



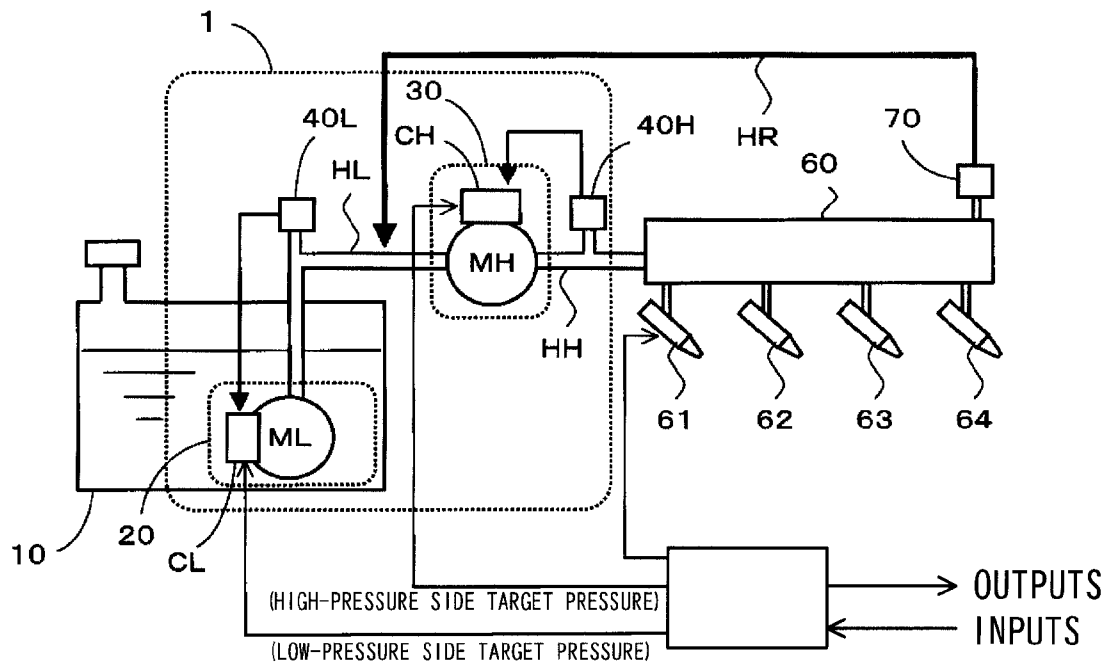
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(19) **United States**(12) **Patent Application Publication**
AKITA(10) **Pub. No.: US 2012/0156056 A1**(43) **Pub. Date: Jun. 21, 2012**(54) **PUMP UNITS**(52) **U.S. Cl. 417/42**(75) **Inventor:** Minoru AKITA, Ama-shi (JP)(73) **Assignee:** AISAN KOGYO KABUSHIKI
KAISHA, Obu-shi (JP)(21) **Appl. No.:** 13/329,241(22) **Filed:** Dec. 17, 2011(30) **Foreign Application Priority Data**

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Publication Classification(51) **Int. Cl.**
F04B 49/06 (2006.01)(57) **ABSTRACT**

A pump unit includes a pump, a motor configured to drive the pump, a control device communicating with the motor and a pressure detection device configured to detect a pressure of a fluid discharged from the pump. The control device is configured to control the motor, so that a pressure detected by the pressure detection device becomes relatively equal to a target pressure. The control device is further configured to determine an estimated pressure of the fluid discharged from the pump. The control device determines whether or not an abnormality occurs based at least one of the following: a detected pressure, a difference between the target pressure and the detected pressure and/or a difference between the detected pressure and the estimated pressure.



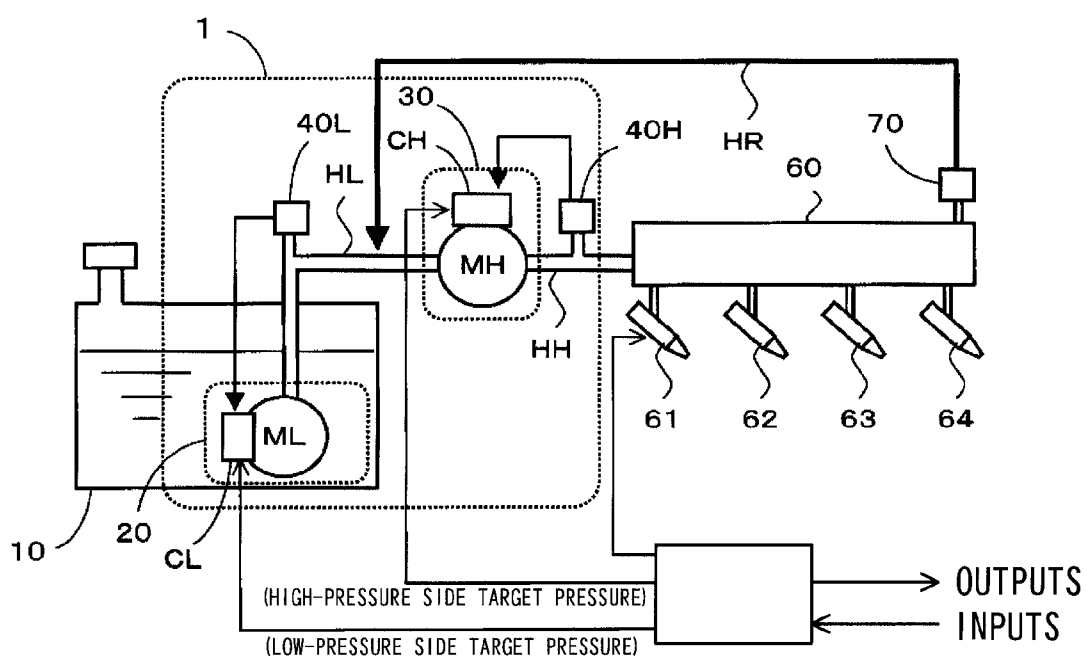


FIG. 1

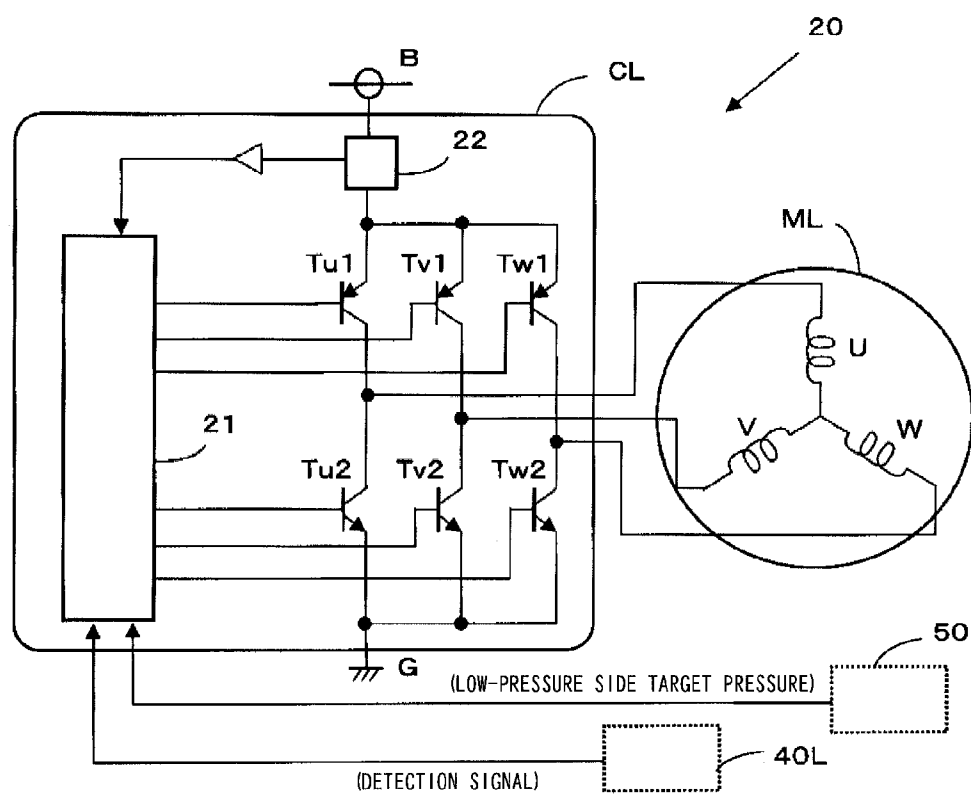


FIG. 2

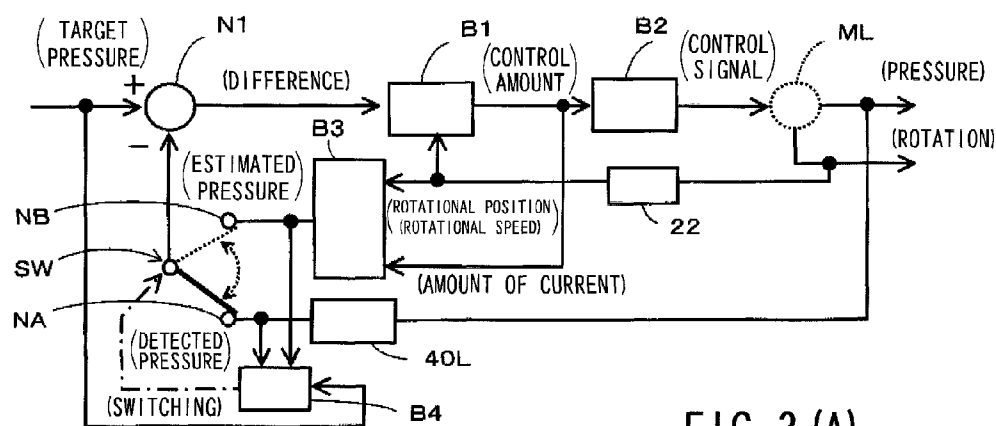


FIG. 3 (A)

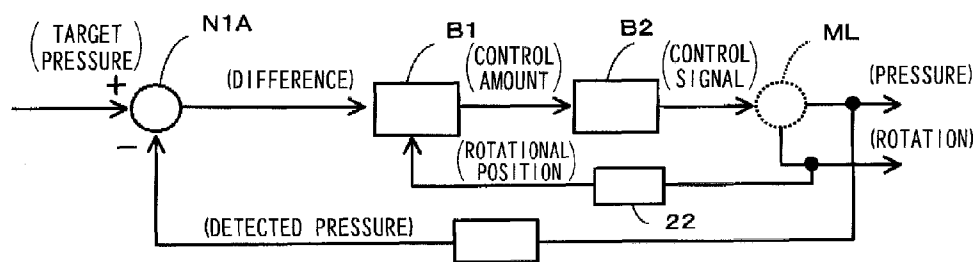


FIG. 3 (B)
PRIOR ART

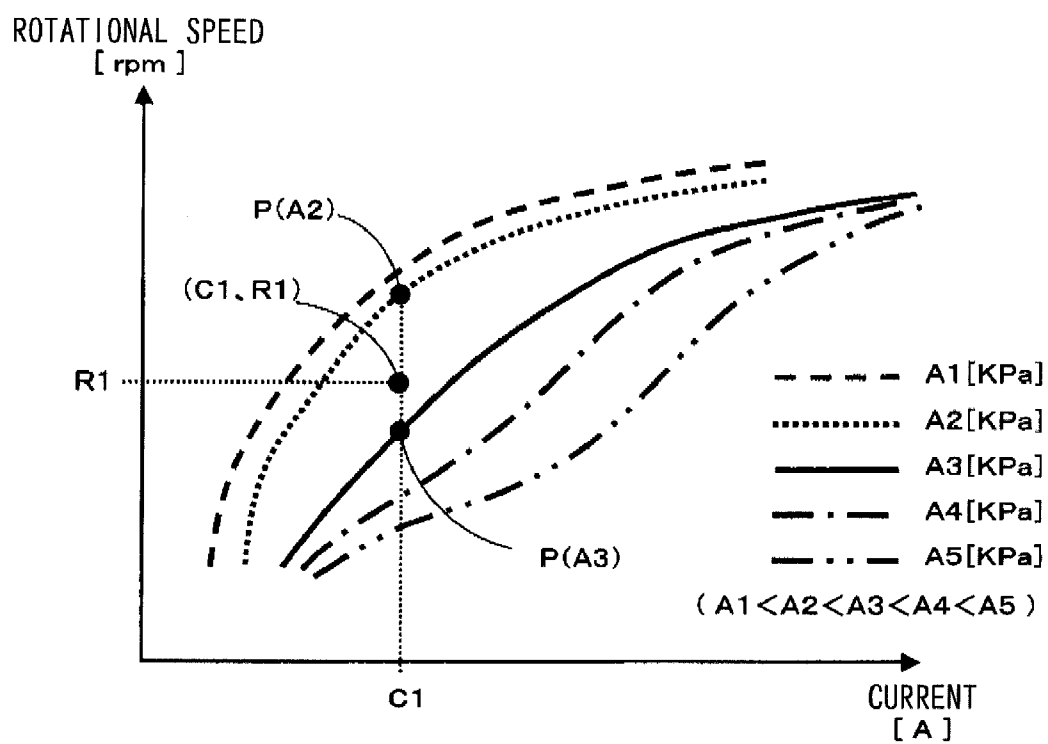


FIG. 4

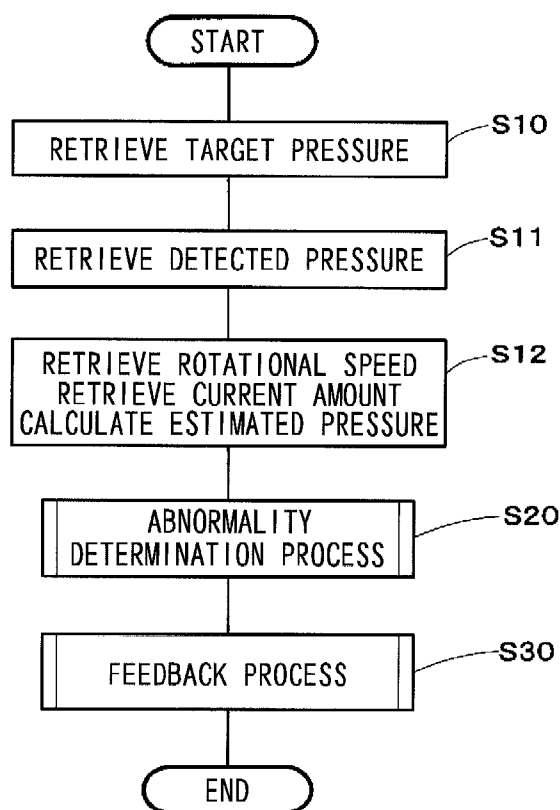


FIG. 5 (A)

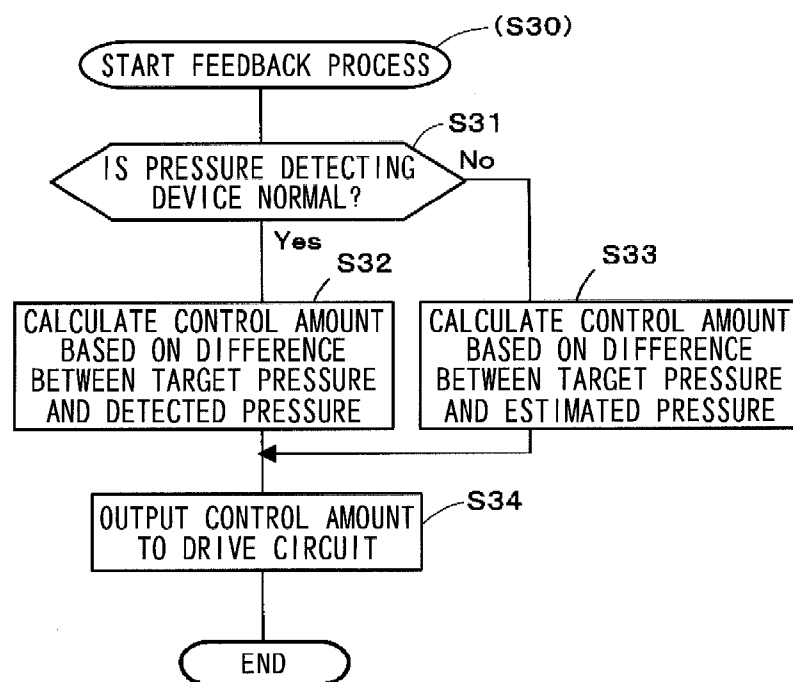


FIG. 5 (B)

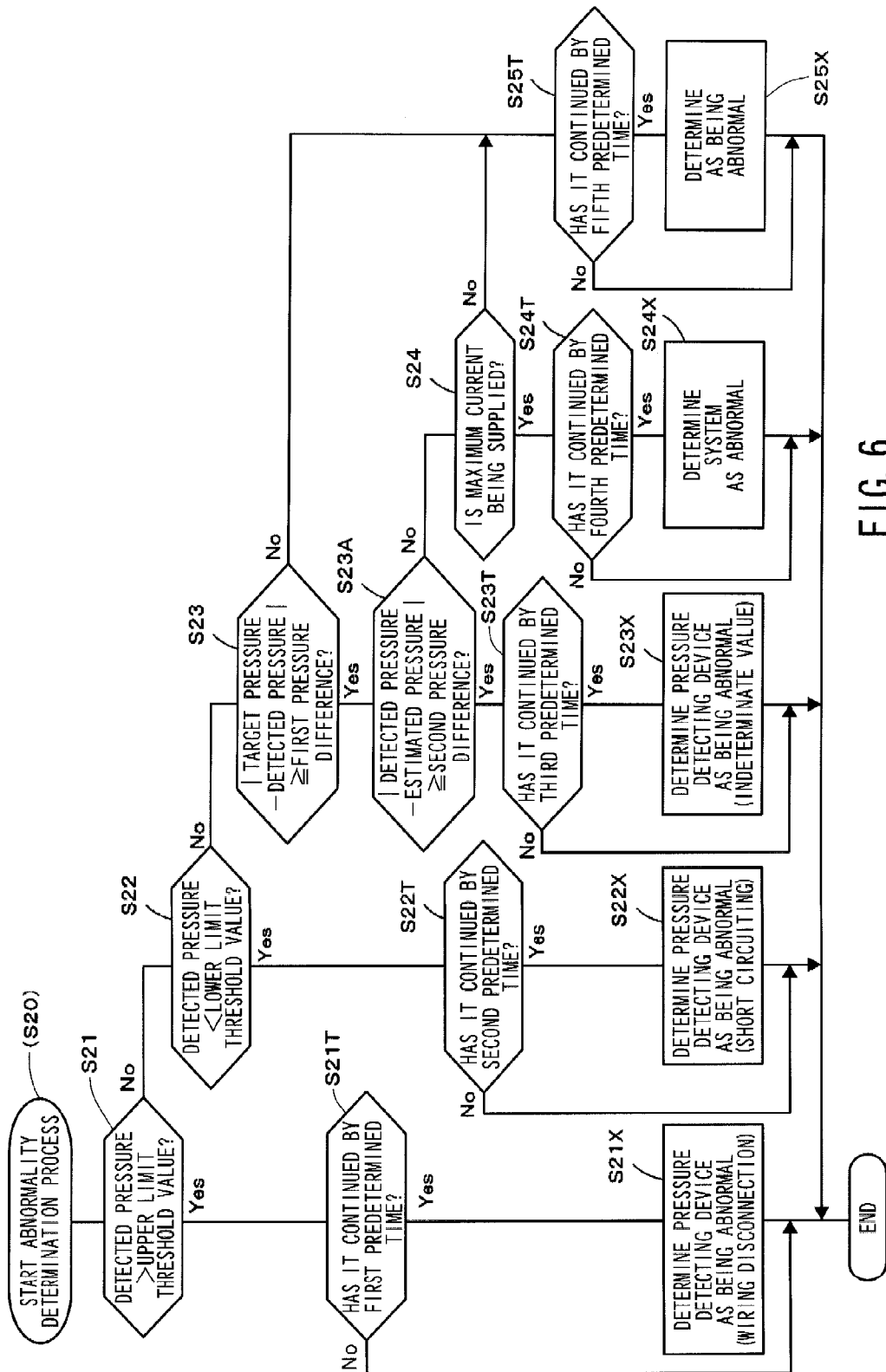


FIG. 6

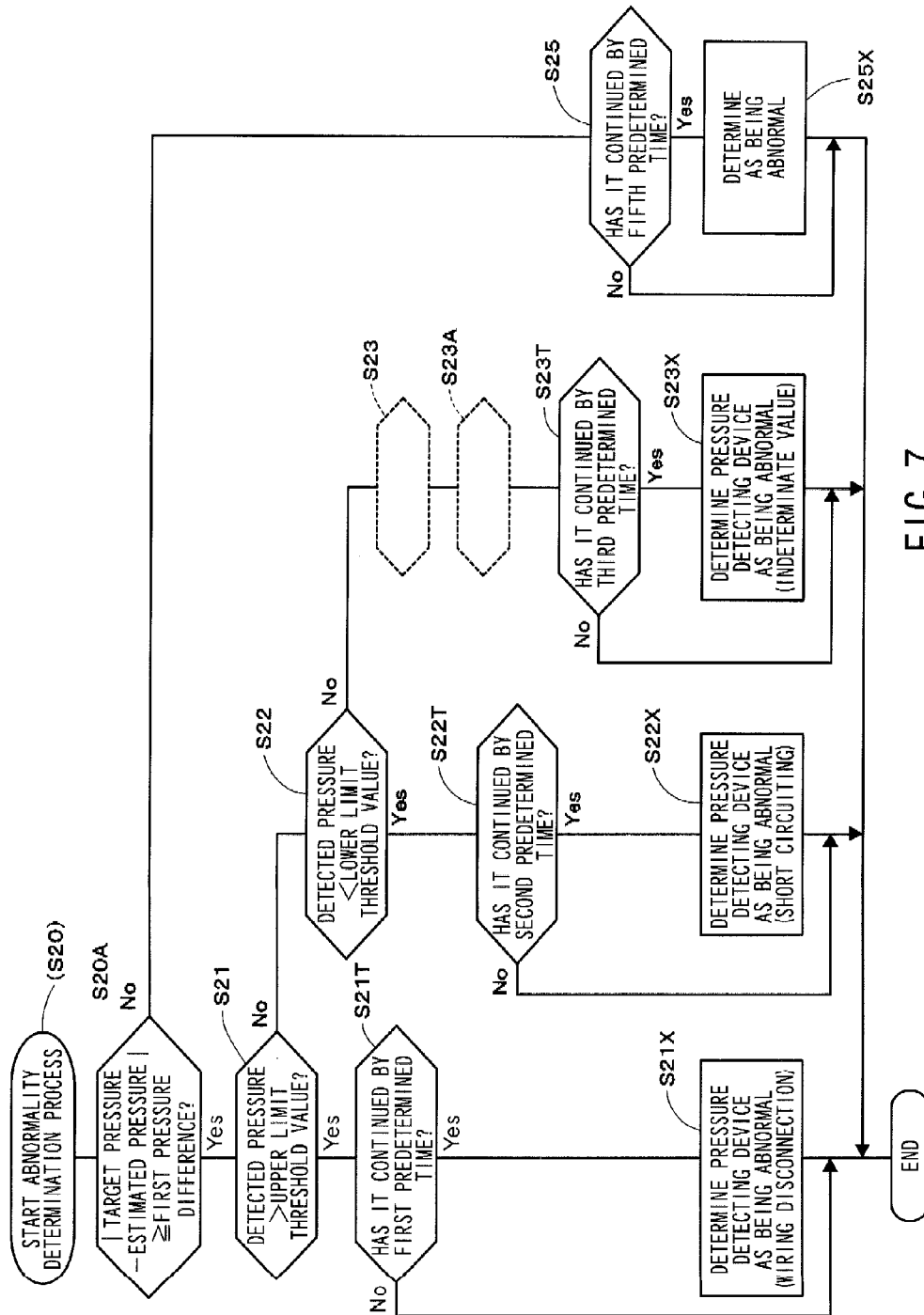


FIG. 7

PUMP UNITS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to Japanese Patent Application Serial Number 2010-281462, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present disclosure relates to pump unit(s) that can control a discharge pressure such that the discharge pressure becomes equal to a target pressure.

[0004] 2. Description of the Related Art

[0005] Fuel injection systems for an internal combustion engine developed in recent years include a so-called inner-cylinder fuel injection system that directly injects high pressure fuel into a high pressure cylinder.

[0006] In a fuel supply apparatus in the inner-cylinder fuel injection system, a low pressure fuel pump and a high pressure fuel pump are placed in series, fuel in a fuel tank is temporarily controlled to a low pressure side target pressure by a low pressure fuel pump, fuel having a low pressure is thereafter converted to a high pressure by a high pressure fuel pump placed at a position near an injector, and the high pressure fuel is then injected from the injector.

[0007] In the fuel supply apparatus of the related art, a feedback control is performed so as to obtain the high pressure side target pressure by the use of a high pressure side pressure sensor for the high pressure fuel pump, and a feedback control is performed so as to obtain the low pressure side target pressure by the use of a low pressure side pressure sensor for the low pressure fuel pump.

[0008] For example, related art described in US Publication No. 2010/0012096 (also published as Japanese Laid-Open Patent Publication No. 2009-540205) discloses a fuel injection apparatus for an internal combustion engine which feeds fuel in a fuel tank to a low pressure region by a feed pump, feeds fuel of the low pressure region to a high pressure region by a high pressure pump, and injects fuel of the high pressure region from an injector. A dedicated low pressure sensor for detecting the pressure in the low pressure region is provided in the low pressure region, and a dedicated high pressure sensor for detecting the pressure in the high pressure region is provided in the high pressure region. Moreover, in the low pressure region, the feed pump is controlled based on the pressure detected by the dedicated low pressure sensor and the high pressure pump is controlled based on the pressure detected by the dedicated high pressure sensor.

[0009] Furthermore, for example, related art described in Japanese Laid-Open Patent Publication No. 2006-175905 discloses a pressure control apparatus for brake liquid of a vehicle which enables the reduction in cost of as well as the simplification of the apparatus by controlling the braking force based on the pressures detected by front wheel pressure sensors, a rotational speed of a pump motor, and a liquid pressure estimated from a supply current. Additionally, such a system does not require the use of a relatively expensive liquid pressure sensor for detecting a supply pressure of a liquid pressure source (a gear pump).

[0010] Furthermore, for example, the related art described in Japanese Laid-Open Patent Publication No. 2009-281184 discloses a fuel supply control apparatus which estimates a

fuel pressure from the rotational speed of a pump, compares an actual fuel pressure detected by a pressure sensor to the estimated fuel pressure, and determines any abnormalities in the relief valve of a pump.

[0011] In any of US Publication No. 2010/0012096 and Japanese Laid-Open Patent Publication Nos. 2006-281184 and 2009-281184, there is a possibility that, when abnormality occurs in the pressure sensor, it is difficult to detect a correct discharge pressure (a liquid pressure) of the pump, and therefore, normal activity may not occur. None of the above publications discloses a method of determining an abnormality in the pressure sensor nor a countermeasure taken in the case that such abnormality occurs in the pressure sensor.

[0012] Therefore, there has been a need in the art for a pump unit that can determine an abnormality in a pressure detecting device.

SUMMARY OF THE INVENTION

[0013] According to the present teachings, a pump unit includes a pump, a motor configured to drive the pump, a control device communicating with the motor; and a pressure detection device configured to detect the pressure of a fluid discharged from the pump. The control device is configured to control the motor, so that the pressure detected by the pressure detection device becomes equal to a target pressure. The control device is further configured to determine an estimated pressure of the fluid discharged from the pump. The control device determines whether or not an abnormality occurs based at least one of the following: a detected pressure, a difference between the target pressure and the detected pressure and/or a difference between the detected pressure and the estimated pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a diagram showing an embodiment of a fuel injection system incorporating a pump unit;

[0015] FIG. 2 is a diagram showing an embodiment of a configuration of the pump apparatus;

[0016] FIG. 3A is a diagram showing an embodiment of control block diagrams;

[0017] FIG. 3B is a diagram showing control block diagrams of the related art;

[0018] FIG. 4 is a diagram that shows an embodiment of current-rotational speed-pressure characteristics measured in advance in a low pressure fuel pump; and

[0019] FIG. 5A is an embodiment of a flowchart showing an embodiment of a process sequence of a low pressure side control device;

[0020] FIG. 5B is an embodiment of a flowchart showing a feedback process performed in the processing sequence of FIG. 5A;

[0021] FIG. 6 is an embodiment of a diagram showing a process sequence of an abnormality determination process in the processing sequence of the low pressure side control device; and

[0022] FIG. 7 is an embodiment of a diagram showing another example of the processing sequence of the abnormality determination process.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Each of the additional features and teachings disclosed above and below may be utilized separately or in

conjunction with other features and teachings to provide improved pump units. Representative examples of the present invention, which examples utilize many of these additional features and teachings both separately and in conjunction with one another, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skilled in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

[0024] In one example, a pump unit includes a pump, a sensor-less brushless motor, and a control device communicating with the brushless motor. The pressure detection device is provided on a discharge side of the pump. The control device controls the brushless motor so that a detected pressure (a pressure detected by the pressure detection device), becomes relatively equal to a target pressure. The control device is further able to determine a value of current supplied to the brushless motor and a rotational speed of the brushless motor. When an abnormality occurs in the pressure detection device, the control device determines an estimated pressure on the discharge side of the pump based on the determined current value and the determined rotational speed. It is then able to control the brushless motor so that the determined estimated pressure becomes equal to the target pressure.

[0025] Thus, when an abnormality occurs in the pressure detection device, the discharge pressure is controlled so as to become relatively equal to the target pressure, through the use of an estimated pressure that is obtained from the current value supplied to the brushless motor and the rotational speed of the brushless motor. Therefore, even in a state in which an abnormality occurs in the pressure detection device and the detected pressure is unusable, a normal control can be continued through the use of an estimated pressure.

[0026] In another embodiment, a pump unit includes a pump, a sensor-less brushless motor configured to drive the pump, a control device communicating with the brushless motor and a pressure detection device disposed on a discharge side of the pump. The control device is configured to control the brushless motor, so that a pressure detected by the pressure detection device becomes equal to a target pressure. The control device is further configured to be able to determine a value of current supplied to the brushless motor and a rotational speed of the brushless motor. The control device determines an estimated pressure on the discharge side of the pump based on the determined current value and the determined rotational speed. In addition, the control device determines whether or not an abnormality occurs based on the detected pressure and the estimated pressure.

[0027] Therefore, it is possible to improve the accuracy of the abnormality determination, for example, by using a calculated difference between the estimated pressure (which is estimated based on the rotational speed and the current value of the brushless motor), and the detected pressure (which is detected by the pressure detection device). Using such a

method, it is possible to perform a high-precision abnormality determination. Such a high-precision abnormality would be determining whether or not the level of the outputted detected signal (representing the pressure) is close to the level normally output. In simple abnormalities such as disconnection abnormalities (open circuits) or short circuit abnormalities (circuit shorts) may be detected.

[0028] The control device may determine whether or not an abnormality occurs based on a difference between the target pressure and the detected pressure and a difference between the detected pressure and the estimated pressure. Therefore, it is possible to determine an abnormality of the pressure detection device based on the difference between the estimated pressure and the detected pressure and also to determine an abnormality of the pressure detection device based on a difference between the target pressure and the detected pressure. Hence, it is possible to further accurately detect abnormalities.

[0029] Certain embodiments will now be described with reference to the drawings. FIG. 1 is a diagram showing a fuel ejection system of an internal combustion engine incorporating a pump unit 20. The pump unit 20 includes a sensor-less brushless motor and may be configured as a low pressure fuel pump unit as will be described later.

[Configuration of Fuel Injection System (FIG. 1)]

[0030] The fuel injection system shown in FIG. 1 has a fuel supply apparatus 1, a pump unit 20 (the low pressure fuel pump unit) and a high pressure fuel pump unit 30.

[0031] Fluid fuel is stored in a fuel tank 10.

[0032] The pump unit 20 includes a low pressure fuel pump ML (configured as a sensor-less brushless motor) and a low pressure side control device CL.

[0033] A low pressure side target pressure may be input from a separate external control device 50 (an engine control computer or the like) to the low pressure side controller CL. The low pressure side controller CL preferably controls the low pressure fuel pump ML such that a discharge pressure of the low pressure fuel pump ML (a pressure in a pipeline HL) becomes a low pressure side target pressure and the fuel in the fuel tank 10 is fed into the pipeline HL (corresponding to a low pressure region). The low pressure fuel pump ML may be a sensor-less brushless motor and will be described below in detail.

[0034] A pressure detection device 40L is provided in the pipeline HL on the discharge side of the low pressure fuel pump ML. The low pressure side control device CL controls the low pressure fuel pump ML so that a pressure detected by the pressure detection means 40L becomes relatively equal to the low pressure side target pressure.

[0035] The high pressure fuel pump unit 30 may include a high pressure fuel pump MH, a high pressure side controller CH and a pressure detection device 40. A high pressure side target pressure may then be input from the separate external control device 50 to the high pressure side controller CH. The high pressure side controller CH controls the high pressure fuel pump MH so that a discharge pressure of the high pressure fuel pump MH (a pressure in a pipeline HH) becomes a high pressure side target pressure. The fuel in the pipeline HL (corresponding to a low pressure region) may then be fed into the pipeline HH (corresponding to a high pressure region).

[0036] A pressure detection device 40H is provided in the pipeline HH of the discharge side of the high pressure fuel pump MH. A high pressure side controller CH controls the

high pressure fuel pump MH so that the pressure in the pipeline HH becomes relatively equal to a high pressure side target pressure based on the pressure detected by the pressure detection device 40. Injectors 61 to 64 inject the high pressure fuel in a delivery pipe 60 connected to the pipeline HH, based on a driving signal from the external control device 50. In an embodiment, when the fuel pressure in the delivery pipe 60 greatly exceeds a hypothetical pressure, fuel returns to the pipeline HL via a valve 70.

[0037] Furthermore, detected signals from various input devices (sensors or the like) may be input into the external control device 50. The external control device 50 may output control signals to various output devices (actuators or the like), such as: driving signals to the injectors 61 to 64 and outputs signals representing the low and high pressure side target pressures.

<Configuration of Pump Unit (FIG. 2)>

[0038] Referring to FIG. 2, the low pressure fuel pump ML may include a sensor-less, brushless motor that has, for example, three-phase coils: U-phase, V-phase and W phase coils. The low pressure side controller CL for controlling the brushless motor has a calculation device 21 such as a CPU, a position detection circuit 22 for detecting a rotation position of the brushless motor and driving circuits (Tu1 to Tw2) that output the driving current to the U phase, the V phase and the W phase coils. The calculation device 21 detects or calculates the rotation position of the brushless motor based on the detected signal from the position detection circuit 22 and outputs the driving signal corresponding to the rotation position from the driving circuits (Tu1 to Tw2).

[0039] In one embodiment, the position detection circuit 22 may be a detection circuit for detecting a counter electromotive current. A pulse signal is input to the position detection circuit 22 each time when the brushless motor reaches a predetermined rotational position and the calculation device 21 switches the driving signal (a PWM signal or the like) each time when the pulse signal is input.

[0040] Furthermore, a low pressure side target pressure is input from the external control device 50 into the calculation device 21, and the detected signal is input from the pressure detection device 40L into the calculation device 21. The calculation device 21 is able to determine the rotational speed of the brushless motor from an interval of pulses of the pulse signal output from the position detection circuit 22. Additionally, the calculation device 21 is able to determine a value of current, which is supplied to the brushless motor, based on the signal (for example, in the case of the PWM signal, the duty of the PWM signal (ratio [%] of an ON pulse width to a pulse period)) which is output to the driving circuits (Tu1 to Tw2) by the calculation device 21.

[0041] In this manner, the calculation device 21 is able to detect or determine the rotational speed and the current value of the brushless motor and control the sensor-less, brushless motor. It may be accomplished through the use of an input state from the position detection circuit 22 naturally required for the rotation control and an output state to the driving circuits, without the need in providing a new detection circuit or the like.

[Control Block Diagram (FIG. 3A) of an Embodiment of the Present Invention and Control Block Diagram (FIG. 3B) of Related Art]

[0042] FIG. 3A shows a control block diagram of an embodiment that controls the low pressure fuel pump ML, and FIG. 3B shows a control block diagram of the related art.

[Control Block Diagram (FIG. 3B) of Related Art]

[0043] As shown in the control block diagram of FIG. 3B, of the related art, a difference between a target pressure (in this case, a low pressure side target pressure) and a detected pressure (an actual discharge pressure from the low pressure fuel pump ML detected by the pressure detection device 40L) is obtained by a node N1A, and the obtained difference is input to a calculation block B1.

[0044] In the calculation block B1, a control amount is calculated based on the input difference. The control amounts suitable for each of the driving circuits (Tu1 to Tw2) are calculated based on the rotation position detection signal from the position detection circuit 22. The calculated control amounts are input to a driving block B2 (the driving circuits (Tu1 to Tw2)). In the driving block B2, the driving signal is output to the low pressure fuel pump ML based on the input control amount.

[0045] The discharge pressure from the low pressure fuel pump ML is detected by the pressure detection device 40L, and the detected actual pressure (the detected pressure) is input to the node N1A for negative feedback.

[Control Block Diagram (FIG. 3A) of a Present Embodiment]

[0046] As shown in FIG. 3A, a calculation block B3 that obtains or determines an estimated pressure, a switching device SW for selecting a pressure for negative feedback to a node N1 and a calculation block B4 for outputting a switching signal to the switching device SW are shown. In this arrangement, an estimated pressure and a detected pressure may be processed for negative feedback to the node N1. Hereafter, a difference between the control block diagram of the present example and the control block diagram of the related art (FIG. 3B) will be described.

[0047] In the present embodiment, a value of current (the current value that is supplied to the low pressure fuel pump ML) is determined based on a control amount obtained by the calculation block B1. A rotational speed (the rotational speed of the low pressure fuel pump ML) is determined based on a detected signal from the position detection circuit 22. Both the value of current and rotational speed are input into the calculation block B3. A discharge pressure (estimated pressure) of the low pressure fuel pump ML is estimated by the calculation block B3. The method of determining the estimated pressure will be described later.

[0048] The estimated pressure calculated by the calculation block B3, the detected pressure detected by the pressure detection device 40L and the target pressure (the low pressure side target pressure) are input into the calculation block B4. Calculation block B4 determines whether or not an abnormality occurs in the pressure detection device 40L. When it is determined that no abnormality occurs in the pressure detection device 40L, the calculation block B4 sets the switching means SW to a side of the detected pressure and conducts a negative feedback of the detected pressure to the node N1. When it is determined that an abnormality occurs in the pressure detection device 40L, the calculation block B4 sets the switching means SW to a side of the estimated pressure and conducts a negative feedback of the estimated pressure to the node N1. The process performed in the calculation block B4 (the process of determining the abnormality of the pressure detection device 40L) will be described later.

[Method of Determining Pressure from Current Value and Rotational Speed (FIG. 4)]

[0049] Next, a method (the processing of the calculation block B3 in FIG. 3A) of determining the pressure from the current value and the rotational speed will be described with reference to FIG. 4. FIG. 4 shows a characteristic graph of the low pressure fuel pump ML. A first dashed line indicates a relationship between the current [A] and the rotational speed [rpm] when the discharge pressure is A1 [kPa]. A second dashed line indicates a relationship between the current [A] and the rotational speed [rpm] when the discharge pressure is A2 [kPa]. A solid line indicates a relationship between the current [A] and the rotational speed [rpm] when the discharge pressure is A3 [kPa]. An alternate long and short dash line indicates a relationship between the current [A] and the rotational speed [rpm] when the discharge pressure is A4 [kPa]. A two-dot chain line indicates a relationship between the current [A] and the rotational speed [rpm] when the discharge pressure is A5 [kPa]. Here, there is a relationship of "A1<A2<A3<A4<A5."

[0050] When the rotational speed is held constant, as the current increases (thereby increasing the load), the pressure also increases. When the current is held constant, as the rotational speed decreases (thereby increasing the load), the pressure also increases (the discharge pressure).

[0051] The calculation device 21 stores the low pressure fuel pump characteristic shown in FIG. 4 and is able to determine the pressure from the detected current value and rotational speed as explained below. In one embodiment, when the detected current value [A] and rotational speed [rpm] are C1 [A] and R1 [rpm], respectively, as shown in FIG. 4, it is possible to obtain the pressure at (C1, R1) by interpolating between a point P (A2) on the A2 [kPa] and a point P (A3) on the A3 [kPa] based on the position at (C1, R1).

[0052] As mentioned above, when the rotational speed is known but the load (the current) of the brushless motor is not known, the correct estimation of the discharge pressure is difficult to obtain. When the current (the load) is known but the rotational speed (the flow rate) is not known, the correct estimation of the discharge pressure is also difficult to obtain. In one embodiment, it is possible to estimate the correct discharge pressure of the brushless motor using the rotational speed (the flow rate) and the current (the load).

[Process Sequence (FIG. 5A) of Low Pressure Side Controller and Process Sequence (FIG. 5B) of Feed Back Process in Process Sequence of FIG. 5(A)]

[0053] Next, an embodiment of a processing sequence of the low pressure side controller CL (the calculation device 21) will be described with reference to FIGS. 5A and 5B. The low pressure side controller CL starts the process shown in FIG. 5A at a predetermined time point whenever an input signal from the position detection circuit 22 is detected.

[0054] In step S10, the low pressure side control device CL receives the target pressure (in this case, a low pressure side target pressure) from an external control device 50 and the process proceeds to step S11.

[0055] In step S11, the low pressure side control device CL receives a signal of the pressure detection devices 40L and determines a pressure based on the received signal (by converting the detected signal into the detected pressure). The process then proceeds to step S12.

[0056] In step S12, the low pressure side control device CL determines a current rotational speed of the low pressure fuel

pump ML from an interval (a period) of pulses in the pulse signal from the position detection circuit 22. Furthermore, the low pressure side control device CL determines a value of current based on the driving signal that is output to the driving circuits (Tu1 to Tw2) by the low pressure side control device CL. A measured voltage of the power source is detected from a voltage detection device is used in the fuel supply apparatus 1. The current value is corrected using a predetermined reference voltage and the measured voltage. For example, if the low pressure fuel pump characteristic shown in FIG. 4 is a characteristic that is measured for a 12 V reference, the reference voltage is 12 [V]. If the measured voltage is 10 [V], the current value is corrected as follows.

$$\text{current value(after correction)} = \text{current value(before correction)} * (12 \text{ [V]} / 10 \text{ [V]})$$

[0057] The estimated pressure is obtained based on the determined rotational speed, the corrected current value and the low pressure fuel pump characteristic shown in FIG. 4. Thereafter process proceeds to step S20. The process in the step S12 corresponds to the process performed in the calculation block B3 shown in FIG. 3A. In some embodiments, the correction of the current value based on the measured voltage may be eliminated.

[0058] In step S20, the low pressure side control device CL determines whether or not an abnormality occurs in the pressure detection device 40L. In step S30, the low pressure side control means CL performs a feedback control of the low pressure fuel pump ML so that the discharge pressure of the low pressure fuel pump ML becomes relatively equal to the low pressure side target pressure and the process ends thereafter.

[0059] Next, the feedback process performed in step S30 in the flowchart of FIG. 5A will be described with reference to FIG. 5B. The process in step S30 corresponds to the process performed by the switching device SW, the node N1, the calculation block B1 and the driving block B2 from FIG. 3A.

[0060] In step S31, the low pressure side control device CL determines whether or not the pressure detection device 40L is normal (in step S20). If it is determined that the pressure detection device 40L is normal (Yes), the process proceeds to step S32. If it is determined that the pressure detection device 40L is abnormal (No), the process proceeds to step S33.

[0061] When the process proceeds to step S32, the low pressure side control device CL determines a difference between the target pressure (the low pressure side target pressure) retrieved in step S10 and the detected pressure retrieved in step S11. It calculates the control amount of the low pressure fuel pump ML based on this difference. The process then proceeds to step S33.

[0062] When the process proceeds to step S33, the low pressure side control device CL determines a difference between the target pressure (the low pressure side target pressure) retrieved in step S10 and the estimated pressure retrieved in step S12. It calculates the control amount of the low pressure fuel pump ML based on this difference and the process proceeds to step S34.

[0063] In step S34, the low pressure side control device CL drives the driving circuits (Tu1 to Tw2) based on the determined control amount and the rotation position detection signal detected in step S12. It also drives the low pressure fuel pump ML. The process then ends.

[Processing Sequence (FIG. 6) for Determining Abnormality of Pressure Detection Device]

[0064] Next, process for detecting abnormalities (which was previously reference n FIG. 5A) will be described with

reference to FIG. 6. The process performed in step S20 corresponds to the process in the calculation block B4 shown in FIG. 3A.

[0065] In step S21, the low pressure side control device CL retrieves the detected signal of the pressure detection device 40L and determines whether or not the detected signal (the detected voltage) is greater than an upper threshold value. In this example, the detected voltage is input as an analog voltage of 0 [V] to 5 [V] depending on the pressure. An upper threshold value of 4.5 [V] is set due to the fact that it is normally unlikely to be reached. If the detected voltage is greater than the upper threshold value (Yes), the process proceeds to step S21T. If the detected voltage is not greater than the upper threshold value (No), the process proceeds to step S22.

[0066] In step S21T, the low pressure side control device CL determines whether or not the upper threshold value has been exceeded for a first predetermined time period. If the determination in step S21T is Yes, then the process proceeds to step S21X. If the determination is No, then the process is ended.

[0067] When the process proceeds to step S21X, the low pressure side control means CL determines that the pressure detection device 40L is abnormal, the process is ended (in this case, it is determined that abnormality occurs due to the disconnection of electric lines).

[0068] When the process proceeds to step S22, the low pressure side control device CL determines whether or not the detected signal (the detected voltage) of the pressure detection device 40L is lower than a lower threshold value. In this example, the detected voltage is input as an analog voltage of 0 [V] to 5 [V] depending on the pressure. A lower threshold value of 0.5 [V] is set due to the fact that it is normally unlikely to be reached. If the detected voltage is lower than the lower threshold value (Yes), the process proceeds to step S22T. If the detected voltage is not lower than the lower threshold value (No), the process proceeds to step S23.

[0069] When the process proceeds to step S22T, the low pressure side control device CL determines whether or not the state of being lower than the lower limit threshold value has been exceeded for a second predetermined time period. If the determination is Yes, then the process proceeds to step S22X. If the determination is No, then the process is ended.

[0070] When the process proceeds to step S22X, the low pressure side control device CL determines that the pressure detection device 40L is abnormal, the process is ended (in this case, it is determined that abnormality occurs due to a short-circuit).

[0071] When the process proceeds to step S23, the low pressure side control device CL determines whether or not the difference between the target pressure (in this case, the low pressure side target pressure) and the detected pressure (the pressure detected by the pressure detection device 40L) is equal to or greater than a first pressure difference (for example, 50 [KPa]). If the difference is equal to or greater than the first pressure difference (Yes), the process proceeds to step S23A. If the difference is less than the first pressure difference (No), the process proceeds to step S25T.

[0072] When the process proceeds to step S23A, the low pressure side control device CL determines whether or not the difference between the detected pressure and the estimated pressure (the pressure estimated from the rotational speed and the current value) is equal to or greater than a second pressure difference (for example, 30 [KPa]). If the difference is equal

to or greater than the second pressure difference (Yes), the process proceeds to step S23T. If the difference is less than the second pressure difference (No), the process proceeds to step S24.

[0073] When the process proceeds to step S23T (Yes), it is determined whether or not the state (as determined in step S23 or S23A) has been continued for a third predetermined time period. If the state has been continued for the third predetermined time period (Yes), then the process proceeds to step S23X. If the state has not been continued for the third predetermined time period (No), then the process is ended.

[0074] If the low pressure side control device CL determines that the pressure detection means 40L is abnormal when the process proceeds to step S23X, then the process is ended. There may be a case where the level of the detected signal may be within the range between the upper threshold value and the lower threshold value, but yet an abnormality (unknown abnormality or characteristic abnormality) is shown to exist. This may occur when the detected pressure signal is not output.

[0075] When the process proceeds to step S24, the low pressure side control device CL determines whether or not a relative maximum current is being supplied. For example, it is determined whether or not a duty of the PWM signal is relatively 100 [%] (a maximum duty). If the relative maximum current is being supplied (Yes), the process proceeds to step S24T. If the relative maximum current is not being supplied (No), the process proceeds to step S25T.

[0076] When the process proceeds to step S24T (Yes), it is determined whether or not the state where the maximum current is supplied has been continued for a fourth predetermined time period. If the state has been continued for a fourth predetermined time period (Yes), the process proceeds to step S24X. If the state has not been continued for the fourth predetermined time period (No), the process is ended.

[0077] When the process proceeds to step S24X, the low pressure side control device CL determines that the system (pipelines or the like) of the fuel supply apparatus 1 is abnormal and the process ends. In this case, however, it is determined that the pressure detection device 40L is not abnormal but rather that a system abnormality such as leakage from pipelines occurs.

[0078] When the process proceeds to step S25T, the low pressure side control device CL determines whether or not the state where no abnormality is found in the preceding step has been continued for a fifth predetermined time period. If the state has been continued for the fifth predetermined time period (Yes), the process proceeds to step S25X. If the state has not been continued for the fifth predetermined time period (No), the process is ended.

[0079] If the process proceeds to step S25X and the low pressure side control means CL determines that the pressure detection device 40L is normal (an abnormality is not found), then the process ends.

[Another Embodiment (FIG. 7) of a Process Sequence for Determines Abnormality of Pressure Detection Device]

[0080] Next, an alternative embodiment of the abnormality determination process sequence shown in the flowchart of FIG. 6 will be described with reference to FIG. 7. A flowchart shown in FIG. 7 is different from that of FIG. 6 in that the process of step S20A (an initial step) is added to the flowchart shown in FIG. 6, and steps S23, S23A, S24, S24T, and S24X

are omitted. The flowchart shown in FIG. 7 will be described, focusing mainly on the differences between it and the flowchart in FIG. 6.

[0081] In step S20A, the low pressure side control device CL determines whether or not a difference between the target pressure (in this case, the low pressure side target pressure) and the estimated pressure is equal to or greater than the first pressure difference (for example, 50 [KPa]). If the difference is equal to or greater than the first pressure difference (Yes), the process proceeds to step S21. If the difference is less than the first pressure difference (No), the process proceeds to step S25T.

[0082] When the process proceeds to step S21, the low pressure side control device CL determines whether or not the detected signal (the detected voltage) is greater than the upper threshold value. If the detected signal is greater than the upper threshold value (Yes), the process proceeds to step S21T. If the detected signal is not greater than the upper threshold value (No), the process proceeds to step S22.

[0083] When the process proceeds to step S22, the low pressure side control device CL determines whether or not the detected signal (the detected voltage) is lower than the lower threshold value. If the detected signal is lower than the lower threshold value (Yes), the process proceeds to step S22T. If the detected signal is not lower than the lower threshold value (No), the process proceeds to step S23T.

[0084] Since the processes in the other steps are the same as the processes described with reference to FIG. 6, the description thereof will be omitted.

[0085] As described above, in the process of the flowchart shown in FIG. 7, the process of the flowchart shown in FIG. 6 is simplified, and the determination in step S24X for the system abnormality is omitted.

[0086] As described above, the pump unit 20 described in the above examples is able to precisely determine whether or not an abnormality occurs in the pressure detection device 40L without need of an additional pressure detection device. In addition, it is able to achieve simplification of the system and reduction in cost.

[0087] Further, if it is determined that an abnormality exists in the pressure detection device 40L, it is possible to safely continue the operation due to the fact that the low pressure fuel pump ML is controlled using the estimated pressure.

[0088] The above examples may be further modified in various ways. For example, the characteristic of the low pressure fuel pump ML is not limited to the characteristic shown in FIG. 4. Also, the low pressure side control device CL and the lower pressure fuel pump ML are not limited to have the configurations shown in FIG. 2. Furthermore, the above examples may be applied to various pump units using the sensor-less brushless motor and may not be limited to the use for a fuel pump of an internal combustion engine.

What is claimed is:

1. A pump unit comprising:

a pump;

a sensor-less brushless motor configured to drive the pump;
a control device communicating with the brushless motor;
and

a pressure detection device disposed on a discharge side of the pump,

wherein the control device is configured to control the brushless motor, so that a pressure detected by the pressure detection device becomes relatively equal to a target pressure; and

wherein the control device is further configured to be able to determine a value of current supplied to the brushless motor and a rotational speed of the brushless motor, such that when an abnormality occurs in the pressure detection device, the control device determines an estimated pressure on the discharge side of the pump based on the determined current value and the determined rotational speed and controls the brushless motor so that the determined estimated pressure becomes relatively equal to the target pressure.

2. A pump unit comprising:

a pump;

a sensor-less brushless motor configured to drive the pump;
a control device communicating with the brushless motor;
a pressure detection device disposed on a discharge side of the pump;

wherein the control device is configured to control the brushless motor, so that a pressure detected by the pressure detection device becomes relatively equal to a target pressure; and

wherein the control device is further configured to be able to determine a value of current supplied to the brushless motor and a rotational speed of the brushless motor, wherein the control device determines an estimated pressure on the discharge side of the pump based on the determined current value and the determined rotational speed; and

wherein the control device determines whether or not an abnormality occurs to the pressure detection device based on the detected pressure and the estimated pressure.

3. The pump unit as in claim 2, wherein the control device determines whether or not an abnormality occurs based on a difference between the target pressure and the detected pressure and a difference between the detected pressure and the estimated pressure.

4. The pump unit as in claim 3, wherein the control device determines that an abnormality occurs if the difference between the target pressure and the detected pressure is equal to or greater than a first pressure difference and the difference between the detected pressure and the estimated pressure is equal to or greater than a second pressure difference.

5. The pump unit as in claim 3, wherein the control device determines that an abnormality has occurred if the difference between the target pressure and the detected pressure has exceeded a first pressure difference and the difference between the detected pressure and the estimated pressure has exceeded a second pressure difference for a predetermined time period.

6. A pump unit comprising:

a pump;

a motor configured to drive the pump;

a control device communicating with the motor; and

a pressure detection device configured to detect a pressure of a fluid discharged from the pump;

wherein the control device is configured to control the motor, so that a pressure detected by the pressure detection device becomes relatively equal to a target pressure; and

wherein the control device is further configured to determine an estimated pressure of the fluid discharged from the pump;

wherein the control device determines whether or not an abnormality occurs based at least one of the following: a

detected pressure, a difference between the target pressure and the detected pressure, and a difference between the detected pressure and the estimated pressure.

7. The pump unit as in claim 6, wherein the control device determines that an abnormality occurs if the detected pressure is greater than an upper threshold value.

8. The pump unit as in claim 7, wherein the control device determines that an abnormality has occurred if the detected pressure has exceeded the upper threshold value for a first predetermined time period.

9. The pump unit as in claim 6, wherein the control device determines that an abnormality occurs if the detected pressure is lower than a lower threshold value.

10. The pump unit as in claim 9, wherein the control device determines that an abnormality has occurred if the detected pressure has not exceeded the lower threshold value for a second predetermined time period.

11. The pump unit as in claim 6, wherein the control device determines that an abnormality occurs if the difference between the target pressure and the detected pressure is equal to or greater than a first pressure difference.

12. The pump unit as in claim 6, wherein the control device determines that an abnormality occurs if the difference

between the detected pressure and the estimated pressure is equal to or greater than a second pressure difference.

13. The pump unit as in claim 6 wherein the control device determines that an abnormality has occurred if the difference between the target pressure and the detected pressure has exceeded a first pressure difference and the difference between the detected pressure and the estimated pressure has exceeded a second pressure difference for a predetermined time period.

14. The pump unit as in claim 6 wherein the control device determines that an abnormality has occurred if a relatively maximum current has been supplied to the motor for a predetermined time period.

15. The pump unit as in claim 6 wherein the motor is a sensorless, brushless motor and the control device is configured to be able to determine a value of current supplied to the motor and a rotational speed of the motor; and the control device can further determine the estimated pressure based on the current value and the rotational speed.

16. The pump unit as in claim 6, wherein the pump is a fuel pump.

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