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(72) Inventors:
• **BABA, Yuichi**
Odawara-shi
Kanagawa 250-0055 (JP)
• **MIURA, Osamu**
Odawara-shi
Kanagawa 250-0055 (JP)

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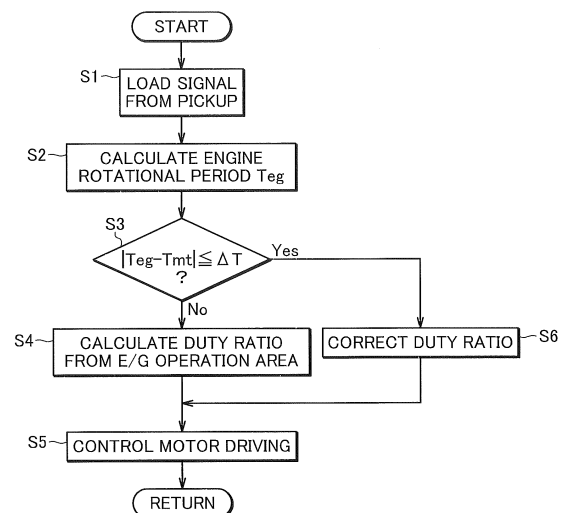
(74) Representative: **Schwabe - Sandmair - Marx**
Patentanwälte Rechtsanwalt
Partnerschaft mbB
Joseph-Wild-Straße 20
81829 München (DE)

(71) Applicant: **Mikuni Corporation**
Tokyo 101-0021 (JP)

(54) **CONTROL DEVICE AND CONTROL METHOD FOR FUEL PUMP**

(57) A plunger (56) is caused to reciprocate by driving of a DC motor (42) to pump a pressurized fuel to an injector (16) and inject the fuel from the injector (16) in synchronization with a combustion cycle of an engine (1). An engine rotational period (T_{eg}) and a motor rotational period (T_{mt}) are compared (S3), and when the periods are different, a duty ratio of a drive current to be supplied to the DC motor (42) is calculated from an operation area of the engine (1) by a normal method (S4). When the engine rotational period (T_{eg}) and the motor rotational period (T_{mt}) are close to each other, the duty ratio of the drive current to be supplied to the DC motor (42) is corrected to be increased or decreased by a predetermined value (S6), and the DC motor (42) is driven and controlled based on the corrected duty ratio (S5). Thus, the motor rotational period (T_{mt}) is constantly set to be different from the engine rotational period (T_{eg}) during the operation of the engine (1).

FIG. 3



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Description**Technical Field**

[0001] The present invention relates to a control device for a fuel pump and a control method for a fuel pump, and more particularly, to a control device for a plunger-type fuel pump that causes a plunger to reciprocate using a motor as a drive source to pump a fuel pressurized to a predetermined pressure to an injector of an engine, and a control method for the fuel pump.

Background Art

[0002] Heretofore, a fuel injection device in which supply of a fuel to an engine is electrically controlled for the purpose of, for example, improving exhaust gas characteristics and enhancing fuel consumption has been in widespread use. Such a fuel injection device is used not only for four-wheel vehicles, but also for various types of two-wheel vehicles, generators, and the like. A fuel injection device of this type has a configuration in which a fuel in a fuel tank is pumped by a fuel pump and pressurized to a predetermined pressure; the pressurized fuel is supplied to an injector provided in an intake pipe of the engine; and opening and closing of the injector is controlled in synchronization with a combustion cycle of the engine to inject the fuel into the intake pipe.

[0003] Such a fuel pump is required to be downsized in an engine with a relatively small exhaust amount that is used in, for example, a two-wheel vehicle, a generator, and the like, and there is also a demand for reducing power consumption required for driving the pump. Accordingly, a plunger-type fuel pump having characteristics suitable for those conditions may be employed.

[0004] A plunger-type fuel pump of this type has a configuration in which a plunger is slidably disposed in a cylinder and is urged in one direction by a return spring, thereby driving the plunger in a direction opposite to the one direction by excitation of a magnet coil. The plunger reciprocates according to a periodic excitation of the magnet coil, with the result that the fuel in the cylinder is pressurized and intermittently discharged. According to such an operating principle, the pressure of the fuel supplied to the injector fluctuates periodically according to a reciprocating motion of the plunger, and variations in the amount of fuel injection occur due to the fluctuation of the fuel pressure even when the injector is controlled to operate at the same valve opening time. This causes a problem that the combustion of the engine becomes unstable and the exhaust gas characteristics and drivability deteriorate.

[0005] Accordingly, for example, in a plunger-type fuel pump disclosed in Patent Document 1, the problem is solved by synchronizing driving of the fuel pump with the rotation of the engine. Specifically, in the plunger-type fuel pump disclosed in Patent Document 1, the injector is driven for a fuel injection time T_{out} from a fuel injection start time t_2 in synchronization with the rotation of the engine, while a time earlier than the fuel injection start time t_2 by a predetermined time T_f is defined as a fuel pump drive start point t_1 , and the fuel pump is driven (the magnet coil is excited) for a fuel pump driving time T_{pump} from the fuel pump drive start point t_1 . As a result, the fuel injection is executed at a constant timing when the fuel pressure is increased by driving of the fuel pump, and thus variations in the amount of fuel injection due to the fluctuation of the fuel pressure can be suppressed.

Prior Art Document**Patent Document**

[0006] Patent Document 1: Japanese Patent Laid-Open No. 2004-52596

Summary of the Invention**Problems to be solved by the Invention**

[0007] In the plunger-type fuel pump disclosed in Patent Document 1, the timing for exciting the magnet coil, which is a drive source, can be freely changed for each combustion cycle of the engine. Accordingly, the timing for driving the fuel pump can be controlled in the manner as described above in accordance with the fuel injection timing that changes every second according to the operation area of the engine. However, in the plunger-type fuel pump in which the motor is used as the drive source, there is a need to change the rotational speed of the motor to change the drive timing, and thus it is actually difficult to rapidly change the rotational speed of the motor in accordance with the fuel injection timing. Therefore, the technique disclosed in Patent Document 1 cannot be applied to the plunger-type fuel pump in which the motor is used as the drive source, and thus another solution to the problem has been conventionally required.

[0008] The present invention has been made to solve the above-mentioned problem, and an object of the present

invention is to provide a control device for a fuel pump, a plunger-type fuel pump using a motor as a drive source is used, which is capable of suppressing variations in the amount of fuel injection due to a fluctuation of a fuel pressure and avoiding deterioration in exhaust gas characteristics and drivability, and a control method for the fuel pump.

Means for Solving the Problems

[0009] In order to achieve the above object, an aspect of the present invention is directed to a control device for a fuel pump, including: a plunger-type fuel pump causing a plunger to reciprocate by driving of a motor to pump a fuel pressurized to a predetermined pressure; an injector injecting the fuel in synchronization with a combustion cycle of an engine, the fuel being pumped from the fuel pump; a motor control unit supplying the motor with a drive current to control the motor; a determination unit executing a determination process for determining whether one of a period of fuel injection by the injector and a period of fuel pumping by the plunger corresponds to a multiple of the other one of the periods; and a motor speed change instruction unit causing the motor control unit to change a rotational speed of the motor when the determination unit determines that the one of the periods corresponds to the multiple of the other one of the periods.

[0010] In the control device for the fuel pump according to the present invention having the configuration described above, when one of the period of fuel injection by the injector and the period of fuel pumping by the plunger corresponds to the multiple of the other one of the periods, the rotational speed of the motor is changed to set the period of fuel pumping to be apart from the period of fuel injection. Accordingly, the period of fuel pumping is constantly different from the period of fuel injection during the operation of the engine, and the relationship between the fuel injection timing and the fuel pumping timing changes in each combustion cycle. Consequently, even if the fuel injection timing and the fuel pumping timing may incidentally overlap each other in a certain combustion cycle, the timings do not overlap each other in the subsequent combustion cycle, so that the operation state in which the combustion of the engine is unstable due to variations in the amount of fuel injection is instantaneously finished within one combustion cycle.

[0011] According to another aspect of the present invention, it is preferable to further include an engine rotational period calculation unit calculating a rotational period of the engine, and a motor rotational period calculation unit calculating a rotational period of the motor, and the determination unit is preferably configured to execute the determination process by comparing the rotational period of the engine calculated by the engine rotational period calculation unit with the rotational period of the motor calculated by the motor rotational period calculation unit.

[0012] In the configuration described above, the rotational speed of the motor is changed according to the determination result of the comparison between the rotational period of the engine and the rotational period of the motor.

[0013] According to still another aspect of the invention, it is preferable to further include a fuel injection timing specifying unit specifying a fuel injection timing of the injector, and a fuel pumping timing specifying unit specifying a fuel pumping timing of the plunger based on a change of a drive current value supplied to the motor by the motor control unit, and the determination unit is preferably configured to execute the determination process by comparing the fuel injection timing of the injector specified by the fuel injection timing specifying unit and the fuel pumping timing of the plunger specified by the fuel pumping timing specifying unit.

[0014] In the configuration described above, the fuel pumping timing of the plunger is specified based on the change of the drive current value of the motor, and the rotational speed of the motor is changed according to the determination result of the comparison between the fuel pumping timing and the fuel injection timing of the injector.

[0015] According to still one more aspect of the invention, the fuel pump is preferably configured to cause a diaphragm to reciprocate by driving of the motor, cause the plunger to reciprocate in synchronization with a reciprocating motion of the diaphragm, and pump the fuel pressurized by the plunger to the injector, the fuel being sent out from the diaphragm.

[0016] In the configuration described above, various operations and effects as described above can be obtained for the fuel pump using both the diaphragm and the plunger.

[0017] Further, a control method for a fuel pump includes: a period determination step of comparing a period of fuel pumping by a plunger-type fuel pump and a period of fuel injection by an injector, and determining whether one of the periods corresponds to a multiple of the other one of the periods, the plunger-type fuel pump being configured to cause a plunger to reciprocate by driving of a motor to pump a fuel, the injector being configured to inject the fuel pumped from the fuel pump in synchronization with a combustion cycle of an engine; and a rotational speed changing step of changing a rotational speed of the motor when it is determined in the period determination step that one of the periods corresponds to the multiple of the other one of the periods.

[0018] According to the control method for the fuel pump of the present invention having the configuration described above, the period determination step compares the period of fuel pumping by the plunger-type fuel pump with the period of fuel injection by the injector, and determines whether one of the periods corresponds to the multiple of the other one of the periods. When it is determined that one of the periods corresponds to the multiple of the other one of the periods, the rotational speed changing step changes the rotational speed of the motor to set the period of fuel pumping to be apart from the period of fuel injection.

Advantageous Effects of the Invention

[0019] According to a control device and a control method for a fuel pump according to the present invention, a plunger-type fuel pump using a motor as a drive source is used, and variations in the amount of fuel injection due to a fluctuation of a fuel pressure are suppressed to thereby avoid deterioration in exhaust gas characteristics and drivability.

Brief Description of the Drawings

[0020]

FIG. 1 is a system configuration diagram illustrating a control device for a fuel pump according to the present invention.

FIG. 2 is a sectional view illustrating details of the fuel pump.

FIG. 3 is a flowchart illustrating a fuel pump control routine executed by an ECU according to a first embodiment.

FIG. 4 is a flowchart illustrating a fuel pump control routine executed by an ECU according to a second embodiment.

Mode for Carrying out the Invention

[0021] Embodiments for embodying the present invention as a control device for a fuel pump for an engine mounted on a two-wheel vehicle, and a control method for the fuel pump will be described below.

[0022] FIG. 1 is a system configuration diagram illustrating a control device for a fuel pump according to the present invention.

[0023] Referring to FIG. 1, an engine 1 is configured as a 4-cycle single-cylinder gasoline engine having an exhaust amount of 50 cc and is mounted on a two-wheel vehicle as a travelling power source. However, the specifications of the engine 1 are not limited to this and can be arbitrarily changed.

[0024] A piston 4 is slidably disposed in a cylinder 3 which is formed in a cylinder block 2 of the engine 1. The piston 4 has a configuration in which the piston 4 is coupled to a crank shaft 6 through a connecting rod 5 and the crank shaft 6 is rotated in accordance with a reciprocating motion of the piston 4. A back end (a side where a transmission which is not illustrated is located) of the crank shaft 6 is provided with a flywheel 7, and a reluctor 7a for detecting a crank angle is formed at a predetermined position on the outer periphery of the flywheel 7.

[0025] A cylinder head 9 which is fixed onto the cylinder block 2 is provided with an intake port 9a and an exhaust port 9b, and an ignition plug 10 is disposed in the cylinder head 9 in a state where a tip end of the ignition plug 10 faces the inside of the cylinder. An intake passage 11, which is connected to the intake port 9a, is provided with an air cleaner 12, a throttle valve 13 which is opened or closed according to a throttle operation by an operator, and an injector 16 which injects a fuel toward the intake port 9a, in this order from an upstream side. An exhaust passage 17 which is connected to the exhaust port 9b is provided with a three-way catalyst 18 for purifying an exhaust gas, and a muffler which is not illustrated.

[0026] An intake valve 20 is disposed on the intake port 9a, and an exhaust valve 21 is disposed on the exhaust port 9b. The intake valve 20 and the exhaust valve 21 are urged against the valve closing side by the valve spring 22 and the valves are opened by an intake cam shaft 23 and an exhaust cam shaft 24 which are rotationally driven in synchronization with the crank shaft 6 on the cylinder head 9. The intake valve 20 and the exhaust valve 21 are opened or closed at a predetermined timing in synchronization with a reciprocating operation of the piston 4, and a combustion cycle of the engine 1 that includes four strokes of intake, compression, expansion, and exhaust is repeated at each crank angle of 720°CA.

[0027] The injector 16 described above is supplied with the fuel (gasoline) stored in the fuel tank 25 from the fuel pump 26. The fuel pump 26 according to this embodiment is one type of plunger-type fuel pumps. The configuration and operating state of the fuel pump will be described below. The fuel pump 26 is configured in such a manner that the fuel having a predetermined pressure necessary for operating the injector 16 can be pressurized and pumped using a combination of a diaphragm and a plunger (hereinafter referred to also as a diaphragm/plunger combined type). The fuel pump 26 is integrated with the injector 16. The fuel pump 26 and the injector 16 are connected to the fuel tank 25 through a supply hose 27 and a return hose 28, respectively.

[0028] When the fuel pump 26 is operated, the fuel in the fuel tank 25 is guided into the fuel pump 26 through the supply hose 27 and pressurized to the predetermined pressure, and the pressurized fuel is supplied to the injector 16 and excess fuel is collected into the fuel tank 25 through the return hose 28. As a result, the fuel having the predetermined pressure is constantly supplied to the injector 16, and the fuel is injected toward the intake port 9a at a predetermined injection timing and injection amount according to the valve opening of the injector 16.

[0029] During the operation of the engine 1, an outside air is sucked into the intake passage 11 through the air cleaner 12 by a negative pressure generated in accordance with a descending motion of the piston 4 in the intake stroke, and the sucked air flows into the cylinder of the engine 1 during the valve opening of the intake valve 20 while the sucked

air is mixed with the fuel injected from the injector 16, after the flow rate of the sucked air is adjusted according to the opening of the throttle valve 13. An air-fuel mixture is subjected to the compression in the subsequent compression stroke and is ignited by the ignition plug 10 in the vicinity of a dead center on the compression, and the air-fuel mixture is burnt during the expansion stroke and a torque is given to the crank shaft 6 through the piston 4. In the subsequent exhaust stroke, the exhaust gas after the combustion is discharged from the cylinder during the valve opening of the exhaust valve 21, and is further discharged to the outside through the three-way catalyst 18 and the muffler while being circulated through the exhaust passage 17.

[0030] The combustion cycle of the engine 1 described above is executed based on the control of the ECU 31 (engine control unit). Accordingly, the input side of the ECU 31 is connected to various sensors, such as an electromagnetic pickup 32, which is disposed to be opposed to the flywheel 7 and outputs a signal in synchronization with the reluctor 7a, a throttle sensor 33, which detects opening of the throttle valve 13, an O₂ sensor 34, which is disposed in the exhaust passage 17 and varies an output stepwise according to a fluctuation of the exhaust air fuel ratio based on a stoichiometry (theoretical air fuel ratio), and a water temperature sensor 35 which detects a cooling water temperature Tw of the engine 1. The output side of the ECU 31 is connected to various devices such as the injector 16, the fuel pump 26, and an ignitor 36 for driving the ignition plug 10.

[0031] Based on information from these sensors, the ECU 31 operates the engine 1 by executing various control operations, such as a fuel injection control for driving the injector 16, an ignition timing control for driving the ignition plug 10, and a pump control for driving the fuel pump 26.

[0032] For example, in the fuel injection control, the ECU 31 determines a target fuel injection amount based on an engine rotational speed Ne calculated from the signal of the electromagnetic pickup 32, a throttle opening θ_{th} detected by the throttle sensor 33, and the like, and drives the injector 16 at a predetermined timing in synchronization with the combustion cycle of the engine 1 and executes the fuel injection.

[0033] In the ignition timing control, the ECU 31 determines the target ignition timing based on the engine rotational speed Ne, the throttle opening θ_{th} , and the like, while performing waveform shaping on the signal of the electromagnetic pickup 32 to generate a crank angle signal having a rectangular wave in synchronization with the reluctor 7a (in other words, a crank angle). Further, the ECU 31 specifies the timing corresponding to the target ignition timing based on the crank angle signal, and drives the ignitor 36 to ignite the ignition plug 10.

[0034] The ECU 31 incorporates a driver circuit 31a for driving a motor (DC motor 42 described below) as a drive source for the fuel pump 26. In the pump control, the ECU 31 drives the fuel pump 26 by supplying a drive current to the motor from the driver circuit 31a during the operation of the engine 1, and pumps the fuel pressurized to the predetermined pressure to the injector 16 (motor control unit).

[0035] Incidentally, as described above, since the fuel pump 26 according to this embodiment is a diaphragm/plunger combined type fuel pump, it is necessary to take measures for suppressing variations in the amount of fuel injection due to a fluctuation of the fuel pressure. However, since a motor is used as the drive source, it is difficult to synchronize driving of the fuel pump with the rotation of the engine, like in the plunger-type fuel pump using the magnet coil as the drive source as disclosed in Patent Document 1.

[0036] Accordingly, in this embodiment, the rotational period of the motor is set to be different from the rotational period of the engine 1, to thereby solve the problem. Prior to giving a detailed description of the pump control below, the configuration of the fuel pump 26 will now be described.

[0037] FIG. 2 is a sectional view illustrating details of the fuel pump 26.

[0038] The casing of the fuel pump 26 is composed of a motor casing 41a, a pump casing 41b, and a regulator casing 41c. The motor casing 41a includes a DC motor 42 (indicated by a dashed line) as a drive source. A cam 43 is fixed to the output shaft 42a of the DC motor 42. When the cam 43 is rotated by driving of the DC motor 42, a cam receiving member 44 reciprocates in a horizontal direction in the drawings (this direction is hereinafter referred to as an axis L direction).

[0039] A central part of a diaphragm 46 is fixed to the cam receiving member 44. The diaphragm 46 defines a diaphragm chamber 47 between the motor casing 41a and the pump casing 41b. The diaphragm 46 reciprocates rightward (hereinafter referred to as an intake side) and leftward (hereinafter referred to as a discharge side) alternately in the drawings according to a reciprocating motion of the cam receiving member 44. When the diaphragm 46 is moved to the intake side, the fuel flows into the diaphragm chamber 47 through the supply hose 27 and the supply passage 50 from the fuel tank 25. When the diaphragm 46 is moved to the discharge side, the fuel in the diaphragm chamber 47 is collected into the fuel tank 25 through the return passage 52 and the return hose 28, and such a transfer of the fuel is repeated for each reciprocating motion of the diaphragm 46.

[0040] In a sleeve 55 which is fitted and fixed to the pump casing 41b, a plunger 56 is slidably disposed along the axis L direction, is coupled to the cam receiving member 44, and reciprocates between the intake side and the discharge side in synchronization with the reciprocating motion of the diaphragm 46. When the plunger 56 is moved to the intake side, a part of the fuel in the diaphragm chamber 47 flows into the plunger 56 through the intake port 56a, and further flows into the pressurization chamber 57 through the check valve 58. The fuel in the pressurization chamber 57 is

pressurized when the plunger 56 is thereafter moved to the discharge side, and the pressurization of the fuel is repeated for each reciprocating motion of the plunger 56.

[0041] The fuel pressurized in the pressurization chamber 57 by a reciprocating motion of the plunger 56 is supplied to a pressure adjustment mechanism 59, which is provided in the regulator casing 41c, through a check valve 60, and the fuel is adjusted to a set pressure by the pressure adjustment mechanism 59. An excess fuel generated by pressure adjustment is discharged to a relief passage 69, and is collected into the fuel tank 25 together with the excess fuel from the diaphragm chamber 47. Further, the fuel whose pressure has been adjusted by the pressure adjustment mechanism 59 is pumped to the injector 16 (illustrated in FIG. 1) from the pressure adjustment chamber 66 through the injector passage 68, and is injected toward the intake port 9a of the engine 1 in accordance with the valve opening of the injector 16.

[0042] As is obvious from the above description, the fuel pump 26 according to this embodiment causes the plunger 56 to reciprocate to pressurize the fuel. Accordingly, the fuel pressure inevitably fluctuates, while the DC motor 42 is used as the drive source, and thus the technique disclosed in Patent Document 1 cannot be applied.

[0043] In view of the above-mentioned problems and characteristics of the fuel pump 26, the present inventor has focused on the following points.

[0044] First, the fuel that is pressurized by the plunger 56 and subjected to pressure adjustment by the pressure adjustment mechanism 59 is supplied to the injector 16 through the injector passage 68, and the pressure of the fuel in a passage from the injector passage 68 to the injector 16 is held at a set pressure (e.g., about 300 kPa) which is stable constantly except for a fuel pumping timing by the plunger 56 (hereinafter referred to as a fuel pumping timing). Accordingly, the fuel injection can be executed under a set fuel pressure, which is constantly stable, as long as the fuel pumping timing does not overlap the fuel injection timing of each combustion cycle, so that effects on the fuel injection amount due to a fluctuation of the fuel pressure can be eliminated.

[0045] On the other hand, for example, when the DC motor 42 of the fuel pump 26 is driven at the predetermined rotational speed N_m , a combustion cycle in which the fuel injection timing changes according to the operation area of the engine 1 and incidentally overlaps the fuel pumping timing is generated. At this time, the period of fuel injection (in other words, a rotational period T_{eg} of the engine 1 described below, which is correlated with a fuel injection time T_{Minj}) matches the period of fuel pumping (in other words, a rotational period T_{mo} of the DC motor 42 described below, which is also correlated with a fuel pumping time T_{mpump}), the combustion cycle in which the fuel pumping timing overlaps the fuel injection timing is continuously generated as long as the engine 1 remains in the operation area. Accordingly, during a period in which such a phenomenon occurs, the combustion of the engine 1 is not stabilized due to variations in the amount of fuel injection and the operation state in which a target A/F cannot be achieved continues, which causes deterioration in exhaust gas characteristics and drivability.

[0046] The problem with overlapping of the fuel injection timing with the fuel pumping timing occurs not only when the periods match each other, but also when one of the periods corresponds to the multiple of the other one of the periods. For example, when the period of fuel injection is twice the period of fuel pumping, the fuel pumping timing continuously overlaps the fuel injection timing in each combustion cycle, like in the case where the periods match each other. On the contrary, when the period of fuel pumping is twice the period of fuel injection, the fuel pumping timing overlaps the fuel injection timing once every combustion cycle, but this state causes a problem and this problem cannot be solved unless the operation area of the engine 1 is changed.

[0047] On the other hand, even if the fuel injection timing and the fuel pumping timing overlap each other in a certain combustion cycle, when one of the period of fuel injection and the period of fuel pumping does not correspond to the multiple of the other one of the periods (when the periods do not match and one of the periods does not correspond to a multiple of 2 or more of the other one of the periods), the timing do not overlap each other without fail in the next combustion cycle. In other words, the operation state in which the combustion of the engine 1 is unstable due to variations in the amount of fuel injection is limited only in one combustion cycle, which does not substantially cause deterioration in exhaust gas characteristics and drivability. Accordingly, an occurrence of overlapping between the fuel injection timing and the pumping timing for one combustion cycle can be regarded as being within an allowable range.

[0048] Based on the above findings, the present inventor has reached a conclusion that if the rotational period of the DC motor 42 is controlled to be constantly different from the rotational period of the engine 1, the relationship between the fuel injection timing and the fuel pumping timing changes every combustion cycle, and the timings may overlap incidentally in one combustion cycle, while overlapping of the periods in continuous combustion cycles, which causes a problem, can be prevented. Accordingly, two types of methods will be sequentially described as a first embodiment and a second embodiment, respectively.

[First Embodiment]

[0049] In this embodiment, a rotational period of the engine 1 is monitored and compared with a rotational period of a DC motor 42, and when the periods are close to each other, the rotational period of the DC motor 42 is controlled in a direction apart from the rotational period of the engine 1. Accordingly, the ECU 31 executes a pump control routine

illustrated in FIG. 3 at a predetermined control interval during an operation of the engine 1.

[0050] First, a signal is captured from the electromagnetic pickup 32 in step S1, and an engine rotational period Teg is calculated based on the signal in step S2 (engine rotational period calculation unit). The engine rotational period Teg described herein refers to a period of fuel injection. In this embodiment, since the 4-cycle single-cylinder gasoline engine 1 is used, the period of fuel injection repeated every two rotations (720°CA) of the engine 1 is treated as the engine rotational period Teg.

[0051] In the subsequent step S3, it is determined whether the engine rotational period Teg and a motor rotational period Tmt are different or not according to the following formula (1) (determination unit, period determination step). The motor rotational period Tmt refers to a period of fuel pumping by the plunger 56 of the fuel pump 26. As described above, the period of fuel pumping repeated every rotation of the DC motor 42 is treated as the motor rotational period Tmt. The ECU 31 functions as a motor control unit. Accordingly, since the drive current is supplied to the DC motor 42 through the driver circuit 31a, the rotational period of the DC motor 42 is calculated based on a duty ratio of the drive current or the like (motor rotational period calculation unit).

$$|\text{engine rotational period Teg} - \text{motor rotational period Tmt}| \leq \text{determination value } \Delta T \dots\dots (1)$$

[0052] The engine rotational period Teg and the motor rotational period Tmt may overlap each other even when the timings do not completely match due to various factors such as a control error of the engine 1 or the DC motor 42, a detection error of the electromagnetic pickup 32 or the like, or an increase or decrease in the engine rotational speed Ne generated between control periods of the ECU 31. Accordingly, a determination value ΔT is preliminarily set as a threshold for the purpose of controlling the rotational periods Teg and Tmt so as to be apart from each other, not only when the rotational periods Teg and Tmt completely match each other, but also when the rotational periods Teg and Tmt are close to each other to some extent (hereinafter expressed as "the periods are close to each other").

[0053] Note that the above formula (1) assumes only that the engine rotational period Teg and the motor rotational period Tmt match each other, and does not assume that one of the periods corresponds to a multiple of the other one of the periods. This is because in the specifications of the engine 1 and the fuel pump 26 according to this embodiment, one of the periods does not correspond to a multiple of the other one of the periods in any operation area. As a matter of fact, in the specifications in which one of the periods may correspond to a multiple of the other one of the periods, the formula may be modified assuming the specifications.

[0054] When the determination result indicates No (negative) in step S3, the process proceeds to step S4, and a duty ratio of the drive current supplied to the DC motor 42 is calculated by a usual method. For example, the duty ratio is calculated as a value suitable for discharging, from the fuel pump 26, the amount of fuel sufficiently enough to meet a target injection amount from the injector 16 at the point, while suppressing the rotational speed Nm of the DC motor 42 to reduce power consumption.

[0055] Specifically, the base value of the duty ratio is calculated from the operation area of the engine 1, for example, the engine rotational speed Ne and the throttle opening θ_{th} (engine load), and the base value is corrected by a correction coefficient according to the cooling water temperature Tw and the battery voltage Vbtt to calculate the final duty ratio. However, the process for calculating the duty ratio is not limited to this. For example, a fixed value that is preliminarily set regardless of the operation area of the engine 1 may be applied as the duty ratio. The duty ratio is calculated as described above, and the drive current to be supplied to the DC motor 42 is controlled based on the duty ratio in the subsequent step S5, and then the routine is terminated.

[0056] On the other hand, when it is determined that the engine rotational period Teg and the motor rotational period Tmt are close to each other and the determination result indicates Yes (positive) in the above step S3, the process shifts to step S6. The duty ratio of the drive current to be supplied to the DC motor 42 is corrected to be increased or decreased by a predetermined value (motor speed change instruction unit, rotational speed changing step), and then the process shifts to the above-mentioned step S5. The value to be corrected is a duty ratio used to achieve the motor rotational period Tmt which is applied to the calculation process in the above formula (1). The motor rotational speed Nm is increased or decreased according to the direction in which the correction is made, to thereby increase or decrease the motor rotational period Tmo so as to be apart from the engine rotational period Teg.

[0057] As is obvious from the above description, the process of step S6 aims to achieve increasing or decreasing the motor rotational speed Nm, as well as increasing or decreasing the motor rotational period Tmo, by adjusting the power to be supplied to the DC motor 42. Accordingly, the method is not limited to the correction of the duty ratio, but instead can be modified in various ways. For example, the power to be supplied to the DC motor 42 may be adjusted by correcting the PWM period and duty ratio of the drive current.

[0058] Note that if the amount of fuel to be discharged from the fuel pump 26 is larger than the target injection amount,

the duty ratio can be corrected to be increased or decreased in the above-mentioned step S6. However, in step S3, in a case where the duty ratio is set according to a minimum required amount of fuel to meet the target injection amount, when the duty ratio is corrected to be decreased, there is a possibility that the motor rotational speed N_m may decrease and the target injection amount cannot be achieved. Accordingly, in this case, the duty ratio may be corrected to be

increased, thereby making it possible to maintain the accurate fuel injection amount.
[0059] By the process of the ECU 31 described above, when the engine rotational period T_{eg} and the motor rotational period T_{mt} are different, the drive current to be supplied to the DC motor 42 is normally controlled based on the duty ratio according to the operation area of the engine 1. On the other hand, when the engine rotational period T_{eg} and the motor rotational period T_{mt} are close to each other, the duty ratio (or the PWM period and the duty ratio) is corrected to thereby increase or decrease the motor rotational speed N_m , thereby setting the motor rotational period T_{mo} to be apart from the engine rotational period T_{eg} .

[0060] Consequently, according to the control device for the fuel pump 26 of this embodiment, the motor rotational period T_{mt} is constantly set to be different from the engine rotational period T_{eg} during the operation of the engine 1, thereby making it possible to change the relationship between the fuel injection timing and the fuel pumping timing for each combustion cycle. Accordingly, even if the fuel injection timing and the fuel pumping timing incidentally overlap each other in a certain combustion cycle, the timings do not overlap each other without fail in the next combustion cycle. Accordingly, the operation state in which the combustion of the engine 1 is unstable due to variations in the amount of fuel injection is instantaneously finished within one combustion cycle. Accordingly, deterioration in exhaust gas characteristics and drivability due to variations in the amount of fuel injection can be avoided by using the diaphragm/plunger combined type fuel pump 26 using the DC motor 42 as a drive source.

[Second Embodiment]

[0061] Next, a second embodiment for embodying the present invention will be described. The hardware configuration of this embodiment is the same as that of the first embodiment, while the process content of the ECU 31 of this embodiment differs from that of the first embodiment. Specifically, in the first embodiment, the duty ratio setting process is switched (step S4 in FIG. 3) based on the result of a comparison between the engine rotational period T_{eg} and the motor rotational period T_{mt} , while in this embodiment, the fuel pumping timing of the plunger 56 is specified based on a change of a drive current value supplied to the DC motor 42, and the duty ratio setting process is switched based on the result of a comparison between the fuel pumping timing and the fuel injection timing of the engine 1. Accordingly, differences in the process of the ECU 31 are focused in the following description.

[0062] First, a current detection circuit 31b as indicated by a dashed line in FIG. 1 is provided in the ECU 31 of this embodiment to detect a drive current value to be supplied to the DC motor 42 from the driver circuit 31a, and the ECU 31 is configured to be able to specify the fuel pumping timing of the plunger 56 based on the detection result of the current detection circuit 31b (fuel pumping timing specifying unit).

[0063] In the pump control routine illustrated in FIG. 4, the ECU 31 first captures the drive current value of the DC motor 42 in step S11, and specifies the fuel pumping timing of the plunger 56 in the current combustion cycle in step S12 based on a change of the drive current value. Since the drive current value of the DC motor 42 has such characteristics that the drive current value is rapidly increased at a timing when the fuel is pumped by the plunger 56, the timing for changing the drive current value to be increased is regarded as the fuel pumping time TM_{pump} .

[0064] In the subsequent step S13, it is determined whether the fuel injection time T_{Minj} of the injector 16 is different from the fuel pumping time TM_{pump} , according to the following formula (2) (determination unit, period determination step). Since the ECU 31 itself drives and controls the injector 16 in the fuel injection control, the drive timing is regarded as the fuel injection time T_{Minj} (fuel injection timing specifying unit).

$$\begin{aligned} & | \text{fuel injection time } T_{Minj} - \text{fuel pumping time } TM_{pump} | \\ & \leq \text{determination value } \Delta TM \dots (2) \end{aligned}$$

[0065] The determination value ΔTM is set in a manner similar to the determination value ΔT in Formula (1), and is preliminarily set not only when the fuel injection time T_{Minj} and the fuel pumping time TM_{pump} completely match each other, but also when the timings are close to each other to some extent (hereinafter expressed as "the periods are close to each other").

[0066] The determination result in step S13 indicates No, the duty ratio of the drive current to be supplied to the DC motor 42 is calculated from the operation area of the engine 1 by a normal method in step S14. When the determination result in the above-mentioned step S13 indicates Yes, the duty ratio (or the PWM period and the duty ratio) of the drive current to be supplied to the DC motor 42 is corrected to be increased or decreased in step S16 (motor speed change

instruction unit, rotational speed changing step), and then the drive current to be supplied to the DC motor 42 is controlled in step S15.

[0067] By the process of the ECU 31 described above, when the fuel injection time T_{Minj} and the fuel pumping time T_{Mpump} are different, the drive current to be supplied to the DC motor 42 is normally controlled based on the duty ratio according to the operation area of the engine 1. On the other hand, when the fuel injection time T_{Minj} and the fuel pumping time T_{Mpump} are close to each other, the motor rotational speed N_m is increased or decreased by correcting the duty ratio. An increase or decrease in the motor rotational speed N_m indicates that the motor rotational period T_{mo} is set to be apart from the engine rotational period T_{eg} , and also indicates that the fuel pumping time T_{Mpump} is set to be apart from the fuel injection time T_{Minj} .

[0068] As a result, operations and effects similar to those of the first embodiment are obtained and repeated explanations thereof are omitted. The motor rotational period T_{mt} is constantly set to be different from the engine rotational period T_{eg} during the operation of the engine 1, thereby making it possible to change the relationship between the fuel injection time T_{Minj} and the fuel pumping time T_{Mpump} for each combustion cycle. Accordingly, deterioration in exhaust gas characteristics and drivability due to variations in the amount of fuel injection can be avoided by using the diaphragm/plunger combined type fuel pump 26 using the DC motor 42 as a drive source.

[0069] Note that the aspects of the present invention are not limited to the above embodiments. For example, the above embodiments embody the present invention as the control device for the fuel pump 26 for the engine 1 mounted on a two-wheel vehicle, but the vehicle on which the engine 1 is mounted is not limited to the two-wheel vehicle. For example, the present invention may be embodied as a control device for a fuel pump for an engine mounted on a three-wheel vehicle or a generator, and a control method for the control device.

[0070] Further, in the embodiments described above, the present invention is applied to the diaphragm/plunger combined type fuel pump 26, but the configuration of the fuel pump 26 is not limited to this. For example, the present invention can also be applied to a plunger-type fuel pump in which fuel is pressurized and supplied only by the plunger 56, without using the diaphragm 46.

Explanation of Reference Signs

[0071]

- 1 engine
- 16 injector
- 26 fuel pump
- 31 ECU (determination unit, motor speed change instruction unit, engine rotational period calculation unit, motor rotational period calculation unit, fuel injection timing specifying unit)
- 31a driver circuit (motor control unit)
- 31b current detection circuit (fuel pumping timing specifying unit)
- 42 DC motor
- 46 diaphragm
- 56 plunger

Claims

1. A control device for a fuel pump, comprising:

- a plunger-type fuel pump causing a plunger to reciprocate by driving of a motor to pump a fuel pressurized to a predetermined pressure;
- an injector injecting the fuel in synchronization with a combustion cycle of an engine, the fuel being pumped from the fuel pump;
- a motor control unit supplying the motor with a drive current to control the motor;
- a determination unit executing a determination process for determining whether one of a period of fuel injection by the injector and a period of fuel pumping by the plunger corresponds to a multiple of the other one of the periods; and
- a motor speed change instruction unit causing the motor control unit to change a rotational speed of the motor when the determination unit determines that the one of the periods corresponds to the multiple of the other one of the periods.

2. The control device for the fuel pump according to Claim 1, further comprising:

an engine rotational period calculation unit calculating a rotational period of the engine; and
a motor rotational period calculation unit calculating a rotational period of the motor,
wherein the determination unit executes the determination process by comparing the rotational period of the
engine calculated by the engine rotational period calculation unit with the rotational period of the motor calculated
by the motor rotational period calculation unit.

3. The control device for the fuel pump according to Claim 1, further comprising:

a fuel injection timing specifying unit specifying a fuel injection timing of the injector; and
a fuel pumping timing specifying unit specifying a fuel pumping timing of the plunger based on a change of a
drive current value supplied to the motor by the motor control unit,
wherein the determination unit executes the determination process by comparing the fuel injection timing of the
injector specified by the fuel injection timing specifying unit with the fuel pumping timing of the plunger specified
by the fuel pumping timing specifying unit.

4. The control device for the fuel pump according to any one of Claims 1 to 3, wherein the fuel pump is configured to
cause a diaphragm to reciprocate by driving of the motor, cause the plunger to reciprocate in synchronization with
a reciprocating motion of the diaphragm, and pump the fuel pressurized by the plunger to the injector, the fuel being
sent out from the diaphragm.

5. A control method for a fuel pump, comprising:

a period determination step of comparing a period of fuel pumping by a plunger-type fuel pump and a period of
fuel injection by an injector, and determining whether one of the periods corresponds to a multiple of the other
one of the periods, the plunger-type fuel pump being configured to cause a plunger to reciprocate by driving of
a motor to pump a fuel, the injector being configured to inject the fuel pumped from the fuel pump in synchro-
nization with a combustion cycle of an engine; and
a rotational speed changing step of changing a rotational speed of the motor when it is determined in the period
determination step that one of the periods corresponds to the multiple of the other one of the periods.

FIG. 1

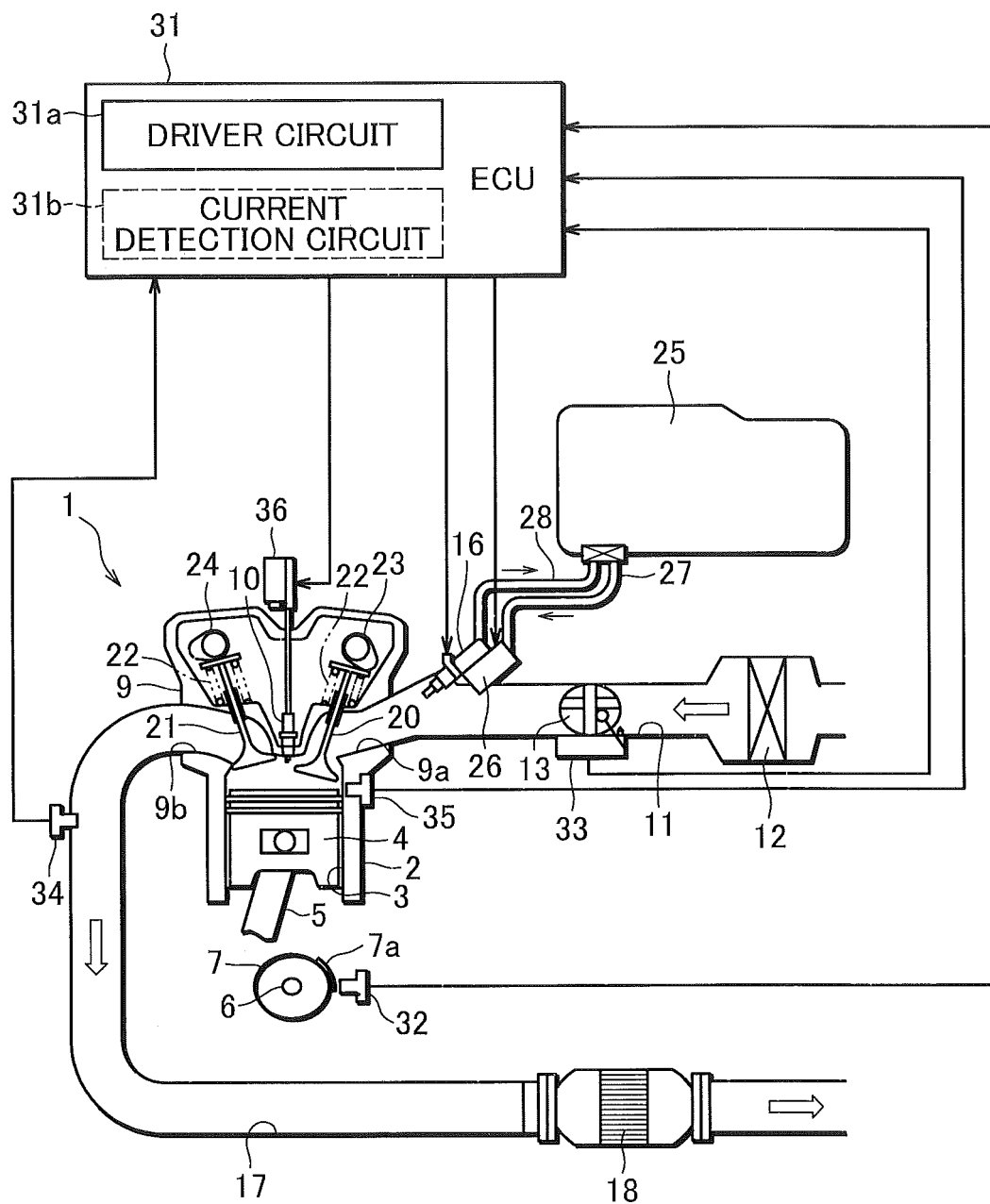


FIG. 2

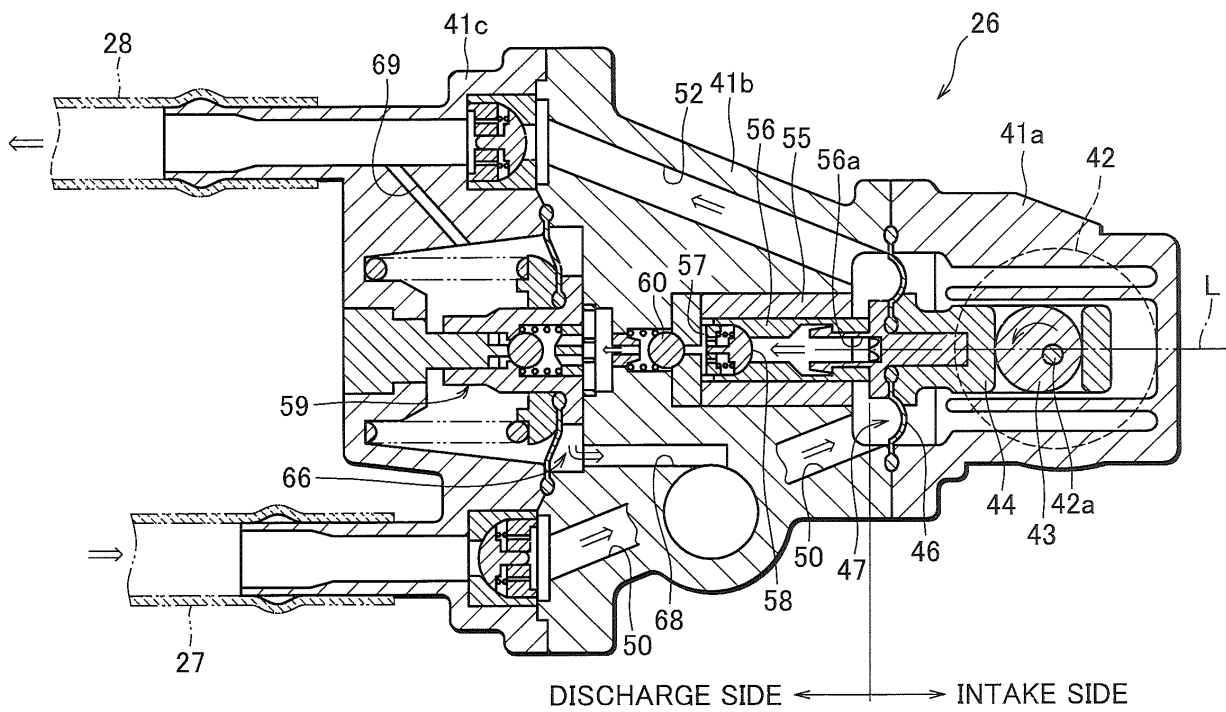


FIG. 3

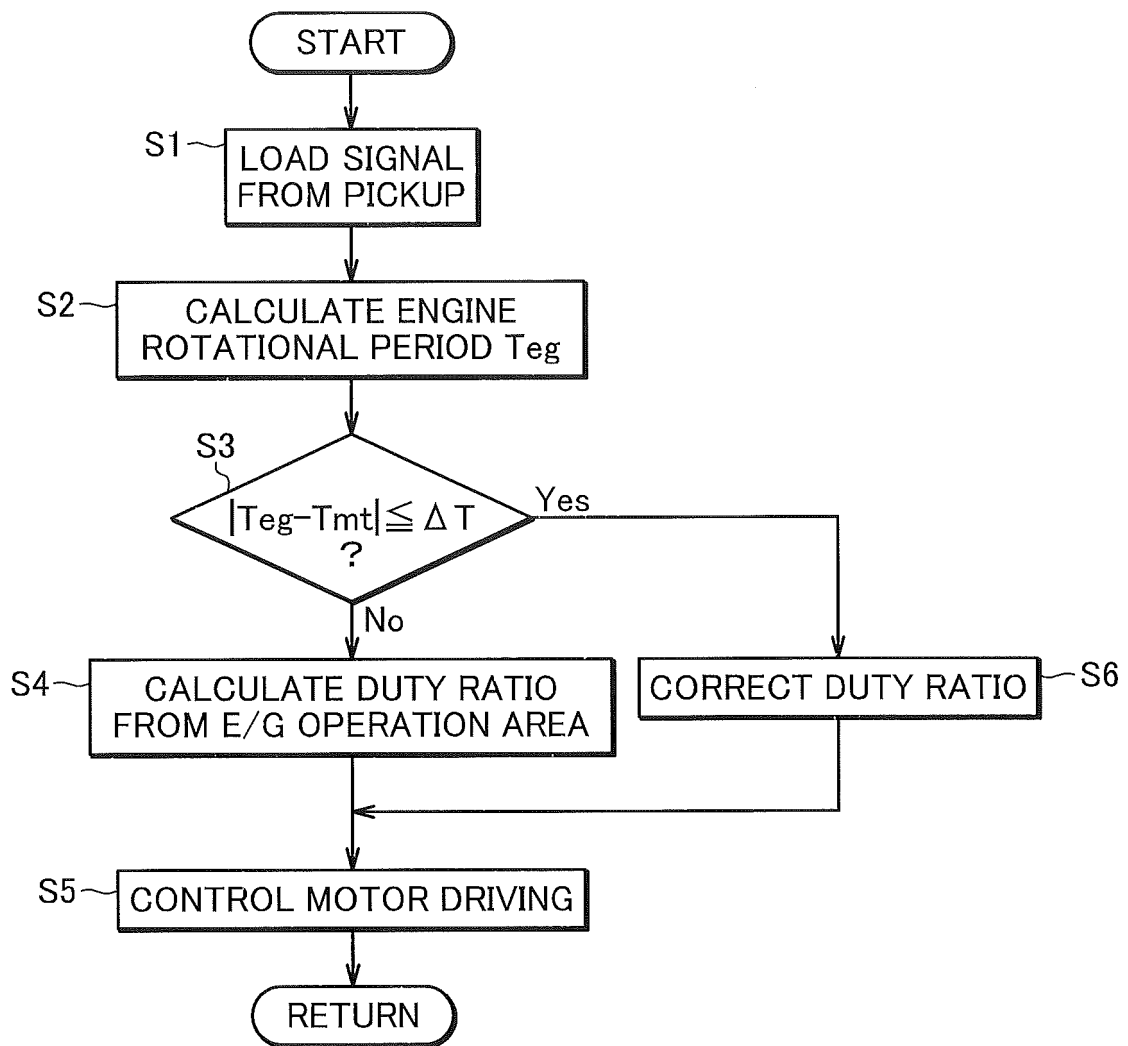
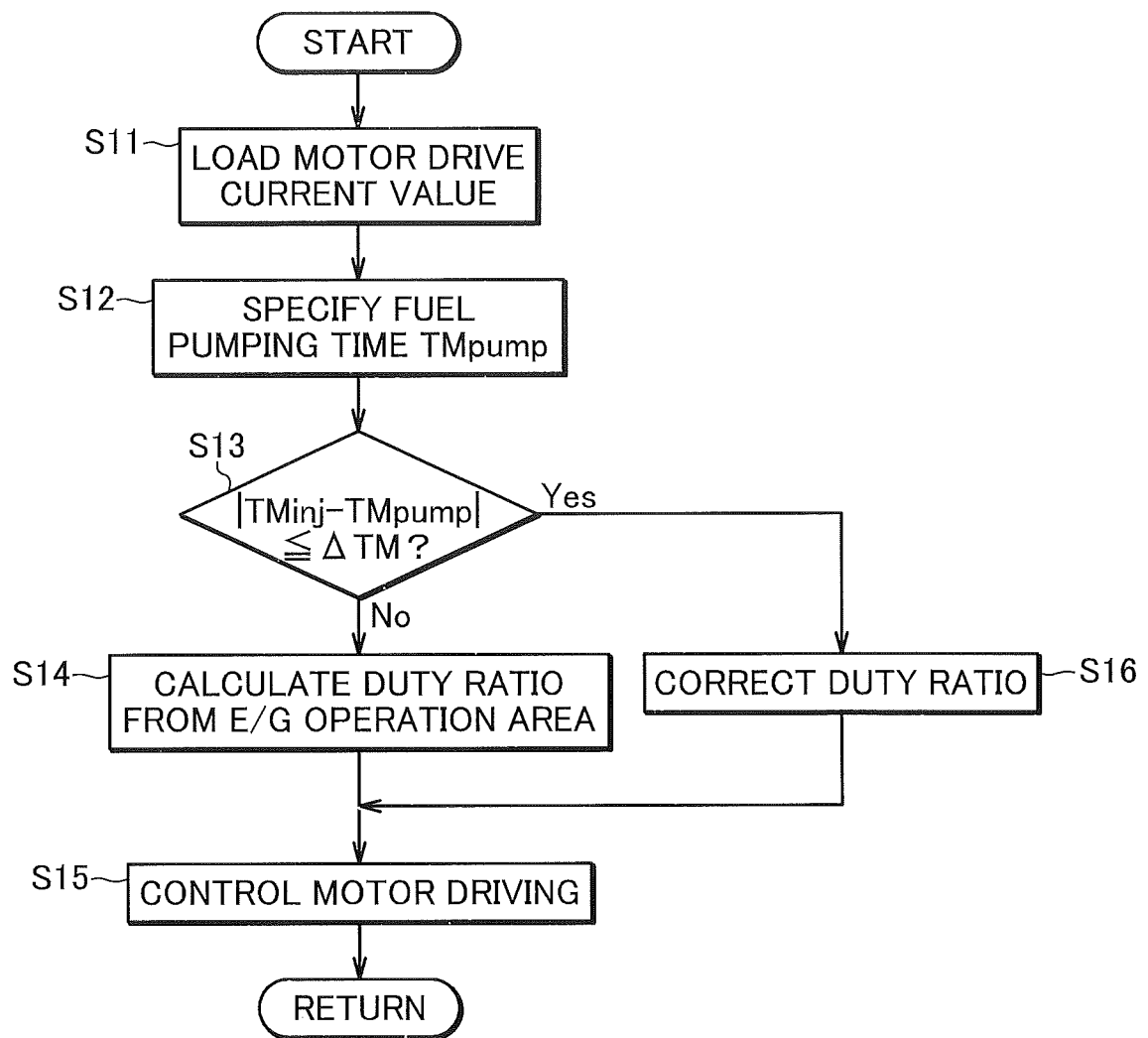


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

F02D41/04(2006.01) i, F02M37/08(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)

F02D41/04, F02M37/08

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-148003 A (Mikuni Corp.), 01 August 2013 (01.08.2013), paragraphs [0002] to [0003]; fig. 5 & WO 2013/108721 A1 & CN 104066967 A	1-5
A	WO 2012/157564 A1 (Mikuni Corp.), 22 November 2012 (22.11.2012), claim 1; fig. 4, 6A to 6D & US 2014/0064989 A1 claim 1; fig. 4, 6A to 6D & WO 2012/157564 A1 & EP 2708729 A1 & CN 103649520 A	1-5
A	JP 2007-162644 A (Denso Corp.), 28 June 2007 (28.06.2007), paragraph [0067] & DE 102006000530 A1	1-5

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

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"&" document member of the same patent family

Date of the actual completion of the international search
24 June 2016 (24.06.16)Date of mailing of the international search report
05 July 2016 (05.07.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/065195

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001-107818 A (Denso Corp.), 17 April 2001 (17.04.2001), paragraphs [0040] to [0041] (Family: none)	1-5
A	JP 2008-121426 A (Toyota Motor Corp.), 29 May 2008 (29.05.2008), claim 1 (Family: none)	1-5
A	JP 10-274131 A (Mitsubishi Motors Corp.), 13 October 1998 (13.10.1998), paragraph [0040] (Family: none)	1-5
A	JP 2013-136990 A (Mikuni Corp.), 11 July 2013 (11.07.2013), claim 1; fig. 3 & WO 2013/099679 A1 & CN 104066969 A	1-5

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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