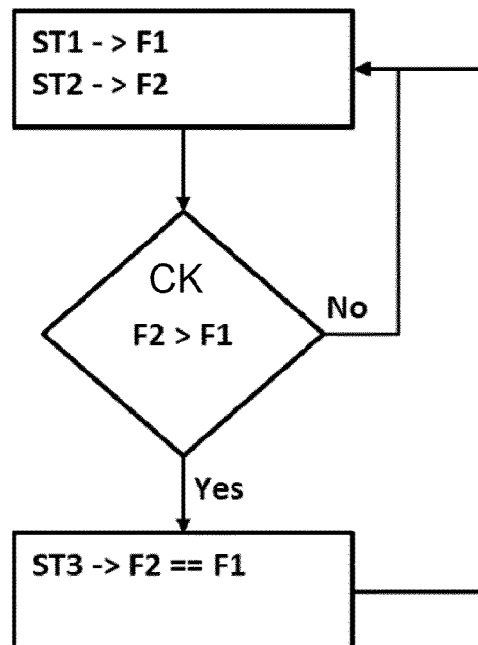


Fig. 3



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