



(11)

EP 4 428 377 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
11.09.2024 Bulletin 2024/37

(51) International Patent Classification (IPC):
F15B 11/08 ^(2006.01) **B66C 13/20** ^(2006.01)

(21) Application number: **21962861.7**

(52) Cooperative Patent Classification (CPC):
B66C 13/20; F15B 11/08

(22) Date of filing: **04.11.2021**

(86) International application number:
PCT/CN2021/128589

(87) International publication number:
WO 2023/077344 (11.05.2023 Gazette 2023/19)

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

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(54) **HYDRAULIC-PRESSURE-BASED CONTROL SYSTEM AND METHOD, LIFTING EQUIPMENT, AND CRAWLER-TYPE TRAVELING EQUIPMENT**

(57) A hydraulic-pressure-based control system and method, lifting equipment, and crawler-type traveling equipment. The control system comprises: a handle (100), which is displaced according to an operation by a user; and a closed circuit (200), wherein the circulation direction of hydraulic oil in the closed circuit (200) comprises a first circulation direction and a second circulation direction. When the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action. The control system further comprises: a controller (300), which is connected to the handle (100) and the closed circuit (200), and is configured to: control the closed circuit (200) to output the hydraulic oil in the first circulation direction when the mechanical equipment performs the descending action, wherein the output hydraulic oil can compensate for a speed decline caused by leakage of the hydraulic oil from a closed pump (220) and a motor (210) of the closed circuit (200), so as to

realise micro-motion control by the hydraulic-pressure-based control system.

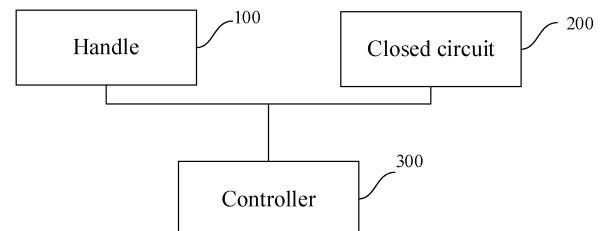


FIG. 1

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Description

Field of the Invention

[0001] The present application relates to the technical field of mechanical equipment control, in particular to a hydraulic-pressure-based control system and method, lifting equipment, and crawler-type traveling equipment.

Background of the Invention

[0002] Currently, the hydraulic-pressure-based control system has become a key application technology of mechanical equipment due to its advantages of energy saving, high energy density, and small number of hydraulic components. Its application scope covers from super-large-tonnage crane vehicles to large-tonnage and medium-tonnage vehicles, and the hydraulic-pressure-based control system replaces the traditional open system. Crawler-type traveling equipment is also widely used in the hydraulic-pressure-based control system for traveling drive.

[0003] During the operation of mechanical equipment, the closed pump and motor have internal leakage. It is assumed that the oil discharge port of the closed pump is a T port, the oil discharge port of the motor is a U port, and the sum of the leakage amounts of the T port and the U port is ΔQ , ΔQ will cause the weight to fall, and the falling speed is proportional to ΔQ : $\Delta V = \alpha \Delta Q$, wherein α is a constant. When the mechanical equipment falls, the closed pump itself will output the flow Q , and the falling speed V of the weight is: $V = \alpha(\Delta Q + Q)$. When the active output of the closed pump is $Q = 0$, the speed reaches a minimum, which is completely determined by the leakage ΔQ , that is, $V = \alpha \Delta Q$. However, if the internal leakage ΔQ is large, the speed V is still large. When the load of the mechanical equipment (such as the lifting equipment or the crawler-type traveling equipment) is relatively large, such as the weight lifted by the lifting equipment is heavy or the crawler-type traveling equipment is on a large slope, the system pressure increases, and the leakage amounts ΔQ of the closed pump and motor are relatively large at this time, resulting in no micro-motion when these working conditions require micro-motion. In this way, as soon as the brake cylinder is opened when the lifting equipment lifts the weight, the weight slides down quickly, which may cause the weight to bump into or crush other objects. Or the crawler-type traveling equipment has a fast downward speed at the beginning, and cannot reduce the speed to achieve micro-motion, so the maneuverability is not good. Therefore, the safety of the hydraulic-pressure-based control system in the prior art has a big problem.

Summary of the Invention

[0004] An object of the present application is to provide a hydraulic-pressure-based control system and method,

lifting equipment, and crawler-type traveling equipment to solve the problem of lower safety of the hydraulic-pressure-based control system in the prior art.

[0005] In order to achieve the above object, a first aspect of an embodiment of the present application provides a hydraulic-pressure-based control system applied to mechanical equipment which includes a hoisting mechanism or a traveling mechanism, the control system including:

a handle, which is displaced according to an operation by a user, a displacement direction of the handle corresponding to an action direction of the mechanical equipment;

a closed circuit, wherein a circulation direction of hydraulic oil in the closed circuit includes a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action; and

a controller, which is connected to the handle and the closed circuit, and is configured to:

judge whether the mechanical equipment performs a descending action according to the displacement direction of the handle;

judge whether the opening degree of the handle is within a first preset range when it is determined that the mechanical equipment performs a descending action;

control the closed circuit to output the hydraulic oil in the first circulation direction when it is determined that the opening degree of the handle is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

[0006] In an embodiment of the present application, the controller is further configured to:

control the closed circuit to output hydraulic oil in the second circulation direction when the opening degree of the handle is within a second preset range; wherein the opening degree of the second preset range is greater than the opening degree of the first preset range.

[0007] In an embodiment of the present application, the displacement direction of the handle includes a first displacement direction and a second displacement direction, the first displacement direction corresponding to an ascending action of the mechanical equipment and the second displacement direction corresponding to a descending action of the mechanical equipment.

[0008] In an embodiment of the present application,

the closed circuit includes:

a motor, which is used for driving a hoisting mechanism or a traveling mechanism of the mechanical equipment to work;
 a closed pump, which is connected with the motor through working pipelines for driving the motor; and
 the working pipelines, which connect the motor with the closed pump, the working pipelines including a high-pressure working pipeline and a low-pressure working pipeline.

[0009] In an embodiment of the present application, the closed circuit further includes:

a pressure sensor, which is connected to the high-pressure working pipeline for obtaining a system pressure of the closed circuit.

[0010] In an embodiment of the present application, the controller is further configured to:

determine a current value input to the closed pump based on a system pressure of the closed circuit obtained by the pressure sensor.

[0011] In an embodiment of the present application, the working pipelines include a first working pipeline and a second working pipeline; the closed pump includes a first working oil port, a second working oil port and a closed pump oil discharge port; the motor includes a first motor oil port, a second motor oil port, and a motor oil discharge port; the first working oil port is connected with the first motor oil port through the first working pipeline, and the second working oil port is connected with the second motor oil port through the second working pipeline.

[0012] In an embodiment of the present application, the first working pipeline is the high-pressure working pipeline and the pressure sensor is arranged on the first working pipeline when the motor drives the hoisting mechanism of the mechanical equipment to work.

[0013] In an embodiment of the present application, the first working pipeline or the second working pipeline is the high-pressure working pipeline when the motor drives the traveling mechanism of the mechanical equipment to work; the pressure sensor includes a first pressure sensor and a second pressure sensor, the first pressure sensor is arranged on the first working pipeline; the second pressure sensor is arranged on the second working pipeline.

[0014] In an embodiment of the present application, the closed circuit further includes:

a rotational speed sensor, which is arranged on the motor or a decelerator for acquiring a rotational speed of the motor.

[0015] In an embodiment of the present application, the controller is further configured to:

adjust the current value input to the closed pump according to the rotational speed of the motor acquired by the rotational speed sensor.

[0016] In an embodiment of the present application,

the closed circuit further includes:

a pressure sensor, which is connected with the high-pressure working pipeline for acquiring a system pressure of the closed circuit; and
 a rotational speed sensor, which is arranged on the motor or a decelerator for acquiring a rotational speed of the motor;
 the controller is further configured to:

determine a current value input to the closed pump according to a system pressure of the closed circuit acquired by the pressure sensor; and

perform closed-loop correction on the current value according to the motor rotational speed acquired by the rotational speed sensor.

[0017] A second aspect of the embodiments of the present application provides a hydraulic-pressure-based control method, applied to a controller of mechanical equipment, the controller is connected with a handle and a closed circuit, the handle is displaced according to an operation by a user, a displacement direction of the handle corresponding to an action direction of the mechanical equipment, a circulation direction of hydraulic oil in the closed circuit includes a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action, the control method including:

judging whether the mechanical equipment performs a descending action according to the displacement direction of the handle;

judging whether the opening degree of the handle is within a first preset range when it is determined that the mechanical equipment performs a descending action;

controlling the closed circuit to output the hydraulic oil in the first circulation direction when it is determined that the opening degree of the handle is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

[0018] In the embodiment of the present application, when the opening degree of the handle is within the first preset range, the descending speed of the mechanical equipment satisfies the following formula:

$$V = \alpha(\Delta Q - Q);$$

wherein, V is the descending speed of the mechanical

equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

[0019] In an embodiment of the present application, the control method further includes:

controlling the closed circuit to output hydraulic oil in the second circulation direction when the opening degree of the handle is within a second preset range; wherein the opening degree of the second preset range is greater than the opening degree of the first preset range.

[0020] In the embodiment of the present application, when the opening degree of the handle is within the second preset range, the descending speed of the mechanical equipment satisfies the following formula:

$$V = \alpha(\Delta Q + Q);$$

wherein, V is the descending speed of the mechanical equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

[0021] A third aspect of an embodiment of the present application provides lifting equipment including the hydraulic-pressure-based control system as described above.

[0022] A fourth aspect of an embodiment of the present application provides crawler-type traveling equipment including the hydraulic-pressure-based control system as described above.

[0023] According to the above technical solutions, when the mechanical equipment performs a descending action, the closed circuit is controlled to output hydraulic oil in the first circulation direction (that is, the direction in which the mechanical equipment performs an ascending action), and the output hydraulic oil can compensate for a speed decline caused by the leakage of the closed pump and motor of the closed circuit, so as to realize the micro-motion control of the hydraulic-pressure-based control system, thereby improving the maneuverability of the mechanical equipment, reducing the opening impact, and further improving the safety of the hydraulic-pressure-based control system.

[0024] Other features and advantages of the present application will be described in detail in the Detailed Description section that follows.

Brief Description of Drawings

[0025] The accompanying drawings are included to provide a further understanding of the application and constitute a part of this specification, and together with the detailed description below serve to explain the application, but are not to be construed as limiting the application. In the drawings:

FIG. 1 is a structural schematic diagram of a hydraulic-pressure-based control system according to an embodiment of the present application;

FIG. 2 is a structural schematic diagram of a handle according to an embodiment of the present application;

FIG. 3 is a schematic diagram of a function relationship between the opening degree of the handle and the current input to a closed circuit of a controller in the prior art;

FIG. 4 is a schematic diagram of a functional relationship between the opening degree of the handle and the current input to the closed circuit by the controller in an embodiment of the present application; FIG. 5 is a structural schematic diagram of a closed circuit according to an embodiment of the application;

FIG. 6 is a schematic diagram of hydraulic oil circulation of the closed circuit according to an embodiment of the application;

FIG. 7 is a schematic diagram of hydraulic oil circulation of the closed circuit according to another embodiment of the present application;

FIG. 8 is a structural schematic diagram of the closed circuit according to another embodiment of the present application;

FIG. 9 is a flowchart illustrating a hydraulic-pressure-based control method according to an embodiment of the present application; and

FIG. 10 is a flowchart illustrating the hydraulic-pressure-based control method according to another embodiment of the present application.

[0026] In the drawings: 100, handle; 200, closed circuit; 300, controller; 210, motor; 220, closed pump; 230, working pipeline; 240, pressure sensor; 250, rotational speed sensor; 221, variable pump; 222, variable pump control oil path; 231, first working pipeline; 232, second working pipeline.

Detailed Description of the Embodiments

[0027] Detailed descriptions of specific embodiments of the present application are set forth below with reference to the accompanying drawings. It should be understood that the specific embodiments described herein are merely illustrative and explanatory of the present application, and are not intended to limit the present application.

[0028] It should be noted that, if the embodiments of the present application relate to directionality indications (such as up, down, left, right, front, back,...), the directionality indications are used only for explaining the relative positional relationship, movement, etc. between components in a particular attitude (as shown in the drawings), and if the particular attitude is changed, the directionality indications are changed accordingly.

[0029] In addition, if there are descriptions of "first",

"second", etc. in the embodiments of the present application, the descriptions of "first", "second", etc. are used for descriptive purposes only, and cannot be understood to indicate or imply relative importance thereof or to implicitly indicate the number of technical features indicated. Thus, features defined as "first" and "second" may explicitly or implicitly include at least one of such features. In addition, the technical solutions of the various embodiments may be combined with each other, but must be based on the realization of those skilled in the art. When the combination of technical solutions is contradictory or cannot be realized, it should be considered that such combination of technical solutions does not exist, nor is it within the scope of protection required by the present application.

[0030] FIG. 1 is a structural schematic diagram of a hydraulic-pressure-based control system according to an embodiment of the present application. As shown in FIG. 1, an embodiment of the present application provides a hydraulic-pressure-based control system, applied to mechanical equipment, the mechanical equipment including a hoisting mechanism or a travelling mechanism, and the control system may include:

a handle 100, which is displaced according to an operation by a user, a displacement direction of the handle 100 corresponding to an action direction of the mechanical equipment;

a closed circuit 200, wherein a circulation direction of hydraulic oil in the closed circuit 200 includes a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action; and

a controller 300, which is connected to the handle 100 and the closed circuit 200, and is configured to:

judge whether the mechanical equipment performs a descending action according to the displacement direction of the handle 100;

judge whether the opening degree of the handle 100 is within a first preset range when it is determined that the mechanical equipment performs a descending action;

control the closed circuit 200 to output the hydraulic oil in the first circulation direction when it is determined that the opening degree of the handle 100 is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

[0031] In an embodiment of the present application, the mechanical equipment may include, but is not limited to, lifting equipment or crawler-type traveling equipment, the lifting equipment including a hoisting mechanism, and

the crawler-type traveling equipment including a traveling mechanism. The hoisting mechanism of the lifting equipment may control ascending and descending of the lifting equipment, the traveling mechanism of the crawler-type traveling equipment may control advancing and retracting of the crawler-type traveling equipment, and the crawler-type traveling equipment may include four traveling states: uphill advance, uphill retreat, downhill advance and downhill retreat.

[0032] The hydraulic-pressure-based control system of an embodiment of the present application includes a handle 100, a closed circuit 200, and a controller 300. The controller 300 is connected to the handle 100 and the closed circuit 200, respectively.

[0033] FIG. 2 is a structural schematic diagram of a handle according to an embodiment of the present application. As shown in FIG. 2, the handle 100 may be displaced according to a user's operation, and the controller 300 may determine the action direction of the mechanical equipment according to the displacement direction of the handle 100. Wherein, the displacement direction may include, but is not limited to, front, back, left, right, etc. For example, it is assumed that displacement of the handle 100 to the left corresponds to an ascending action of the mechanical equipment, and displacement of the handle 100 to the right corresponds to a descending action of the mechanical equipment. When the user moves the handle 100 to the left, the mechanical equipment performs an ascending action; when the user moves the handle 100 to the right, the mechanical equipment performs a descending action.

[0034] In the present embodiment, the handle 100 has a certain idle stroke. As shown in FIG. 2, the handle 100 has no output within a range of 0 to β . When the angle of β is reached, the controller 300 may output a corresponding current signal to the closed circuit 200 according to the opening degree of the handle 100.

[0035] In an embodiment of the present application, the circulation direction of the hydraulic oil in the closed circuit 200 may include a first circulation direction and a second circulation direction. When the circulation direction of the hydraulic oil is the first circulation direction, the mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action.

[0036] For example, the displacement of the handle 100 to the right corresponds to a descending direction of the mechanical equipment.

[0037] FIG. 3 is a schematic diagram of a function relationship between the opening degree of the handle and the current input to a closed circuit of a controller in the prior art. As shown in the FIG.3, in the prior art, the controller 300 controls the hydraulic oil of the closed circuit 200 to be output in the second circulation direction when acquiring the action of displacement of the handle 100 to the right, so that the circulation direction of the closed circuit 200 is the second circulation direction, further

causing the mechanical equipment to perform a descending action. The handle 100 has no output within the range of 0 to β . When the angle of β is reached, the controller 300 may input a minimum current i_{min} to the closed circuit 200. As the opening degree of the handle 100 increases, the current input by the controller 300 to the closed circuit 200 increases, so does the descending speed of the mechanical equipment. When the opening degree of the handle 100 reaches the maximum opening degree, the current input to the closed circuit 200 by the controller 300 reaches the maximum current i_{max} , and at this time, the flow of the hydraulic oil of the closed circuit and the descending speed of the mechanical equipment reach the maximum. The currents output by the above processes are all co-currents. Since there is internal leakage in both the motor and the closed pump in the closed circuit 200, the higher the pressure of the closed circuit, the greater the amount of internal leakage, the corresponding phenomena are: as soon as the brake cylinder is opened when the lifting equipment lifts the weight, the weight slides down quickly, which may cause the weight to bump into or crush other objects; or the crawler-type traveling equipment has a fast downward speed at the beginning, and cannot reduce the speed to achieve micro-motion, so the maneuverability is not good.

[0038] Therefore, after the controller 300 of the embodiment of the present application acquires the action of displacement of the handle 100 to the right, when the opening degree of the handle 100 is within a range such as γ , the closed circuit 200 is controlled to output the hydraulic oil in the first circulation direction such that the circulation direction of the closed circuit 200 is the first circulation direction (i.e., the direction in which the mechanical equipment performs the ascending action), and the output hydraulic oil causes the mechanical equipment to perform the ascending action, while the internal leakage of the closed pump and the motor in the closed circuit 200 causes the mechanical equipment to perform the descending action. It is assumed that the sum of the internal leakage amounts of the closed pump and the motor of the closed circuit 200 is ΔQ which causes the weight to fall, and the falling speed of the weight is proportional to ΔQ : $\Delta V = \alpha \Delta Q$, wherein α is a constant. When the mechanical equipment falls, the closed pump itself outputs the flow Q , at this moment, the descending speed is $V = \alpha(\Delta Q - Q)$, wherein Q is the flow output by the controller 300 in the first circulation direction of the closed circuit 200, when $Q = \Delta Q$, then the descending speed of the mechanical equipment can be controlled to be zero, the value of Q is gradually decreased, and the descending speed can be gradually increased to achieve controlled micro-motion of the speed from zero. When $Q = 0$, the speed is the speed caused entirely by internal leakage. If the descending speed needs to continue to increase, the controller then controls the closed circuit 200 to output the hydraulic oil in the second circulation direction, and the speed is restored to $V = \alpha(\Delta Q + Q)$. FIG. 4 is a schematic diagram of a functional relationship be-

tween the opening degree of the handle and the current input to the closed circuit by the controller in an embodiment of the present application. As shown in FIG. 4, the handle 100 has no output within a range of 0- β . When the angle of β is reached, the controller 300 may input the current i_a to the closed circuit 200. Wherein, i_a is determined by the leakage amount of the closed pump at the current operating condition of the closed circuit 200, i_a causes the closed circuit 200 to output the hydraulic oil in the first circulation direction, and the output flow Q is equal to the sum of the internal leakage amounts of the closed circuit at the current operating condition. As the opening degree of the handle 100 increases to γ , the current input by the controller 300 to the closed circuit 200 is gradually reduced to a minimum current i_{min} . If the opening degree of the handle 100 is increased after reaching γ , the controller controls the closed circuit 200 to output the hydraulic oil in the second circulation direction, and the current is increased stepwise with the opening degree of the handle 100 from the minimum current i_{min} until reaching the maximum current i_{max} . In the above control, the opening degree of the handle 100 is a micro-motion region in the range of $\beta \sim \gamma$, wherein the range of $\beta \sim \gamma$ is a first preset range in the embodiment of the present application. At the angle of β , the descending speed of the mechanical equipment is completely zero; when the opening degree is greater than the angle of γ , the speed is determined by the amount of internal leakage of the closed circuit 200, and the descending speed of the mechanical equipment in this range is controlled according to the opening degree ratio of the handle 100, and the maneuverability is good.

[0039] By the above technical solution, when the mechanical equipment performs a descending action, the closed circuit is controlled to output the hydraulic oil to the first circulation direction, i.e., a direction in which the mechanical equipment performs an ascending action, the output hydraulic oil can compensate for the speed decline caused by the leakage of the closed pump and the motor of the closed circuit to realize the micro-motion control of the hydraulic-pressure-based control system, which can improve the maneuverability of the mechanical equipment, reduce the opening impact, and thus improve the safety of the hydraulic-pressure-based control system.

[0040] In an embodiment of the present application, the controller 300 may be further configured to:

control the closed circuit 200 to output the hydraulic oil to the second circulation direction when the opening degree of the handle 100 is within the second preset range;
wherein, the opening degree of the second preset range is greater than the opening degree of the first preset range.

[0041] As shown in FIG. 4, the first preset range in the embodiment of the present application is the range of

$\beta \sim \gamma$, and the opening degree of the handle 100 is a micro-motion region in the range of $\beta \sim \gamma$. The controller 300 controls the closed circuit 200 to output the hydraulic oil in the first circulation direction such that the circulation direction of the closed circuit 200 is the first circulation direction (i.e., the direction in which the mechanical equipment performs the ascending action) to realize the micro-motion control of the hydraulic-pressure-based control system.

[0042] The second preset range in the embodiment of the present application is that the opening degree of the handle 100 is greater than the angle of γ . When the opening degree is within the second preset range, i.e., the opening degree of the handle 100 is greater than the angle of γ , the controller controls the closed circuit 200 to output the hydraulic oil to the second circulation direction. At this time, the speed of the mechanical equipment is determined by the amount of internal leakage of the closed circuit 200, and the descending speed of the mechanical equipment is controlled in accordance with the opening degree ratio of the handle 100, and the maneuverability is good.

[0043] In an embodiment of the present application, the displacement direction of the handle 100 includes a first displacement direction and a second displacement direction, the first displacement direction corresponding to the ascending action of the mechanical equipment, and the second displacement direction corresponding to the descending action of the mechanical equipment.

[0044] Specifically, the handle 100 can be displaced according to the operation of the user, and the controller 300 can determine the action direction of the mechanical equipment according to the displacement direction of the handle 100. Wherein, the displacement direction may include, but is not limited to, front, back, left, right, etc. For example, it is assumed that the first displacement direction of the handle 100 is displacement to the left and the second displacement direction is displacement to the right. The displacement of the handle 100 to the left corresponds to the ascending action of the mechanical equipment, and displacement of the handle 100 to the right corresponds to the descending action of the mechanical equipment. When the user moves the handle 100 to the left, the mechanical equipment performs the ascending action; when the user moves the handle 100 to the right, the mechanical equipment performs the descending action.

[0045] It should be noted that the displacement direction in the embodiment of the present application is not limited to the above-mentioned front, rear, left and right, but may be any other displacement direction corresponding to the action direction of the mechanical equipment. Also, the displacement direction of the handle 100 is not limited to two displacement directions, and a plurality of displacement directions corresponding to the action direction of the mechanical equipment may be provided as necessary.

[0046] FIG. 5 is a structural schematic diagram of a

closed circuit according to an embodiment of the application. As shown in FIG. 5, in an embodiment of the present application, the closed circuit 200 may include:

- 5 a motor 210, which is used for driving a hoisting mechanism or a traveling mechanism of the mechanical equipment to work;
- a closed pump 220, which is connected with the motor 210 through a working pipeline 230 for driving the motor 210; and
- 10 the working pipelines 230, which connect the motor 210 with the closed pump 220, the working pipelines 230 including a high-pressure working pipeline and a low-pressure working pipeline.

[0047] In the embodiment of the present application, the closed circuit 200 generally consists of a motor 210 and a closed pump 220. The motor 210 and the closed pump 220 are connected by working pipelines 230. In operation of the closed circuit 200, at least one of the working pipelines 230 is a high-pressure working pipeline and the other is a low-pressure working pipeline. The closed pump 220 drives the motor 210 to perform forward or reverse rotation, and the motor 210 drives the hoisting mechanism or the traveling mechanism of the mechanical equipment to work by forward or reverse rotation.

[0048] As shown in FIG. 5, in the present embodiment, the working pipelines 230 may include a first working pipeline 231 and a second working pipeline 232; the closed pump 220 may include a first working oil port P1, a second working oil port P2, and a closed pump oil discharge port T; the motor 210 may include a first motor oil port A, a second motor oil port B, and a motor oil discharge port U; the first working oil port P1 may be connected to the first motor oil port A through the first working pipeline 231, and the second working oil port P2 may be connected to the second motor oil port B through the second working pipeline 232.

[0049] In the embodiment of the present application, the closed pump 220 may include a first working oil port P1 and a second working oil port S1, and the motor 210 may include a first motor oil port A and a second motor oil port B, the first working oil port P1 and the first motor oil port A may be connected by the first working pipeline 231, and the second working oil port S1 and the second motor oil port B may be connected by the second pipeline 232.

[0050] FIG. 6 is a schematic diagram of hydraulic oil circulation of the closed circuit according to an embodiment of the application. As shown in FIG. 6, when the mechanical equipment performs an ascending action, the first working oil port P1 outputs the hydraulic oil, the hydraulic oil reaches the first motor oil port A of the motor 210 and enters the motor 210 through a path of the first working oil port P1-the first working pipeline 231-the first motor oil port A, and the motor 210 is rotated to achieve the ascending action of the mechanical equipment. The hydraulic oil is then outputted from the second motor oil

port B, passes the path of the second motor oil port B-the second working pipeline 232-the second working oil port S1, is sucked into the closed pump through the second working oil port S1, and is outputted through the first working oil port P1, and the above process repeats. The hydraulic oil circulation direction is shown in FIG. 6.

[0051] FIG. 7 is a schematic diagram of hydraulic oil circulation of the closed circuit according to another embodiment of the present application. As shown in FIG. 7, when the mechanical equipment performs the descending action, the second working oil port S1 outputs the hydraulic oil, the hydraulic oil reaches the second motor oil port B of the motor 210 and enters the motor 210 through a path of the second working oil port S1-the second working pipeline 232-the second motor oil port B, and the motor 210 is rotated to achieve the descending action of the mechanical equipment. The hydraulic oil is then outputted from the first motor oil port A, passes the path of the first motor oil port A-the first working pipeline 231-the first working oil port P1, is sucked into the closed pump through the first working oil port P1, and is outputted through the second working oil port S1, and the above process repeats. The hydraulic oil circulation direction is shown in FIG. 7.

[0052] In an embodiment of the present application, the closed pump 220 may include:

a variable pump 221 for outputting hydraulic oil; and
a variable pump control oil path 222 connected to the variable pump 221 for determining an output direction and a discharge amount of hydraulic oil of the variable pump 221.

[0053] In the embodiment of the present application, the variable pump control oil path 222 may include a first pilot proportional valve Y1, a second pilot proportional valve Y2, and a variable adjusting mechanism;

[0054] First ends of the first pilot proportional valve Y1 and the second pilot proportional valve Y2 are respectively connected with two ends of the variable adjusting mechanism, second ends of the first pilot proportional valve Y1 and the second pilot proportional valve Y2 are respectively connected with an oil replenishment device; the push rod of the variable adjusting mechanism is connected with the swash plate of the variable pump 221 to adjust the output direction and the discharge amount of the hydraulic oil.

[0055] Specifically, the variable pump control oil path 222 is used to determine an output direction and a discharge amount of the hydraulic oil of the variable pump 221. The variable pump 221 in the closed pump 220 includes a first working oil port P1, a second working oil port S1, and a closed pump oil discharge port T. The variable pump control oil path includes a first pilot proportional valve Y1, a second pilot proportional valve Y2, and a variable adjusting mechanism. The push rod of the variable adjusting mechanism is connected with the swash plate of the variable pump 221. The input current

values of the first pilot proportional valve Y1 and the second pilot proportional valve Y2 can be adjusted by adjusting the opening degree of the operating handle, since the output amount of the pilot proportional valve varies with the change in the current value. Therefore, the greater the value of the current input by the first pilot proportional valve Y1, the higher the forward rotational speed of the motor 210, and the greater the value of the current input by the second pilot proportional valve Y2, the higher the reverse rotational speed of the motor 210. By controlling the variable pump 221 through the variable pump control oil path 222, the hydraulic oil flow of the hydraulic-pressure-based control system can be controlled, thereby controlling the rotational speed of the motor 210.

[0056] In the embodiment of the present application, when the first pilot proportional valve Y1 is energized, the hydraulic oil is outputted by the first working oil port P1, the motor 210 can drive the mechanical equipment to perform an ascending action; when the second pilot proportional valve Y2 is energized, the hydraulic oil is output by the second working oil port S1, and the motor 210 can drive the mechanical equipment to perform a descending action.

[0057] In particular, when the first pilot proportional valve Y1 is energized, the first working oil port P1 outputs the hydraulic oil, the hydraulic oil reaches the first motor oil port A of the motor 210 and enters the motor 210 through a path of the first working oil port P1-the first working pipeline 231-the first motor oil port A, and the motor 210 is rotated to achieve the ascending action of the mechanical equipment. The hydraulic oil is then outputted from the second motor oil port B, passes the path of the second motor oil port B-the second working pipeline 232-the second working oil port S1, is sucked into the closed pump through the second working oil port S1, and is outputted through the first working oil port P1, and the above process repeats. The hydraulic oil circulation direction is shown in FIG. 6.

[0058] When the second pilot proportional valve Y2 is energized, the second working oil port S1 outputs the hydraulic oil, the hydraulic oil reaches the second motor oil port B of the motor 210 and enters the motor 210 through a path of the second working oil port S1-the second working pipeline 232-the second motor oil port B, and the motor 210 is rotated to achieve the descending action of the mechanical equipment. The hydraulic oil is then outputted from the first motor oil port A, passes the path of the first motor oil port A-the first working pipeline 231-the first working oil port P1, is sucked into the closed pump through the first working oil port P1, and is outputted through the second working oil port S1, and the above process repeats. The hydraulic oil circulation direction is shown in FIG. 7.

[0059] In the embodiment of the present application, when the opening degree of the handle 100 is within the first preset range, the opening degree of the handle 100 is in the micro-motion region. For example, when the opening degree of the handle 100 reaches an angle of

β , the controller 300 controls the first pilot proportional valve Y1 to be energized, the first working oil port P1 outputs the hydraulic oil, the hydraulic oil reaches the first motor oil port A of the motor 210 and enters the motor 210 through a path of the first working oil port P1-the first working pipeline 231-the first motor oil port A, and the motor 210 is rotated to achieve the ascending action of the mechanical equipment. As the opening degree of the handle 100 increases to a second preset range, e.g., the opening degree of the handle 100 reaches an angle of γ , the current of the first pilot proportional valve Y1 decreases stepwise to a minimum current i_{min} . As the opening degree of the handle 100 is increased stepwise, the controller 300 controls the second pilot proportional valve Y2 to be energized, the second working oil port S 1 outputs the hydraulic oil, the hydraulic oil reaches the second motor oil port B of the motor 210 and enters the motor 210 through a path of the second working oil port S 1-the second working pipeline 232-the second motor oil port B, and the motor 210 is rotated to achieve the descending action of the mechanical equipment.

[0060] In this way, when the opening degree of the handle 100 is within the first preset range, the controller 300 may control the closed circuit to output the hydraulic oil to the first circulation direction (i.e., a direction in which the mechanical equipment performs the ascending action), the output hydraulic oil can compensate for the speed decline caused by the leakage of the closed pump and the motor of the closed circuit to realize the micro-motion control of the hydraulic-pressure-based control system, which can improve the maneuverability of the mechanical equipment, reduce the opening impact, and thus improve the safety of the hydraulic-pressure-based control system. When the opening degree of the handle 100 is within a second preset range, the controller 300 may control the closed circuit to output the hydraulic oil in a second circulation direction (i.e., a direction in which the mechanical equipment performs a descending action). In a second preset range, the speed of the mechanical equipment is determined by the amount of internal leakage of the closed circuit 200. In this range, the descending speed of the mechanical equipment is controlled in accordance with the opening degree ratio of the handle 100, and the maneuverability is good.

[0061] As shown in FIG. 5, in an embodiment of the present application, the closed circuit 200 may further include:

a pressure sensor 240, which is connected to the high-pressure working pipeline for obtaining a system pressure of the closed circuit.

[0062] In the embodiment of the present application, the load of the mechanical equipment is different under different operating conditions, so that the amount of internal leakage ΔQ of the closed circuit 200 is different, so that the current i_a input to the closed circuit 200 by the controller 300 is different. Therefore, the value of ΔQ is related to the system pressure of the closed circuit 200, thus the pressure sensor 240 may be connected at the

high-pressure working pipeline of the closed circuit 200 to obtain the system pressure of the closed circuit.

[0063] In an embodiment of the present application, the controller 300 may be further configured to:

determine a current value input to the closed pump 220 based on a system pressure of the closed circuit obtained by the pressure sensor 240.

[0064] In an embodiment of the present application, the relationship between the ΔQ and the system pressure P can be obtained experimentally, i.e., $\Delta Q = f(P)$ so as to determine the relationship between i_a and the system pressure P, $i_a = f_1(P)$. Accordingly, the current value i_a input by the controller 300 to the closed-loop 200 can be determined based on the system pressure obtained by the pressure sensor 240. In one example, the controller 300 can determine i_a from the last memorization of the system pressure P before the mechanical equipment performs the descending action to achieve precise micro-motion descending control.

[0065] Embodiments of the present application allow for greater accuracy in the micro-motion control of the hydraulic-pressure-based control system by providing the pressure sensor 240.

[0066] In the embodiment of the present application, when the motor 210 drives the hoisting mechanism of the mechanical equipment to work, the first working pipeline 231 is a high-pressure working pipeline, and the pressure sensor 240 may be provided on the first working pipeline 231.

[0067] Specifically, when the mechanical equipment is lifting equipment, the mechanical equipment includes a hoisting mechanism, and the motor 210 drives the hoisting mechanism of the mechanical equipment to hoist up or hoist down. Therefore, when the motor 210 drives the hoisting mechanism of the mechanical equipment to work, the first working pipeline 231 is a high-pressure working pipeline, and only one pressure sensor 240 is required to be provided on the first working pipeline 231 (i.e., the high-pressure working pipeline).

[0068] In the present embodiment, when the motor 210 drives the traveling mechanism of the mechanical equipment to work, the first working pipeline 231 or the second working pipeline 232 is a high-pressure working pipeline; the pressure sensor 240 may include a first pressure sensor and a second pressure sensor (not shown), the first pressure sensor may be arranged on the first working pipeline; a second pressure sensor may be arranged on the second working pipeline.

[0069] In particular, when the mechanical equipment is crawler-type traveling equipment, the mechanical equipment includes a traveling structure, the motor 210 drives the traveling mechanism of the mechanical equipment to go uphill, downhill, forward and backward, therefore, the high-low-pressure working pipelines of the hydraulic-pressure-based control system of the crawler-type traveling equipment are not fixed, the high-pressure working pipeline may be the first working pipeline 231 or the second working pipeline 232, therefore, two pressure

sensors (not shown in the figure) need to be provided. In this way, it is possible to obtain the system pressure of the closed circuit 200 by the mechanical equipment during descending in any operating condition, and to improve the accuracy of the current value input by the controller 300 to the closed circuit 200.

[0070] FIG. 8 is a structural schematic diagram of the closed circuit according to another embodiment of the present application. As shown in FIG. 8, in an embodiment of the present application, the closed circuit 200 may further include:

a rotational speed sensor 250, which is arranged on the motor 210 or a decelerator for acquiring a rotational speed of the motor 210.

[0071] The controller 300 may be further configured to: adjust the current value input to the closed pump 220 according to the rotational speed of the motor 210 acquired by the rotational speed sensor 250.

[0072] In an embodiment of the present application, a rotational speed sensor 250 may also be added to the motor 210 or decelerator to establish a relationship between the opening degree value of the handle 100 and the desired descending speed. When the mechanical equipment descends, the controller can detect the actual rotational speed of the motor 210 according to the actual position of the handle 100, compare the actual rotational speed of the motor 210 with the desired rotational speed, when the actual rotational speed of the motor 210 does not coincide with the desired rotational speed, the controller 300 adjusts the current value input to the closed pump 220. For example, if the desired rotational speed is 0.5 m/s and the actual rotational speed obtained by the rotational speed sensor 250 is 0.6 m/s, the rotational speed of the motor needs to be regulated. If the opening degree of the handle 100 at this time is in the first preset range, i.e., the micro-motion region, it is necessary to increase the current value inputted to the closed pump 220, i.e., increase the ascending speed of the mechanical equipment, to decrease the descending speed of the mechanical equipment; if the opening degree of the handle 100 is within the second preset range at this time, it is necessary to reduce the current value input to the closed pump 220, i.e., reduce the descending speed of the mechanical equipment, thereby achieving a precise control of the rotational speed.

[0073] It should be noted that the rotational speed sensor 250 of the present embodiment may be provided on the motor 210 or the decelerator, but may also be provided on other devices that can obtain the actual rotational speed of the motor 210.

[0074] In an embodiment of the present application, the closed circuit may further include:

- a pressure sensor, which is connected with the high-pressure working pipeline for acquiring a system pressure of the closed circuit; and
- a rotational speed sensor, which is arranged on the motor or a decelerator for acquiring a rotational

speed of the motor;
the controller is further configured to:

- determine a current value input to the closed pump according to a system pressure of the closed circuit acquired by the pressure sensor; and
- perform closed-loop correction on the current value according to the motor rotational speed acquired by the rotational speed sensor.

[0075] In an embodiment of the present application, the relationship between ΔQ and the system pressure P can be obtained experimentally, i.e., $\Delta Q = f(P)$ so as to determine the relationship between i_a and the system pressure P , $i_a = f_1(P)$. Thus, the current value i_a input by the controller to the closed circuit can be determined based on the system pressure obtained by the pressure sensor.

[0076] In the embodiment of the present application, on the basis of obtaining the pressure of the system and obtaining the value of the current input by the controller to the closed circuit, it is also possible to add a rotational speed sensor to the motor or the decelerator to establish the relationship between the opening degree value of the handle and the desired descending speed. While the mechanical equipment descends, the controller can detect the actual rotational speed of the motor according to the actual position of the handle, compare the actual rotational speed of the motor with the desired rotational speed, when the actual rotational speed of the motor does not coincide with the desired rotational speed, the controller adjusts the current value input to the closed pump. For example, if the desired rotational speed is 0.5 m/s, and the actual rotational speed obtained by the rotational speed sensor is 0.6 m/s, the rotational speed of the motor needs to be reduced. If the opening degree of the handle at this time is in the first preset range, i.e., the micro-motion region, it is necessary to increase the current value inputted to the closed pump, i.e., to increase the ascending speed of the mechanical equipment, to decrease the descending speed of the mechanical equipment; if the opening degree of the handle is in the second preset range at this time, it is necessary to reduce the current value input to the closed pump, i.e., to reduce the descending speed of the mechanical equipment. In this way, closed-loop correction of the control value monitored by the pressure sensor can be achieved, thereby achieving a more accurate control of the rotational speed.

[0077] The embodiments of the present application implement both the rotational speed sensor and the pressure sensor, monitoring of the pressure sensor gives a control value, and closed-loop correction is performed using the rotational speed sensor to achieve more accurate control of the rotational speed.

[0078] FIG. 9 is a flowchart illustrating a hydraulic-pressure-based control method according to an embodiment of the present application. As shown in FIG. 9, an em-

bodiment of the present application provides a hydraulic-pressure-based control method, applied to a controller of mechanical equipment, the controller is connected with a handle and a closed circuit, the handle is displaced according to an operation by a user, a displacement direction of the handle corresponding to an action direction of the mechanical equipment, a circulation direction of hydraulic oil in the closed circuit includes a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action, the control method including:

step S91, whether the mechanical equipment performs a descending action is judged according to the displacement direction of the handle;

step S92, whether the opening degree of the handle is within a first preset range is judged when it is determined that the mechanical equipment performs a descending action;

step S93, the closed circuit is controlled to output the hydraulic oil in the first circulation direction when it is determined that the opening degree of the handle is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

[0079] In an embodiment of the present application, after the controller of the embodiment of the present application acquires the action of displacement of the handle to the right, when the opening degree of the handle is within a range such as y , the closed circuit is controlled to output the hydraulic oil in the first circulation direction such that the circulation direction of the closed circuit is the first circulation direction (i.e., the direction in which the mechanical equipment performs the ascending action), and the output hydraulic oil causes the mechanical equipment to perform the ascending action, while the internal leakage of the closed pump and the motor in the closed circuit causes the mechanical equipment to perform the descending action.

[0080] By the above technical solution, when the mechanical equipment performs a descending action, the closed circuit is controlled to output hydraulic oil in the first circulation direction, i.e., a direction in which the mechanical equipment performs an ascending action, the output hydraulic oil can compensate for the speed decline caused by the leakage of the closed pump and the motor of the closed circuit to realize the micro-motion control of the hydraulic-pressure-based control system, which can improve the maneuverability of the mechanical equipment, reduce the opening impact, and thus improve the safety of the hydraulic-pressure-based control system.

[0081] In the embodiment of the present application,

when the opening degree of the handle is within the first preset range, the descending speed of the mechanical equipment satisfies the following formula:

$$V = \alpha(\Delta Q - Q);$$

wherein, V is the descending speed of the mechanical equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

[0082] In particular, it is assumed that the sum of the internal leakage amounts of the closed pump and the motor of the closed circuit 200 is ΔQ which causes the weight to fall with a falling speed proportional to ΔQ : $\Delta V = \alpha \Delta Q$, wherein α is a constant. When the mechanical equipment falls, the closed pump itself outputs the flow Q , at this moment, the descending speed is $V = \alpha(\Delta Q - Q)$, wherein Q is the flow output by the controller 300 in the first circulation direction of the closed circuit 200, when $Q = \Delta Q$, then the descending speed of the mechanical equipment can be controlled to be zero, the value of Q is gradually decreased, and the descending speed can be gradually increased to achieve controlled micro-motion of the speed from zero. When $Q = 0$, the speed is the speed caused entirely by internal leakage.

[0083] FIG. 10 is a flowchart illustrating a hydraulic-pressure-based control method according to another embodiment of the present application. As shown in FIG. 10, in an embodiment of the present application, the control method may further include:

step S94, when the opening degree of the handle is within a second preset range, the closed circuit is controlled to output the hydraulic oil to the second circulation direction;

wherein, the opening degree of the second preset range is greater than the opening degree of the first preset range.

[0084] In the embodiment of the present application, when the opening degree of the handle is within the second preset range, the descending speed of the mechanical equipment satisfies the following formula:

$$V = \alpha(\Delta Q + Q);$$

wherein, V is the descending speed of the mechanical equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

[0085] In the embodiment of the present application, If the descending speed needs to continue to increase, the controller then controls the closed circuit to output the hydraulic oil in the second circulation direction, and the speed is restored to $V = \alpha(\Delta Q + Q)$. FIG. 4 is a schematic diagram of a functional relationship between the opening

degree of the handle and the current input to the closed circuit by the controller in an embodiment of the present application. As shown in FIG. 4, the handle 100 has no output within a range of $0\sim\beta$. When the angle of β is reached, the controller may input current i_a to the closed circuit. Wherein, i_a is determined by the leakage amount of the closed pump at the current operating condition of the closed circuit, i_a causes the closed circuit to output the hydraulic oil in the first circulation direction, and the output flow Q is equal to the sum of the internal leakage amounts of the closed circuit at the current operating condition. As the opening degree of the handle increases to the angle of γ , the current input by the controller to the closed circuit is gradually reduced to a minimum current i_{min} . If the opening degree of the handle is increased after reaching the angle of γ , the controller controls the closed circuit to output the hydraulic oil in the second circulation direction, and the current is increased stepwise with the opening degree of the handle from the minimum current i_{min} until reaching the maximum current i_{max} . In the above control, the opening degree of the handle is a micro-motion region in the range of $\beta\sim\gamma$, wherein the range of $\beta\sim\gamma$ is a first preset range in the embodiment of the present application. At the angle of β , the descending speed of the mechanical equipment is completely zero; when the opening degree is greater than the angle of γ , the speed is determined by the amount of internal leakage of the closed circuit, and the descending speed of the mechanical equipment in this range is controlled according to the opening degree ratio of the handle, and the maneuverability is good.

[0086] Embodiments of the present application also provide lifting equipment including the hydraulic-pressure-based control system described above.

[0087] Embodiments of the present application also provide crawler-type traveling equipment including the hydraulic-pressure-based control system described above.

[0088] Preferred embodiments of the present application are described in detail above in conjunction with the accompanying drawings, however, the present application is not limited to the specific details in the above embodiments, within the scope of the technical idea of the present application, many simple variations can be made to the technical solutions of the present application, which all belong to the protection scope of the present application.

[0089] It is further noted that the various specific features described in the above embodiments can be combined in any suitable manner, insofar as they are not inconsistent. In order to avoid unnecessary repetition, various possible combinations are not further described herein.

[0090] In addition, any combination of the various embodiments of the present application can be made without departing from the spirit of the present application and should be considered as disclosed herein.

Claims

1. A hydraulic-pressure-based control system applied to mechanical equipment, the mechanical equipment comprising a hoisting mechanism or a traveling mechanism, **characterized in that** the control system comprises:

a handle, which is displaced according to an operation by a user, a displacement direction of the handle corresponding to an action direction of the mechanical equipment;

a closed circuit, wherein a circulation direction of hydraulic oil in the closed circuit comprises a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action; and

a controller, which is connected to the handle and the closed circuit, and is configured to:

judge whether the mechanical equipment performs a descending action according to the displacement direction of the handle; judge whether the opening degree of the handle is within a first preset range when it is determined that the mechanical equipment performs a descending action; and control the closed circuit to output the hydraulic oil in the first circulation direction when it is determined that the opening degree of the handle is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

2. The control system according to claim 1, **characterized in that** the controller is further configured to:

control the closed circuit to output hydraulic oil in the second circulation direction when the opening degree of the handle is within a second preset range;

wherein the opening degree of the second preset range is greater than the opening degree of the first preset range.

3. The control system according to claim 1, **characterized in that** the displacement direction of the handle comprises a first displacement direction and a second displacement direction, the first displacement direction corresponding to an ascending action of the mechanical equipment and the second displacement direction corresponding to a descending action

of the mechanical equipment.

4. The control system according to claim 1, **characterized in that** the closed circuit comprises:

a motor, which is used for driving the hoisting mechanism or the traveling mechanism of the mechanical equipment to work;
a closed pump, which is connected with the motor through working pipelines for driving the motor; and
the working pipelines, which connect the motor with the closed pump, the working pipelines comprising a high-pressure working pipeline and a low-pressure working pipeline.

5. The control system according to claim 4, **characterized in that** the closed circuit further comprises:
a pressure sensor, which is connected to the high-pressure working pipeline for obtaining a system pressure of the closed circuit.

6. The control system according to claim 5, **characterized in that** the controller is further configured to:
determine a current value input to the closed pump based on the system pressure of the closed circuit obtained by the pressure sensor.

7. The control system according to claim 5, **characterized in that**, the working pipelines comprise a first working pipeline and a second working pipeline; the closed pump comprises a first working oil port, a second working oil port and a closed pump oil discharge port; the motor comprises a first motor oil port, a second motor oil port, and a motor oil discharge port; the first working oil port is connected with the first motor oil port through the first working pipeline, and the second working oil port is connected with the second motor oil port through the second working pipeline.

8. The control system according to claim 7, **characterized in that** the first working pipeline is the high-pressure working pipeline and the pressure sensor is arranged on the first working pipeline when the motor drives the hoisting mechanism of the mechanical equipment to work.

9. The control system according to claim 7, **characterized in that** the first working pipeline or the second working pipeline is the high-pressure working pipeline when the motor drives the traveling mechanism of the mechanical equipment to work; the pressure sensor comprises a first pressure sensor and a second pressure sensor, the first pressure sensor is arranged on the first working pipeline; the second pressure sensor is arranged on the second working pipeline.

10. The control system according to claim 4, **characterized in that** the closed circuit further comprises:
a rotational speed sensor, which is arranged on the motor or a decelerator for acquiring a rotational speed of the motor.

11. The control system according to claim 10, **characterized in that** the controller is further configured to:
adjust a current value input to the closed pump according to the rotational speed of the motor acquired by the rotational speed sensor.

12. The control system according to claim 4, **characterized in that** the closed circuit further comprises:

a pressure sensor, which is connected with the high-pressure working pipeline for acquiring a system pressure of the closed circuit; and
a rotational speed sensor, which is arranged on the motor or a decelerator for acquiring a rotational speed of the motor;
the controller is further configured to:

determine a current value input to the closed pump according to a system pressure of the closed circuit acquired by the pressure sensor; and
perform closed-loop correction on the current value according to the motor rotational speed acquired by the rotational speed sensor.

13. A hydraulic-pressure-based control method, applied to a controller of mechanical equipment, **characterized in that**, the controller is connected with a handle and a closed circuit, the handle is displaced according to an operation by a user, a displacement direction of the handle corresponding to an action direction of the mechanical equipment, a circulation direction of hydraulic oil in the closed circuit comprises a first circulation direction and a second circulation direction; when the circulation direction of the hydraulic oil is the first circulation direction, mechanical equipment performs an ascending action; and when the circulation direction of the hydraulic oil is the second circulation direction, the mechanical equipment performs a descending action, the control method comprising:

judging whether the mechanical equipment performs a descending action according to the displacement direction of the handle;
judging whether the opening degree of the handle is within a first preset range when it is determined that the mechanical equipment performs a descending action; and
controlling the closed circuit to output the hydraulic oil in the first circulation direction when

it is determined that the opening degree of the handle is within the first preset range, so as to realise micro-motion control by the hydraulic-pressure-based control system.

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14. The control method according to claim 13, **characterized in that**, when the opening degree of the handle is within the first preset range, the descending speed of the mechanical equipment satisfies the following formula:

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$$V = \alpha(\Delta Q - Q);$$

wherein, V is the descending speed of the mechanical equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

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15. The control method according to claim 13, **characterized in that** the control method further comprises:

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controlling the closed circuit to output hydraulic oil in the second circulation direction when the opening degree of the handle is within a second preset range;

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wherein the opening degree of the second preset range is greater than the opening degree of the first preset range.

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16. The control method according to claim 15, **characterized in that**, when the opening degree of the handle is within the second preset range, the descending speed of the mechanical equipment satisfies the following formula:

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$$V = \alpha(\Delta Q + Q);$$

wherein, V is the descending speed of the mechanical equipment, α is a constant, ΔQ is the sum of internal leakage amounts of the closed circuit, and Q is the flow output by the closed circuit.

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17. Lifting equipment, **characterized by** comprising the hydraulic-pressure-based control system according to any one of claims 1 to 12.

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18. Crawler-type traveling equipment, **characterized by** comprising the hydraulic-pressure-based control system according to any one of claims 1 to 12.

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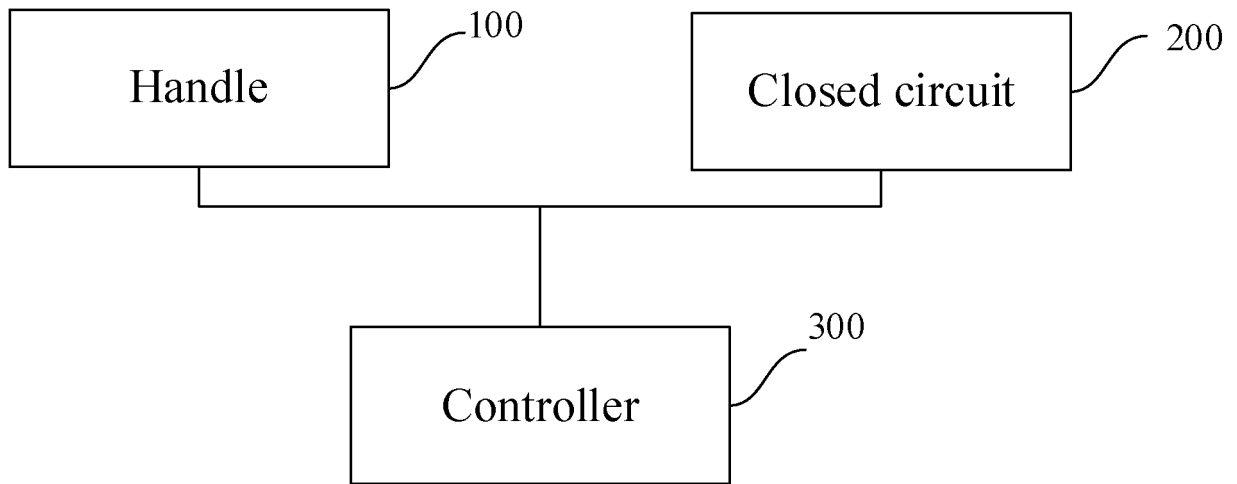


FIG. 1

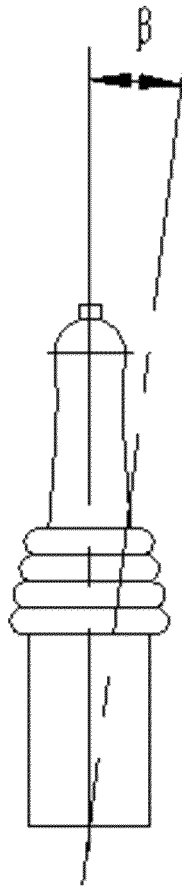


FIG. 2

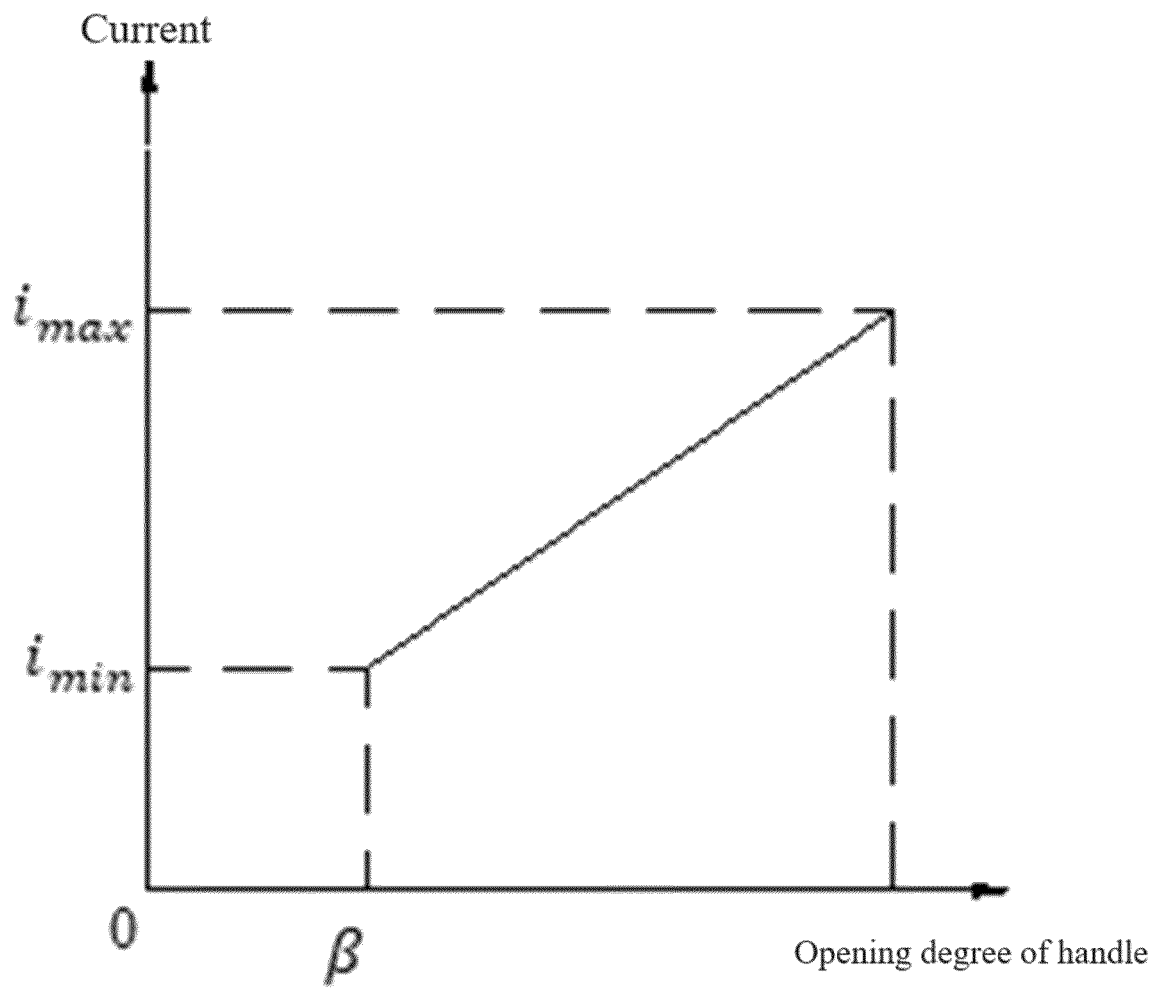


FIG. 3

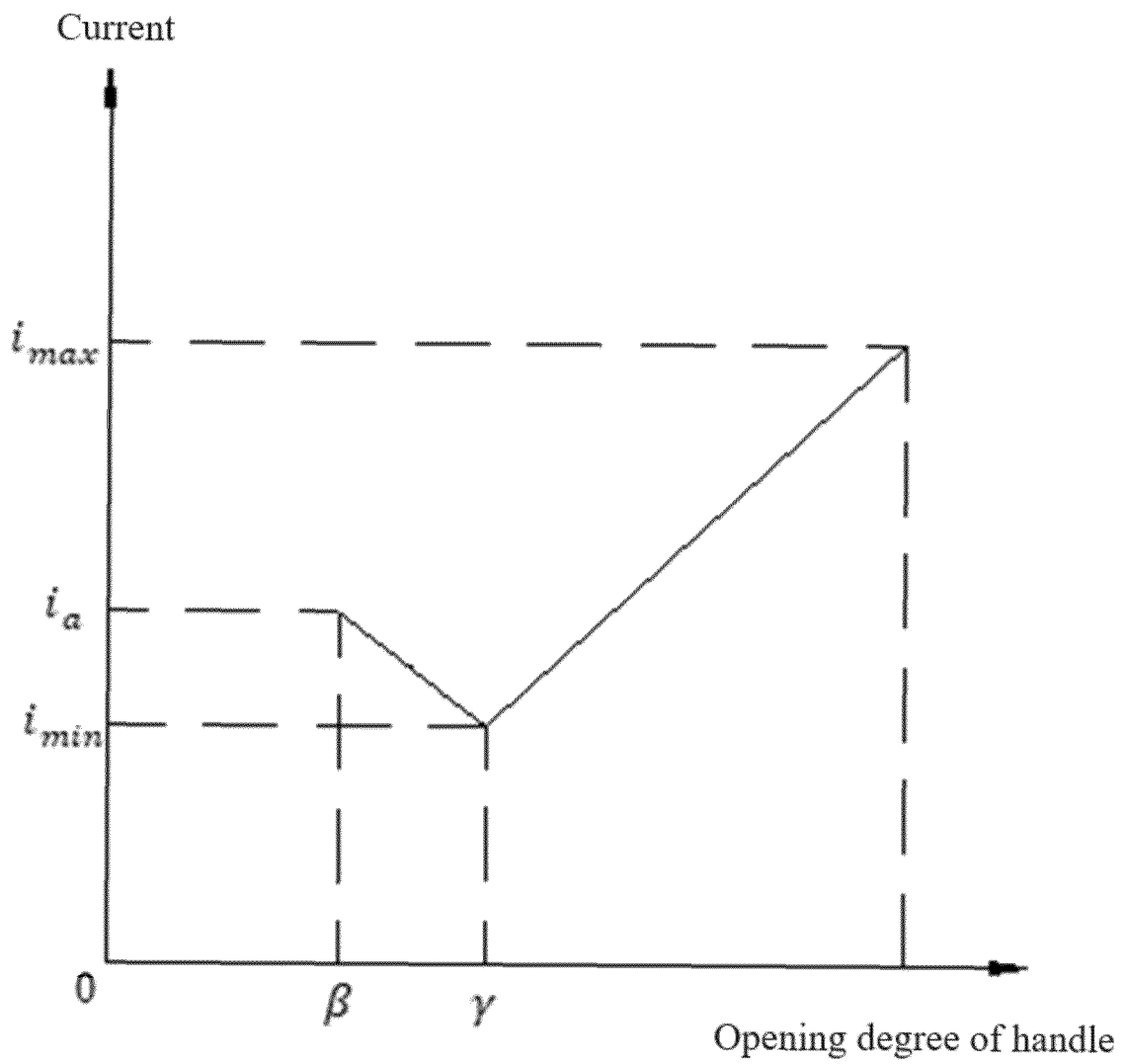


FIG. 4

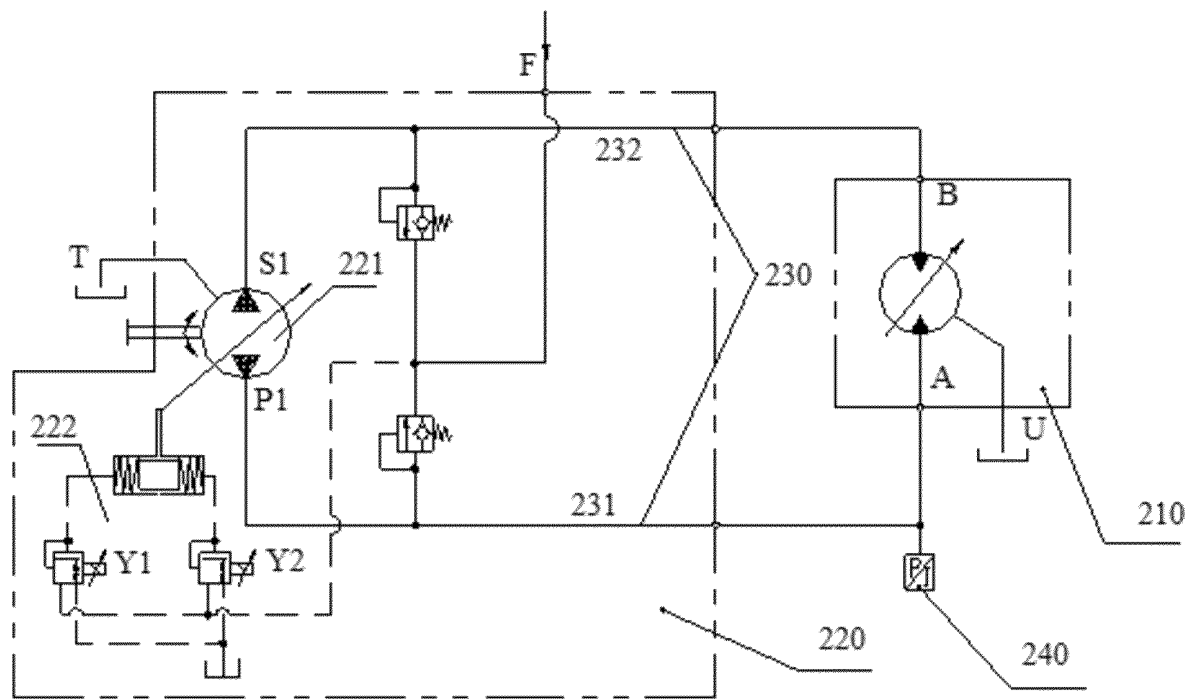


FIG. 5

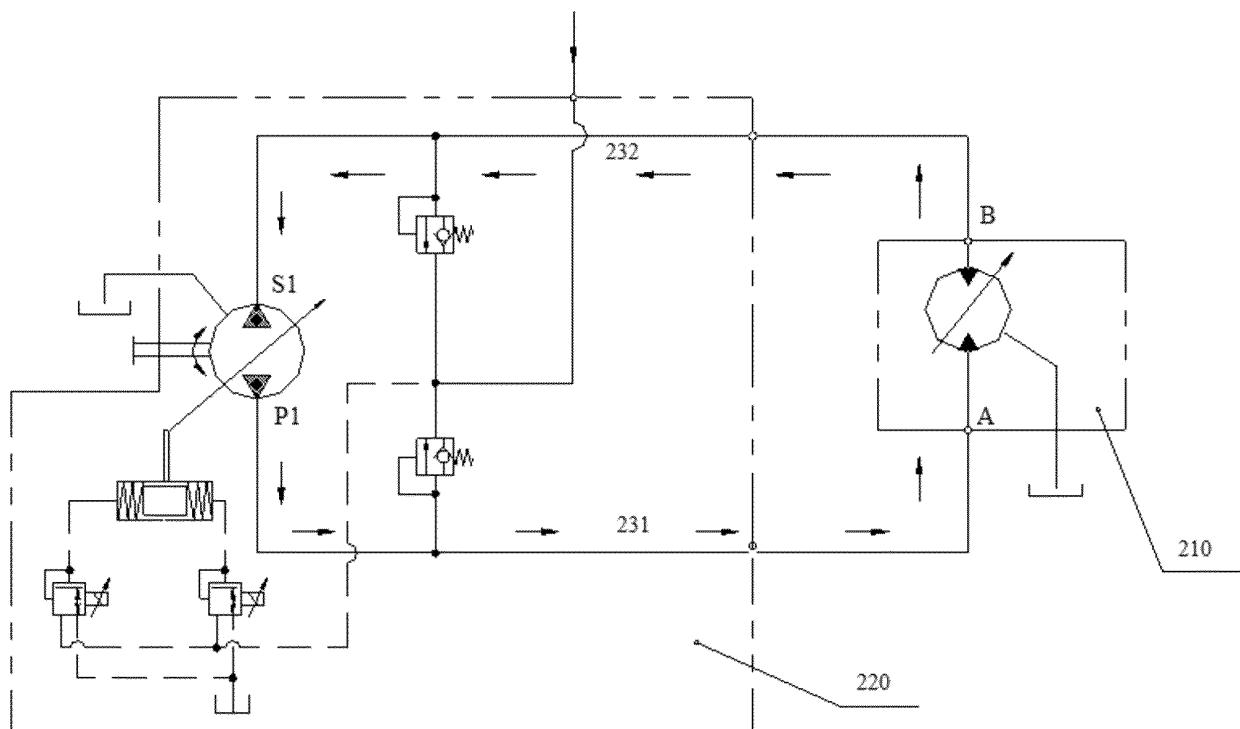


FIG. 6

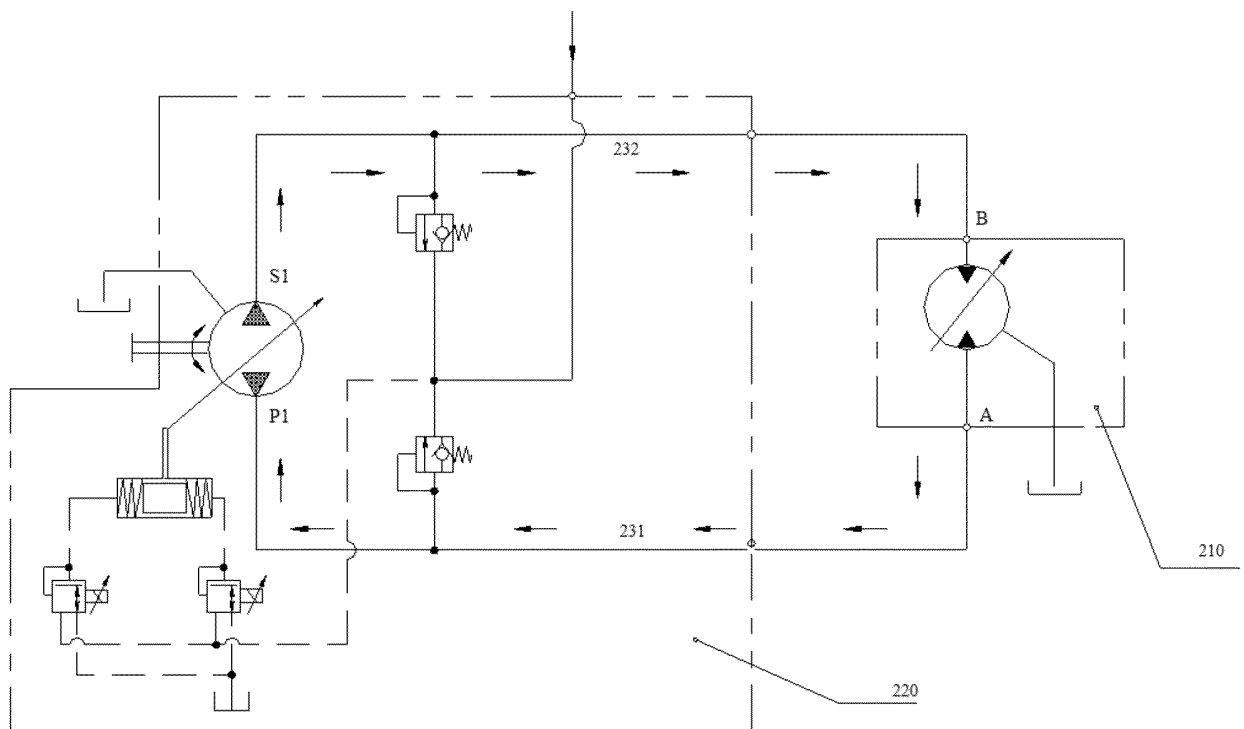


FIG. 7

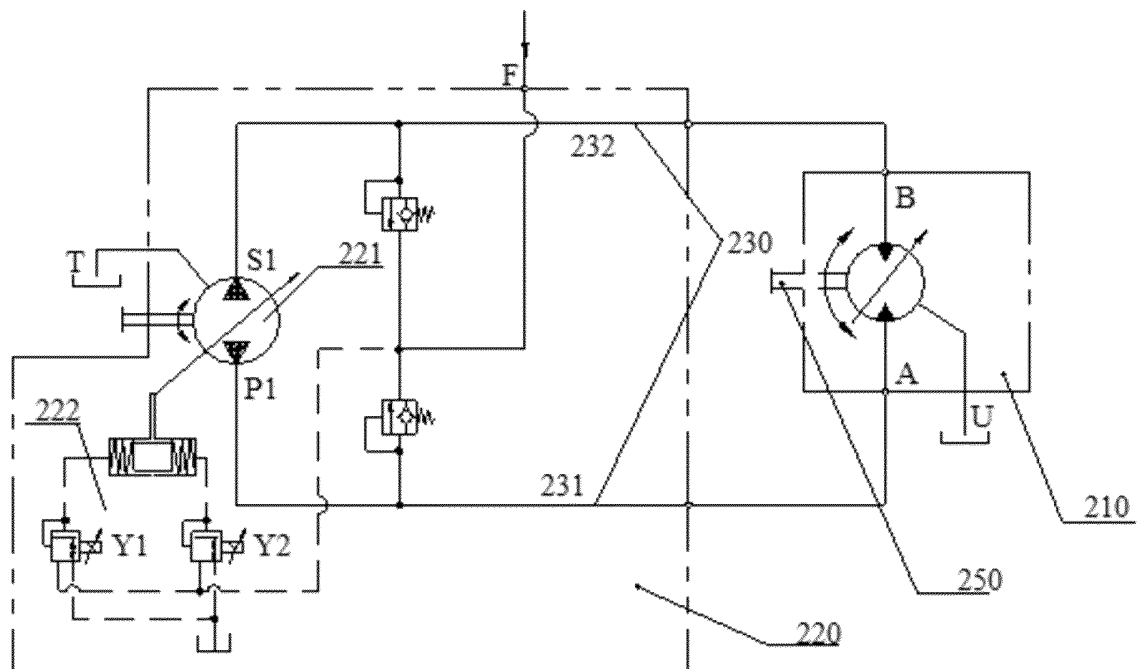


FIG. 8

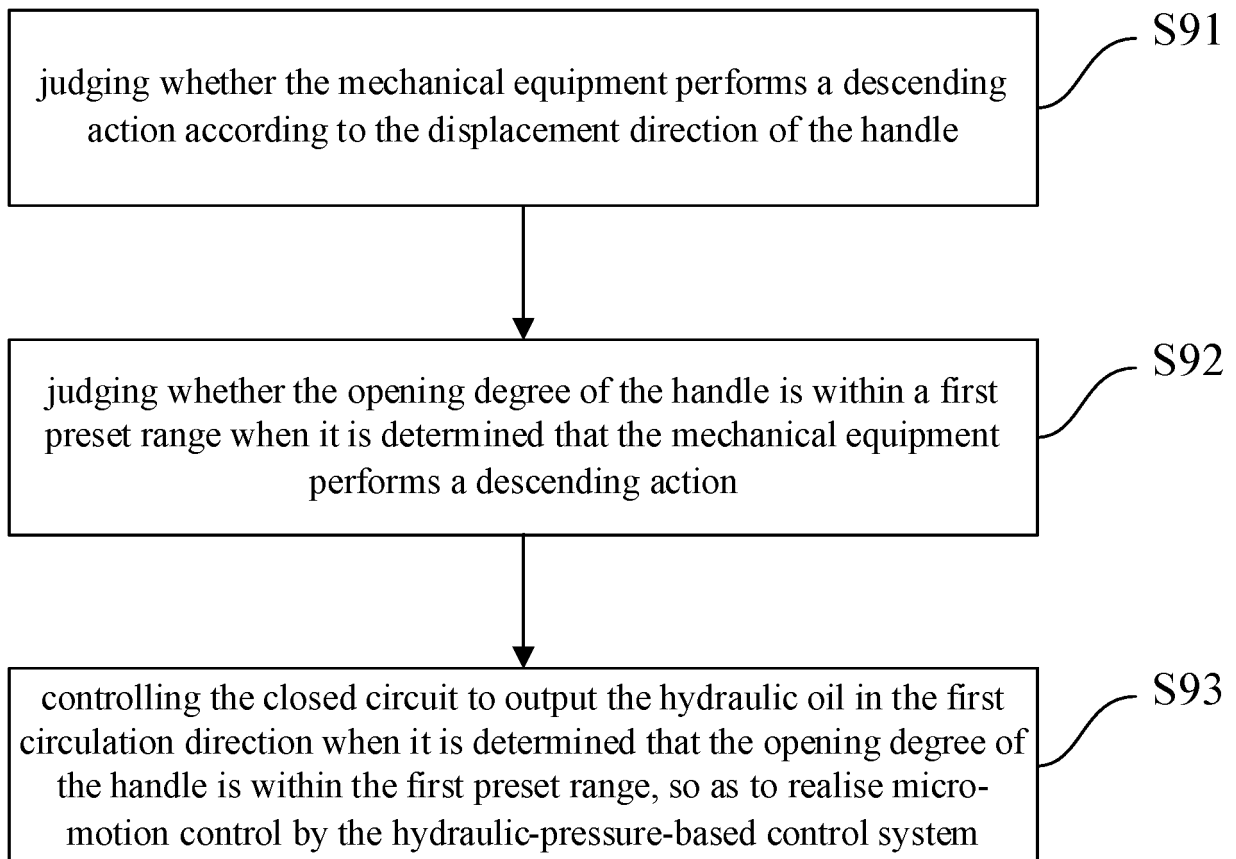


FIG. 9

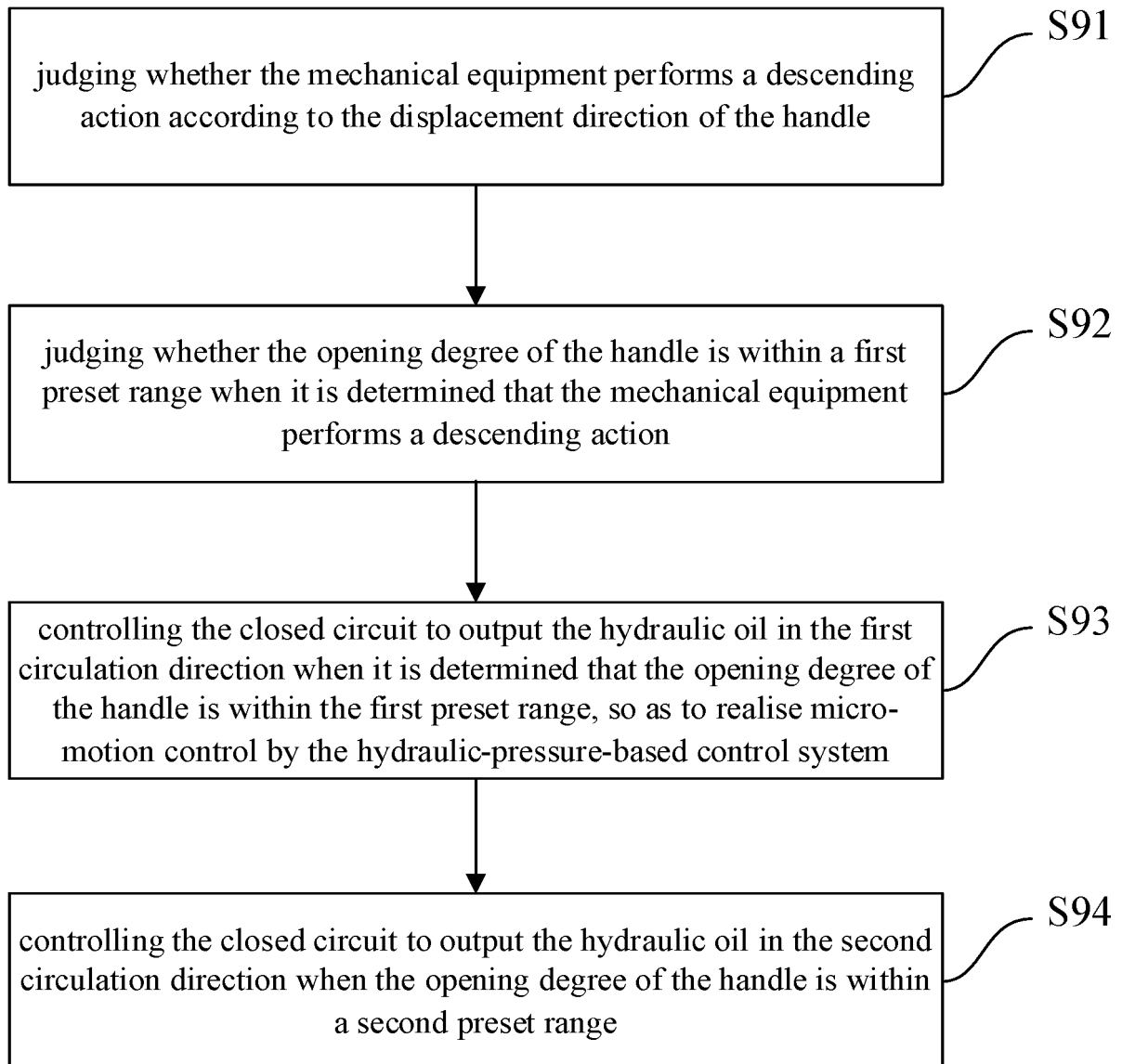


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/128589

A. CLASSIFICATION OF SUBJECT MATTER

F15B 11/08(2006.01)i; B66C 13/20(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F15B; B66C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS; CNTXT; CNKI; VEN; USTXT; EPTXT; WOTXT: 闭, 回路, 油路, 微动, 微调, 微控, 速度, 泄漏, 泄露, 开度, 开口, 手柄, 操作杆, 操纵杆, control+, hand+, lever, open+, closed, loop, adjust, speed, velocity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 203976236 U (ZOOMLION HEAVY INDUSTRY SCIENCE&TECHNOLOGY CO., LTD.) 03 December 2014 (2014-12-03) description, paragraphs [0023]-[0065], and figures 1-4	1-18
A	CN 210710631 U (XUZHOU SUWELL POWER TRANSMISSION MACHINERY CO., LTD.) 09 June 2020 (2020-06-09) entire document	1-18
A	US 9624079 B2 (KOMATSU MFG CO., LTD.) 18 April 2017 (2017-04-18) entire document	1-18

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

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Date of the actual completion of the international search

23 December 2021

Date of mailing of the international search report

01 March 2022

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2021/128589

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 203976236 U	03 December 2014	None	
CN 210710631 U	09 June 2020	CN 110615392 A	27 December 2019
US 9624079 B2	18 April 2017	CN 104884381 B	07 December 2016
		CN 104884381 A	02 September 2015
		JP 5774224 B1	09 September 2015
		US 2016289055 A1	06 October 2016
		DE 112013000267 B4	23 March 2017
		WO 2015097911 A1	02 July 2015
		JP WO2015097911 A1	23 March 2017
		DE 112013000267 T5	27 August 2015

Form PCT/ISA/210 (patent family annex) (January 2015)