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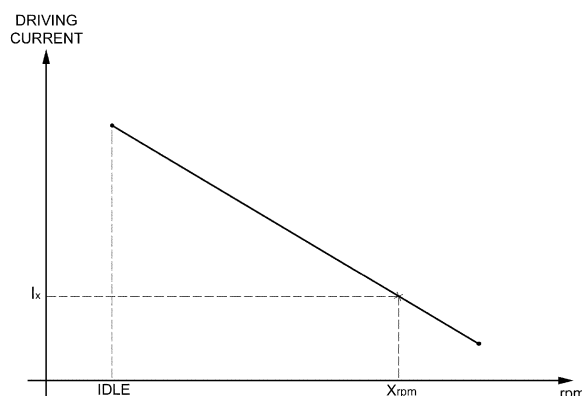
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(54) **A CONTROL METHOD OF ACTUATING A MOVEMENT OF AT LEAST ONE OF A BOOM AND AN IMPLEMENT CONNECTED TO THE BOOM IN A WORK VEHICLE POWERED BY A MOTOR, A CORRESPONDING CONTROL SYSTEM AND A WORK VEHICLE COMPRISING SUCH CONTROL SYSTEM**

(57) A control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor is disclosed. Actuating the boom and the implement occurs by means of a joystick controlled by a user, a movement of the joystick in a predetermined control area according to a first preset direction causing the actuation of the boom by a first hydraulic actuator and a movement of the joystick in said control area according to a second preset direction causing the actuation of the implement by a second hydraulic actuator. Each hydraulic actuator includes a respective open centre directional solenoid valve whose opening degree is controlled by means of a driving current as a function of the position of the joystick. The control method comprises providing a predetermined reference model of the driving current of the first and second open centre directional solenoid valves, indicative of the relation between the driving current and the rotational speed of the motor, acquiring the position of the joystick, acquiring the current rotational speed of the motor, and when the joystick is moved on a preset boundary, retrieving from the reference model an actual driving current value according to the current rotational speed of the motor.



**FIG.4**

## Description

### Technical field

**[0001]** The present invention relates generally to a work vehicle, such as for example a compact wheel loader, and particularly to a control method of actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor and to a corresponding control system.

### Prior art

**[0002]** Motorized work vehicles are well known for use in material handling that carry an implement and have a hydraulically operated lifting arm for moving the implement. Examples of such vehicles are tractors and loaders.

**[0003]** A loader is a heavy equipment machine used in construction to move aside on the ground or load materials such as asphalt, demolition debris, dirt, snow, feed, gravel, logs, raw minerals, recycled material, rock, sand, woodchips, etc. into or onto another type of machinery (such as a dump truck, conveyor belt, feed-hopper, or railroad car). There are many types of loader, which, depending on design and application, are called by various names, including bucket loader, front loader, front-end loader, payloader, scoop, shovel, skip loader, wheel loader, or skid-steer. In particular, compact wheel loaders are compact vehicles that have road wheels and carry a working implement, such as a bucket, attached to a lift arm or boom, that is hydraulically powered.

**[0004]** Referring to figure 1, a work vehicle 1, such as a compact wheel loader, is shown. However, the invention is not limited to such a kind of work vehicle, but is applicable to any other kind of work vehicle.

**[0005]** A compact wheel loader includes a bucket 2 connected to a frame 3 of the work vehicle for movement relative thereto. As shown, a pair of booms 5 (only one being shown) is each pivotally connected at one end on opposite sides of frame 3. The bucket 2 is pivotally connected at the opposite end of booms for tilting movement relative to the frame 3 about a generally horizontal axis. The above-described features form no substantial part of the present invention and are generally well known in the art. A bucket may be replaced in operation by any other implement or attachment.

**[0006]** Usually, the movement of the boom 5 and of the bucket 2 is controlled by the user through a joystick 7 placed inside an operator's cab or cabin 9 of the work vehicle 1.

**[0007]** As can be seen in figure 2, which shows a control diagram of the work vehicle 1, the boom 5 and the bucket 2 are moved by an hydraulic control circuit 10 comprising a first and a second hydraulic actuators 12, 14 which are controlled by an electronic control unit 16 through respective solenoid valves 18, 20 according to the position of the joystick 7 controlled by the user.

**[0008]** Figure 3 shows an exemplary joystick of a work vehicle. A movement of the joystick in an associated bi-dimensional control area A according to a first direction y causes the actuation of the boom and a movement of the joystick in said control area A according to a second direction x causes the actuation of the implement. The intersection of said x and y directions is defined as origin O of the control area A, and corresponds to the neutral position of the joystick.

**[0009]** A neutral region N around the neutral position of the joystick is a region where the boom and implement are not actuated. A region externally surrounding the neutral region is defined a driving region and indicated D in this figure.

**[0010]** For example, according to the orientation depicted in figure 3, in an embodiment where the implement is a bucket when the joystick is moved up from the origin O of the control area A according to the y direction the boom is lowered with respect to ground and when the joystick is moved down from the origin O according to the y direction the boom is lifted towards ground. Further, when the joystick is moved right from the origin O according to the x direction the implement, e.g. a bucket, is tilted towards a dumping position, and when the joystick is moved left from the origin O according to the x direction the implement, e.g. the bucket, is tilted towards a dig position and beyond.

**[0011]** A combination of movement in both directions x and y of the joystick is allowed in order to move simultaneously the boom and the bucket.

**[0012]** Further attachments that can be operated in parallel to the bucket (and the boom) by means of respective hydraulic actuators (not shown) which are controlled by an electronic control unit 16 through respective solenoid valves in a like manner, e.g. by means of push-buttons embodied in the joystick or according to the position of a separate joystick controlled by the user.

**[0013]** Load-sensing valves allow a pressure compensation so that downstream channels take proportional allocation of flow depending on the load. The flow rate at a predetermined opening degree is not dependent upon the load downstream each valve and is not dependent upon the pump inlet flow.

**[0014]** When a plurality of loads is actuated, load-sensing valves with flow sharing also prevent the working fluid from taking the path of least resistance. However, this solution is very expensive. Advantageously, open centre directional solenoid valves are less expensive than load-sensing valves. Disadvantageously, in open centre directional solenoid valves the flow rate at a predetermined opening degree is dependent upon the pump inlet flow, the number of valves supplied by the pump and the load downstream each valve.

**[0015]** For example, each hydraulic actuator comprises an hydraulic cylinder operatively connected respectively to the boom and the implement, that uses hydraulic power of a working fluid to facilitate mechanical operation, the working fluid being controlled by means of open

centre directional solenoid valves 18, 20. As liquids are nearly impossible to compress, a hydraulic actuator can exert a large force. The rate of actuation of the boom and implement is controlled by the opening degree of the respective open centre directional solenoid valve 18, 20 by means of a driving current thereof as a function of the position of the joystick.

**[0016]** The hydraulic flow rate of the working fluid required to operate the boom and the implement is produced by a hydraulic fixed displacement pump P connected to a fluid reservoir T and driven by an internal combustion engine or an electrical motor M (hereinafter simply referred to as motor) of the vehicle, e.g. by a mechanical linkage. Therefore, the rate of movement of the boom and the implement at a predetermined joystick position is dependent upon the motor rotational speed. For instance, when the motor is working at a high rotational speed, it is necessary a minimum movement of the joystick by the user to start the movement of the boom and/or the implement. On the contrary, when the motor is working at a low rotational speed, it is necessary a large movement of the joystick by the user to start the movement of the boom and/or the bucket.

**[0017]** The situation is similar when the user try to stop the movement of the boom and/or the implement through the joystick. For instance, when the motor is working at a high rotational speed, it is necessary to move the joystick at a first distance from a neutral position of the joystick to stop the actuation of the boom and/or the implement. On the contrary, when the motor is working at a low rotational speed, it is necessary to move the joystick at a second distance from a neutral position of the joystick, higher than said first distance, to stop the actuation of the boom and/or the implement.

**[0018]** Disadvantageously, this uncertainty about the position of the joystick in which the actuation of the boom and/or the implement is started and stopped affects the controllability of the boom and/or implement by the user. Therefore, the working precision of work vehicle is reduced.

#### Summary of the invention

**[0019]** The aim of the present invention is to provide a solution that avoids the drawbacks of the prior art. Particularly, an aim of the present invention is to improve the controllability of a boom and/or implement in a work vehicle in situations in which the motor may be working at high or low rotational speed.

**[0020]** According to the invention, this aim is achieved by a control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor, having the features claimed in claim 1.

**[0021]** Preferred embodiments are defined in the dependent claims, whose content is also to be considered an integral part of the present description. Features of the dependent claims may be combined with the features

of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

**[0022]** Further subjects of the invention are a control system for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor, as well as a work vehicle, as claimed.

**[0023]** In summary, an actuation strategy of a boom and/or an implement (and possibly of any further attachment) of a work vehicle is disclosed according to which the opening of at least one of the open centre directional solenoid valves of the hydraulic actuating means of the boom and the implement is modulated by considering the motor speed so as to guarantee that the start/stop movement of the boom or the implement occurs always at the same joystick position.

#### Brief description of the drawings

**[0024]** Further functional and structural characteristics and advantages of the present invention are set out in the detailed description below, provided purely as a non-limiting example, with reference to the attached drawings, in which:

- figure 1 shows a prior art exemplary work vehicle, in particular a compact wheel loader;
- figure 2 shows a prior art control diagram of a work vehicle;
- figure 3 shows an exemplary joystick of a work vehicle;
- figure 4 shows an exemplary reference model according to the invention; and
- figure 5 shows a control diagram of a work vehicle according to the invention.

#### Detailed description

**[0025]** In the following description, unless otherwise defined, all terms (including technical and scientific terms) are to be interpreted as is customary in the art. It will be further understood that terms in common usage should also be interpreted as is customary in the relevant art and not in an idealized or overly formal sense unless expressly so defined herein. All orientation terms, such as upper and lower, are used in relation to the drawings and should not be interpreted as limiting the invention.

**[0026]** In the following, a preferred embodiment of a control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor is described. Reference is made to the control diagram of Figure 2 that has been previously described, and the electronic control unit 16 is configured to implement the control method of the invention.

**[0027]** As disclosed above and with further reference to Figure 3, actuation of the boom 5 and the implement 2 occurs by means of joystick 7 controlled by a user,

whose movement in the control area A according to direction y causes the actuation of the boom 5 by first hydraulic actuating means 12 and whose movement in the control area A according to direction x causes the actuation of the implement 2 by second hydraulic actuating means 14.

**[0028]** Each hydraulic actuating means 12, 14 include an hydraulic cylinder operatively connected respectively to the boom 5 and the implement 2, and a respective first and second open centre directional solenoid valve 18, 20 whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder.

**[0029]** An hydraulic flow rate of the working fluid is produced by a hydraulic pump P driven by the motor M.

**[0030]** The rate of actuation of the boom 5 is controlled by the opening degree of the first open centre directional solenoid valve 18 by means of the driving current thereof as a function of a first component of the position P of the joystick 7 along direction y in the control area A. The rate of actuation of the implement 2 is controlled by the opening degree of the second open centre directional solenoid valve 20 by means of the driving current thereof as a function of a second component of the position P of the joystick 7 along direction x in the control area A. The first component of the position P of the joystick 7 along direction y is indicated  $y_P$  in figure 3 and is the projection over y axis of a vector representing the position P of the joystick in the control area A. The second component of the position P of the joystick 7 along direction x is indicated  $x_P$  in figure 3 and is the projection over x axis of the vector representing the position P of the joystick in the control area A.

**[0031]** In the control area A of the joystick 7, the driving region D and the neutral region N are separated by a preset boundary B.

**[0032]** The control method comprises the step of providing a predetermined reference model of at least one among the driving current of the first open centre directional solenoid valve 18 and the driving current of the second open centre directional solenoid valve 20, indicative of the relation between the driving current and the rotational speed of the motor.

**[0033]** Further, the control method comprises the step of acquiring a signal  $S_e$  or data indicative of the current rotational speed of the motor M.

**[0034]** Then, when the joystick 7 is moved on the preset boundary B, an actual driving current value is retrieved from the reference model according to the acquired signal or data indicative of the current rotational speed of the motor M. The retrieved actual driving current value being intended to at least one among the first open centre directional solenoid valve 18 or the second open centre directional solenoid valve 20.

**[0035]** An exemplary reference model is illustrated in figure 4. On the Y-axis are reported the driving current values and on the X-axis are reported the values of motor rotational speed in rpm, revolutions per minute.

**[0036]** By applying the control method according to the

invention, by considering that the acquired signal or data indicative of the current rotational speed indicates a rotation speed equal to  $X_{rpm}$ , the driving current value  $I_x$  is retrieved from the reference model. Then, the driving current value  $I_x$  is used to actuates at least one among the first open centre directional solenoid valve or the second open centre directional solenoid valve.

**[0037]** Preferably, the reference model is an analytic model or a look-up table.

**[0038]** As shown in figure 3, the preset boundary can have a constant distance from the neutral position of the joystick, i.e. the intersection of the first preset direction x and the second preset direction y. However, in different examples, the preset boundary B may have an ellipsoidal shape.

**[0039]** Preferably, the preset boundary B is pre-set by the manufacturer of the work vehicle 1.

**[0040]** According to an embodiment of the invention, the reference model includes a plurality of driving current curves as a function of the distance of the preset boundary from the neutral position of the joystick, said plurality of driving current curves being not parallel.

**[0041]** Always referring to figure 2, the neutral region N can be a region around a position of intersection O of said first and second preset directions x, y, and said driving region D can be a region surrounding said neutral region N.

**[0042]** Referring now to figure 5, the invention concerns also a control system 10 for actuating a movement of at least one of a boom 5 and an implement 2 connected to the boom 5 in a work vehicle 1 powered by a motor.

**[0043]** The control system 10 comprises input means adapted to receive at least a signal  $S_j$  indicative of a position in a control area of a joystick 7 controlled by a user for actuating the boom 5 and the implement 2, and input means adapted to receive a signal  $S_e$  indicative of the rotational speed of the motor M.

**[0044]** Further, the control system 10 comprises storage means adapted to store a reference model of at least one among the driving current of the first open centre directional solenoid valve 18 and the driving current of the second open centre directional solenoid valve 20, indicative of the relation between at least the position of the preset boundary B and the rotational speed of the motor M.

**[0045]** In addition, the control system 10 comprises output means adapted to issue at least a signal  $S_{Dc}$  indicative of a driving current intended to control an opening degree of at least an open centre directional solenoid valve of hydraulic actuating means of said at least one of a boom 5 and an implement 2.

**[0046]** The control system 10 is arranged to carry out a control method according to the invention.

**[0047]** Further, the invention concerns also a work vehicle 1, in particular compact wheel loader, comprising a motor M arranged to power the work vehicle 1, a boom 5 and an implement 2 connected to the boom 5, a joystick 7 operatively controlled by a user for actuating the boom

5 and the implement 2. The joystick 7 is movable in a predetermined control area A according to a first preset direction x for actuating the boom 5 and in a second preset direction y for actuating the implement 2.

**[0048]** Further, the work vehicle comprises first hydraulic actuating means 12 for actuating the boom 5 and second hydraulic actuating means 14 for actuating the implement 2. The first hydraulic actuating means and the second hydraulic actuating means each include an hydraulic cylinder operatively connected respectively to the boom 5 and the implement 2, and a respective first and second open centre directional solenoid valve 18, 20 whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder. The opening degree of said first and second open centre directional solenoid valve 18, 20 is operatively controlled by means of a respective driving current.

**[0049]** In addition, the work vehicle includes a hydraulic pump P driven by the motor M to produce an hydraulic flow rate of the working fluid, and a control system for actuating the movement of at least one of the boom and the implement, according to the invention.

**[0050]** Therefore, by virtue of the present invention, the uncertainty about the position of the joystick in which the actuation of the boom and/or the implement is started and stopped is eliminated. Therefore, the controllability of the boom and/or implement and possible auxiliary attachments by the user and the working precision of work vehicle are increased.

**[0051]** Where the present invention has been described referring to a joystick configured to be operated by movement in a bi-dimensional control area combining the actuation of the boom and the actuation of the implement, it would be clear to a skilled person that a pair of independent joysticks or levers movable along respective, separate unidimensional control tracks are comprised within the scope of the invention as an equivalent embodiment, the principle of the invention being the same.

**[0052]** The example embodiments are described in sufficient detail to enable those of ordinary skill in the art to implement a control system in a work vehicle arranged to carry out the disclosed control method herein described.

**[0053]** Naturally, the principle of the invention remaining unchanged, the embodiments and the constructional details may vary widely from those described and illustrated purely by way of non-limiting example, without thereby departing from the scope of the invention as defined in the appended claims.

## Claims

1. A control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor, wherein actuating the boom and the implement oc-

curs by means of a joystick controlled by a user, a movement of the joystick in a predetermined control area according to a first preset direction causing the actuation of the boom by first hydraulic actuating means and a movement of the joystick in said control area according to a second preset direction causing the actuation of the implement by second hydraulic actuating means,

wherein the first hydraulic actuating means and the second hydraulic actuating means each include an hydraulic cylinder operatively connected respectively to the boom and the implement, and a respective first and second open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder; an hydraulic pressure of the working fluid being produced by a hydraulic pump driven by the motor;

the rate of actuation of the boom being controlled by the opening degree of the first open centre directional solenoid valve by means of a driving current thereof as a function of a first component of the position of the joystick along said first preset direction in the control area, and the rate of actuation of the implement being controlled by the opening degree of the second open centre directional solenoid valve by means of a driving current thereof as a function of a second component of the position of the joystick along said second preset direction in the control area;

the control area of the joystick comprising a driving region and a neutral region around a neutral position of the joystick, the driving region and the neutral region being separated by a preset boundary;

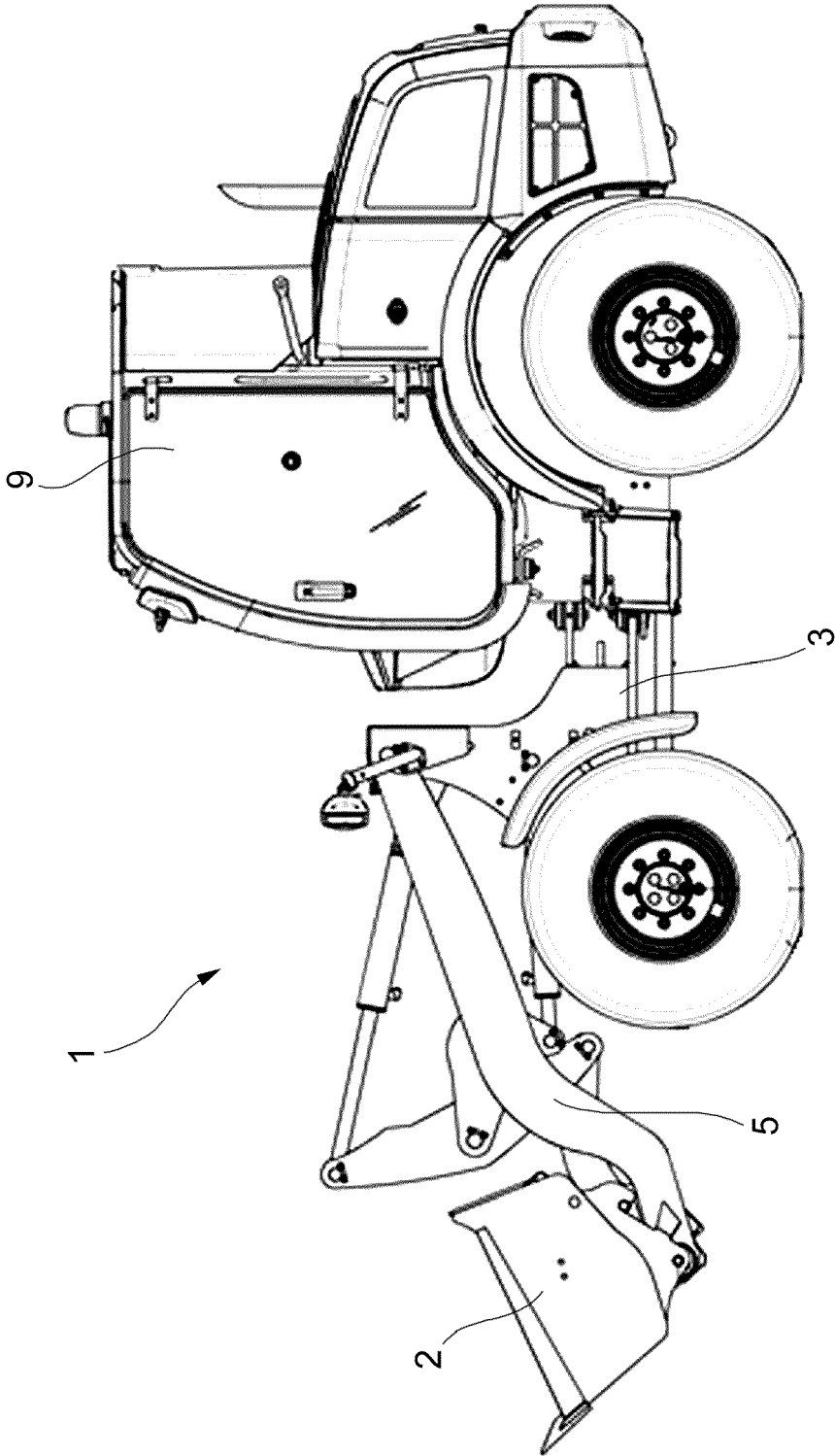
the control method comprising the steps of:

- a) providing a predetermined reference model of at least one among the driving current of the first open centre directional solenoid valve and the driving current of the second open centre directional solenoid valve, indicative of the relation between the driving current and the rotational speed of the motor;
- b) acquiring a signal or data indicative of a position of the joystick in said control area over time;
- c) acquiring a signal or data indicative of the current rotational speed of the motor;
- d) when the joystick is moved on the preset boundary, retrieving from the reference model an actual driving current value according to the acquired signal or data indicative of the current rotational speed of the motor, the retrieved actual driving current value being intended to at least one among the first open centre directional solenoid valve or the second open centre directional solenoid valve.

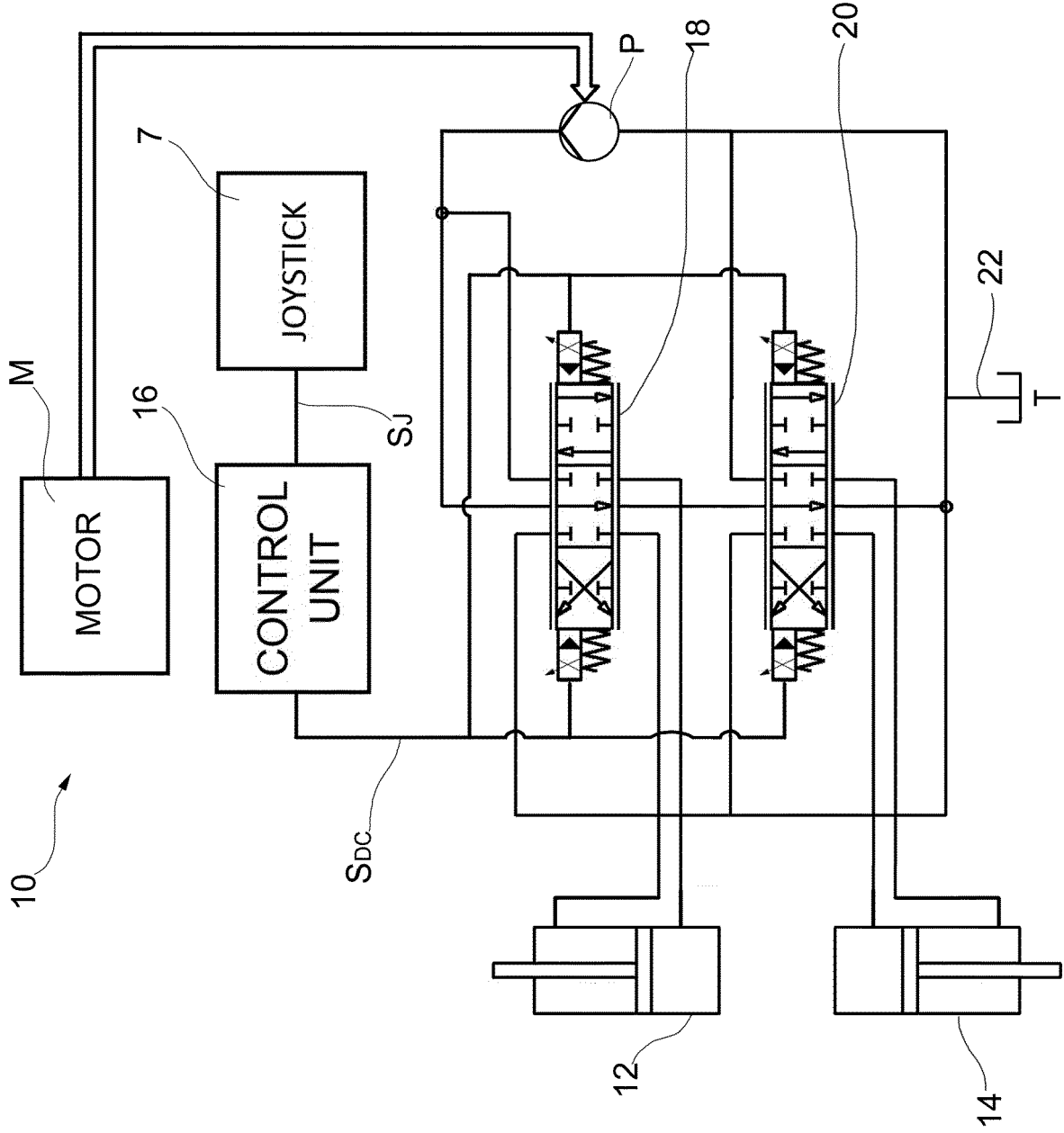
2. The control method according to Claim 1, wherein the reference model is an analytic model or a look-up table.
3. The control method according to Claim 1 or 2, wherein the preset boundary has a constant distance from the neutral position of the joystick. 5
4. The control method according to any one of the preceding claims, wherein said reference model includes a plurality of driving current curves as a function of the distance of the preset boundary from the neutral position of the joystick. 10
5. A control system for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle powered by a motor, comprising: 15
  - first input means adapted to receive at least a signal indicative of a position in a control area of a joystick controlled by a user for actuating the boom and the implement; 20
  - second input means adapted to receive at least a signal indicative of the rotational speed of the motor; 25
  - storage means adapted to store a reference model of at least one among the driving current of the first open centre directional solenoid valve and the driving current of the second open centre directional solenoid valve, indicative of the relation between at least the position of the preset boundary and the rotational speed of the motor; 30
  - output means adapted to issue at least a signal indicative of a driving current intended to control an opening degree of at least an open centre directional solenoid valve of hydraulic actuating means of said at least one of a boom and an implement, 35
  - the system being arranged to carry out a control method according to any one of claims 1 to 4. 40
6. Work vehicle, in particular compact wheel loader, comprising: 45
  - a motor arranged to power the work vehicle;
  - a boom and an implement connected to the boom;
  - a joystick operatively controlled by a user for actuating the boom and the implement, the joystick being movable in a predetermined control area according to a first preset direction for actuating the boom and in a second preset direction for actuating the implement, 50
  - first hydraulic actuating means for actuating the boom and second hydraulic actuating means for actuating the implement, wherein the 55

first hydraulic actuating means and the second hydraulic actuating means each include an hydraulic cylinder operatively connected respectively to the boom and the implement, and a respective first and second open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder, the opening degree of said first and second open centre directional solenoid valve being operatively controlled by means of a respective driving current;

- a hydraulic pump driven by the motor to produce an hydraulic flow rate of the working fluid; and
- a control system for actuating the movement of at least one of the boom and the implement, according to Claim 5.

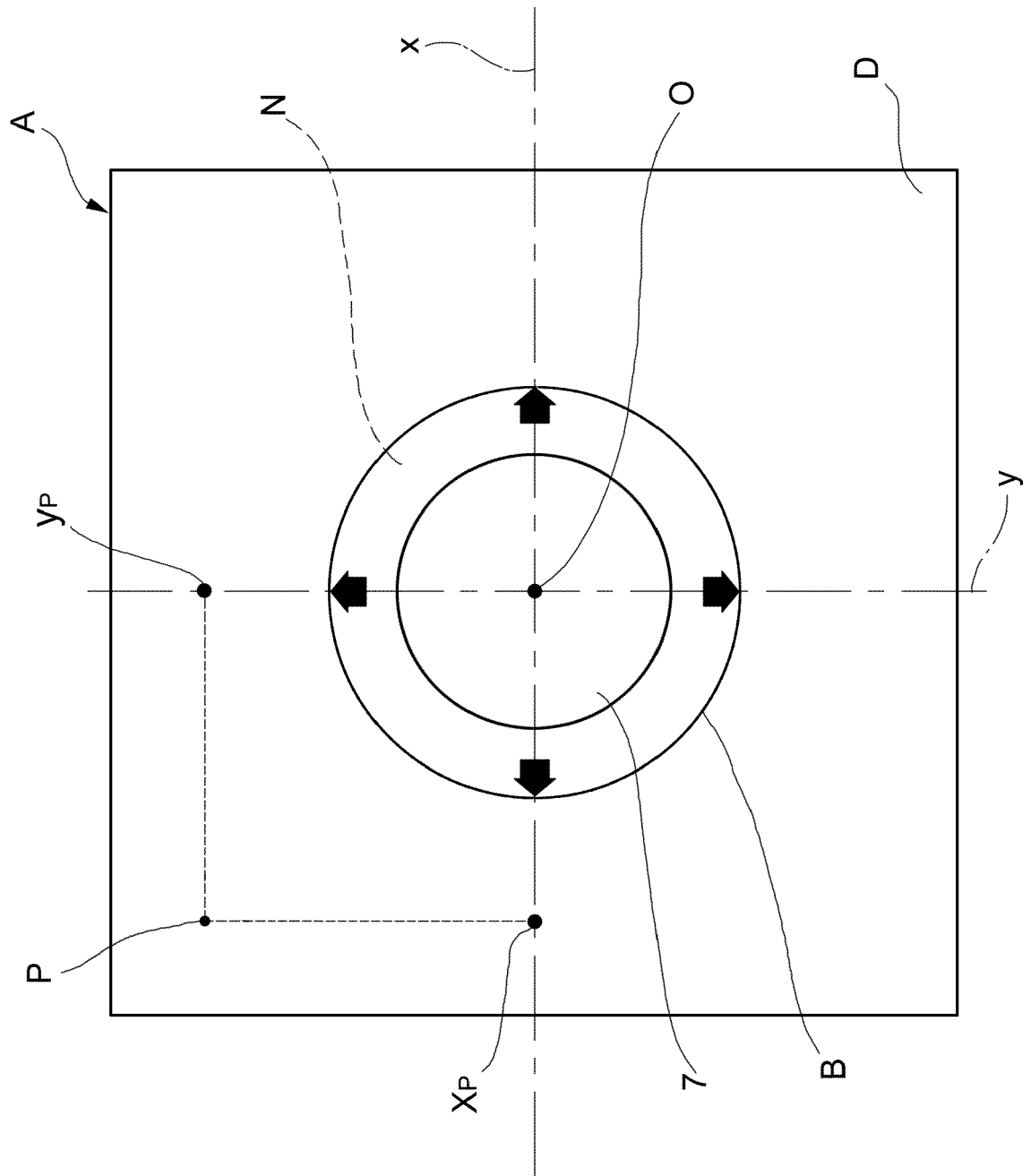


**FIG.1**  
(PRIOR ART)



**FIG.2**  
(PRIOR ART)





### FIG. 3

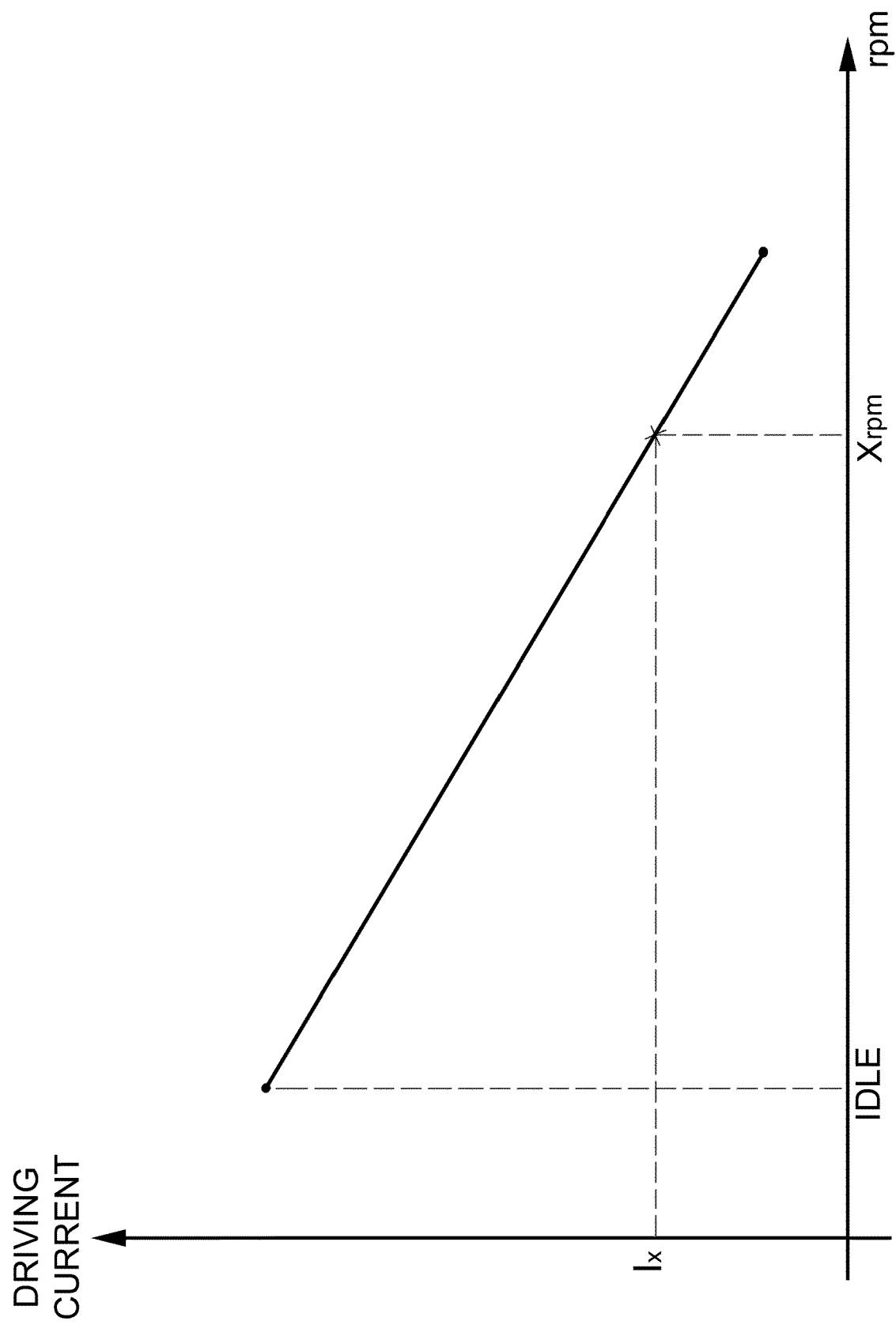


FIG.4

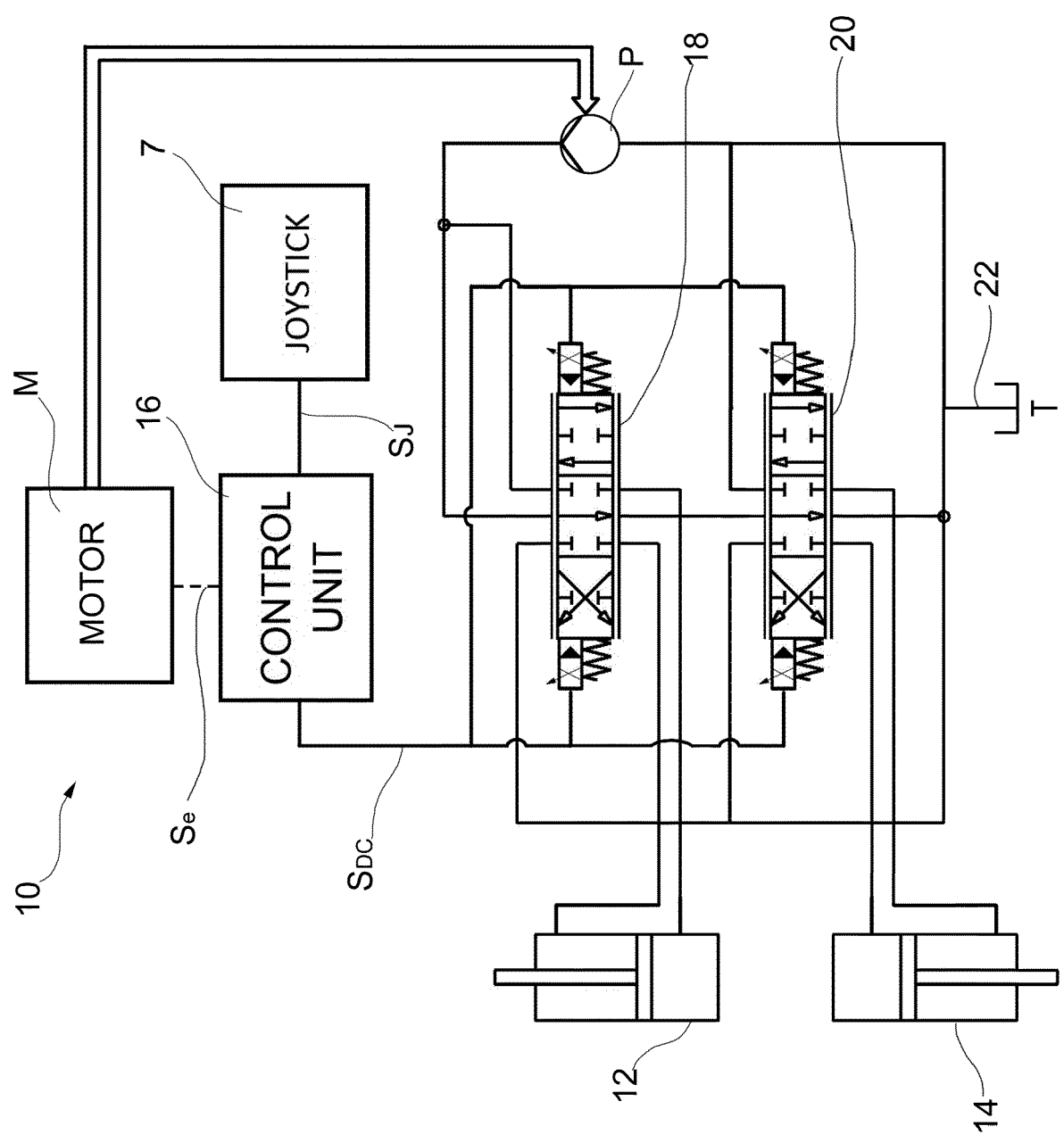


FIG.5



## EUROPEAN SEARCH REPORT

Application Number  
EP 20 16 8289

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Place of search		Date of completion of the search	Examiner
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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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**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 20 16 8289

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
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