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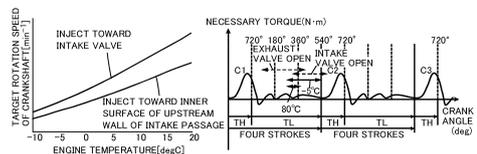
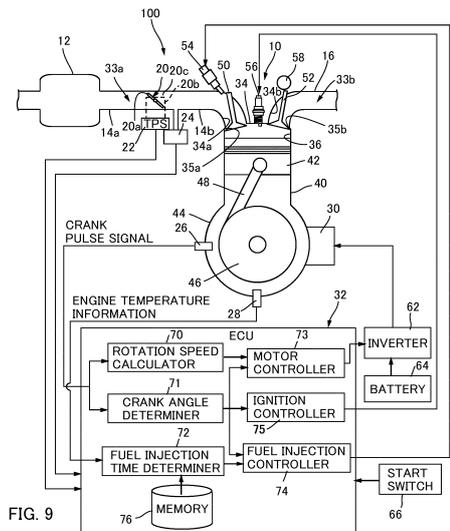
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(54) **ENGINE UNIT**

(57) Provided is an intake-pipe fuel injection four-stroke engine unit capable of enhancing startability of an engine 10 in which a high-load region TH and a low-load region TL are present in four strokes. The engine unit includes: a four-stroke engine body 10 having the high-load region TH and the low-load region TL in four strokes; a permanent magnet starter motor 30 including a permanent magnet and configured to rotate a crank shaft 46; and an ECU 32 configured to control the permanent magnet starter motor 30. The rotation speed of the permanent magnet starter motor 30 is controlled based on a temperature of the four-stroke engine body 10 measured by an engine temperature sensor 28 such that an increase in the rotation speed of the crank shaft 46 is suppressed while the crank angle is in the low-load region TL and from when a fuel injection device 54 injects fuel to an intake passage 33a to when an intake valve 50 is closed.



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Description

TECHNICAL FIELD

[0001] The present teaching relates to an engine unit that includes a high-load region and a low-load region in four strokes and starts by cranking a crankshaft with a starter motor.

BACKGROUND ART

[0002] A known engine of a vehicle is a four-stroke engine (e.g., a single-cylinder engine) that includes, in four strokes, a high-load region where a load for rotating a crankshaft of the engine is high and a low-load region where the load for rotating the crankshaft of the engine is small.

[0003] Patent Document 1 (Japanese Patent Application Publication No. 2003-343404) discloses an engine starting apparatus that starts an engine by temporarily rotating a crankshaft in a reverse direction to stop the crankshaft and then rotating the crankshaft in a normal direction.

[0004] In the engine starting apparatus of Patent Document 1, after the rotation of the crankshaft of the engine has stopped, a motor causes the crankshaft to rotate in the reverse direction to a position at which the load increases in the reverse rotation, that is, halfway in an expansion stroke. Thereafter, the engine starting apparatus rotates the motor in the normal direction from the halfway position in the expansion stroke to thereby rotate the crankshaft in the normal direction.

[0005] As described above, the crankshaft is rotated in the reverse direction to the position at which the load increases, that is, the halfway position in the expansion stroke so that the crankshaft rotates in a low-load region from halfway of the expansion stroke to a compression stroke in starting the engine. Subsequently, the engine reaches a first high-load region. Thus, before the engine reaches the first high-load region, the rotation speed of the crankshaft can be increased. By using both of a large inertial force with the high rotation speed and an output torque of a starter motor, the engine can pass over the first high-load region.

[0006] Patent Document 2 (International Patent Publication No. WO2015/093576) discloses an engine unit in which while the crankshaft rotates in the normal direction after a combustion operation of a four-stroke engine body has stopped, a resistance is applied to the normal rotation of the crankshaft with a three-phase brushless motor.

[0007] The engine unit stops the crankshaft at a position of a compression stroke in the four-stroke engine body. Then, in accordance with an input of a start instruction in stopping the crankshaft, the three-phase brushless motor rotates the crankshaft in the normal direction from the stop position of the compression stroke.

[0008] Accordingly, in the case of starting the four-

stroke engine body in accordance with the input of the start instruction, even with a small output torque of the motor, the rotation of the crankshaft can be started at a position at which the four-stroke engine can be easily started.

[0009] In the case where the crankshaft starts rotating in accordance with the input of the start instruction as described above, the rotation speed of the crankshaft gradually increases from the stopped state. In the case where the normal rotation of the crankshaft starts from the compression stroke, the rotation speed of the crankshaft is low in the compression stroke. As described above, in the case where the rotation speed of the crankshaft is low in the compression stroke, the crankshaft is not affected by a compression reaction force by a gas in a combustion chamber. Consequently, the crankshaft can rotate quickly over a load in the high-load region of the compression stroke.

CITATION LIST

PATENT DOCUMENT

[0010]

Patent Document 1: Japanese Patent Application Publication No. 2003-343404

Patent Document 2: International Patent Publication No. WO2015/093576

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0011] The inventors of the present teaching evaluated startability of the engine in which the high-load region and the low-load region are present in four strokes as described in Patent Documents 1 and 2. Consequently, the inventors of the present teaching found that in some specific phases, a load varies largely so that startability of the engine degrades.

[0012] It is therefore an object of the present teaching to provide a configuration capable of enhancing startability in the engine in which the high-load region and the low-load region are present in four strokes.

SOLUTION TO PROBLEM

[0013] The inventors of the present teaching evaluated startability of a previously presented engine in which a high-load region and a low-load region are present in four strokes.

[0014] The previously presented engine in which the high-load region and the low-load region are present in four strokes, startability of the engine is enhanced by utilizing an inertial force obtained by increasing the rotation speed of the crankshaft in the low-load region. Thus, the engine basically shows excellent startability.

[0015] However, through the examination, the inventors of the present teaching found that in some specific phases, a large variation of a load of the engine degrades startability of the engine conversely when the rotation speed of the crankshaft is increased in the low-load region.

[0016] Specifically, in the engine in which the high-load region and the low-load region are present in four strokes, even with an extremely low engine temperature, the rotation speed of the crankshaft increases in the low-load region. In particular, with an extremely low engine temperature, the load of the engine further increases, and thus, control of increasing an inertial force by increasing the rotation speed of the crankshaft in the low-load region is considered to be preferable.

[0017] However, if the rotation speed of the crankshaft is increased in the low-load region with an extremely low engine temperature, vaporization of injected fuel is suppressed under a reduced vapor pressure of fuel due to the temperature decrease. This suppression of vaporization and the increase in the rotation speed of the crankshaft reduce the time from fuel injection start to completion of an intake stroke. Accordingly, the amount of fuel flowing into a combustion chamber decreases.

[0018] Consequently, the total heat generation amount of fuel contributing to combustion decreases so that a torque obtained by combustion cannot be sufficiently obtained, and the engine cannot be started in some cases. In addition, in the engine in which the high-load region and the low-load region are present in four strokes, a large combustion interval might cause a similar phenomenon in next combustion.

[0019] As described above, in the engine in which the high-load region and the low-load region are present in four strokes, when the rotation speed of the crankshaft is increased in the low-load region with an extremely low engine temperature, startability might degrade conversely, in some cases. The inventors of the present teaching found the foregoing phenomenon through the evaluation of startability of the engine in which the high-load region and the low-load region are present in strokes.

[0020] As disclosed in Patent Documents 1 and 2, in the engine in which the high-load region and the low-load region are present in four strokes, startability is enhanced by using an inertial force obtained by increasing the rotation speed of the crankshaft in the low-load region. Since the load of the engine further increases with an extremely low engine temperature, it is not conceivable to reduce the inertial force by suppressing an increase in the rotation speed of the crankshaft in the low-load region.

[0021] However, in the case of a permanent magnet starter motor, a torque can be increased as the rotation speed decreases. The inventors of the present teaching found that in the engine in which the high-load region and the low-load region are present in four strokes, such a characteristic of a permanent magnet starter motor can be used for sufficiently increasing the energy obtained

by the first combustion even when an increase in the rotation speed of the crankshaft is suppressed in the low-load region after the rotation of the crankshaft from the stopped state and before the first combustion with an extremely low engine temperature. In addition, in an engine temperature region where startability does not degrade, the increase in the rotation speed of the crankshaft can be promoted in the low-load region after the rotation of the crankshaft from the stopped state and before the first combustion, and startability as the same level as before can be obtained.

[0022] Based on the results of the examination described above, the inventors of the present teaching arrived at the configuration as follows.

[0023] The present teaching employs the following configuration in order to solve the problem described above.

(1) An engine unit according to one embodiment of the present teaching includes:

a four-stroke engine body including a combustion chamber having an intake port and an exhaust port, an intake valve configured to open and close the intake port, an exhaust valve configured to open and close the exhaust port, an intake passage connected to the intake port and configured to guide air in the atmosphere into the combustion chamber through the intake port, an exhaust passage connected to the exhaust port, a fuel injection device configured to inject fuel into the intake passage, an ignition device configured to ignite an air-fuel mixture including fuel and air in the combustion chamber, a piston configured to move to and fro in the combustion chamber, and a crank shaft connected to the piston to rotate in accordance with the to-and-fro movement of the piston, a high-load region where a load for rotating the crank shaft is high and a low-load region where the load for rotating the crank shaft is low being present in four strokes: a permanent magnet starter motor that includes a permanent magnet and is configured to rotate the crank shaft; a control device that controls the permanent magnet starter motor, the fuel injection device, and the ignition device; an engine temperature detector that detects a temperature of the four-stroke engine body; and a crank angle detector that detects a crank angle, the crank angle being a position of a rotation angle of the crank shaft, wherein the control device drives the permanent magnet starter motor to rotate the crank shaft from a stopped state, controls the fuel injection device while a crank angle of the crank shaft is in the low-load region, thereby injecting fuel into the intake passage, controls a rotation speed of the permanent magnet starter motor so that an increase in a rotation speed of the crank shaft is suppressed, based on the temperature of the four-stroke engine body detected by the engine temperature detector while the crank angle of the crank shaft is in the low-load region

and from when the fuel injection device injects fuel into the intake passage to when the intake valve is closed, and starts the four-stroke engine body by igniting the air-fuel mixture in the combustion chamber by using the ignition device while the crank angle of the crank shaft is in the high-load region.

With the configuration described above, the rotation speed of the permanent magnet starter motor is controlled in accordance with the temperature of the engine unit so that the rotation speed of the crankshaft can be reduced. Thus, the fuel injection time is increased so that the time for fuel evaporation in accordance with the engine temperature can be obtained. In addition, since the permanent magnet starter motor has a large torque in low-speed rotation, energy sufficient for starting the engine can be obtained. Thus, this configuration described above can enhance startability of the engine.

(2) In another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The control device controls the rotation speed of the permanent magnet starter motor such that a rotation speed of the crank shaft obtained when the temperature of the four-stroke engine body detected by the engine temperature detector is a first temperature is lower than a rotation speed of the crank shaft obtained when the temperature of the four-stroke engine body detected by the engine temperature detector is a second temperature higher than the first temperature.

With this configuration, at a low engine temperature, the time for fuel evaporation can be obtained so that startability of the engine can be enhanced.

(3) In yet another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The fuel injection device injects fuel toward the intake valve. The injection of fuel to a position near the intake port can increase efficiency of fuel supply.

(4) In still another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The control device determines a rotation speed of the crank shaft in accordance with a fuel injection time determined based on the temperature of the four-stroke engine body detected by the engine temperature detector.

With this configuration, control of the fuel injection time in accordance with the engine temperature can be easily performed. Thus, start of the engine can be more efficiently controlled.

(5) In still another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The engine temperature detector is a sensor that detects a temperature of a coolant of the four-stroke engine body or a temperature of oil in an oil passage. With this configuration, the sensor necessary as a function of the engine is shared so that the configuration of the engine unit can be

simplified.

(6) In still another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The control device causes the fuel injection device to inject fuel until the fuel injection time exceeds a predetermined time in which fuel necessary for engine start is allowed to be supplied. With this configuration, a predetermined amount or more of fuel supply to the engine can be obtained so that startability of the engine can be enhanced.

(7) In still another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The control device controls the rotation speed of the motor such that as the temperature of the four-stroke engine body detected by the engine temperature detector decreases, the rotation speed of the crank shaft in the fuel injection time decreases. With this configuration, the time for fuel evaporation at low temperatures can be obtained so that startability of the engine can also be enhanced at low temperatures.

(8) In still another aspect, the engine unit according to the present teaching preferably includes a configuration as follows: The four-stroke engine body further includes a decompression mechanism that temporarily opens the exhaust valve in order to eject the air-fuel mixture in the combustion chamber while the crank angle of the crank shaft is in the high-load region. In the configuration, including the decompression mechanism as described above, the rotation speed of the crankshaft might be insufficiently increased by the first combustion in starting the engine. On the other hand, application of the configurations described above enables energy for starting the engine to be obtained by the first combustion, and thus, startability of the engine can be enhanced.

[0024] The terminology used herein is used for the purpose of defining some particular embodiments only and is not intended to limit the present teaching. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0025] It will be further understood that the terms "including," "comprising" or "having" and the variations thereof when used in this specification, specify the presence of stated features, steps, elements, components, and/or their equivalents, but can include steps, operations, elements, components, and/or one or more of the groups.

[0026] It will be further understood that the terms "mounted," "connected," "coupled," and/or their equivalents are used broadly and encompass both direct and indirect mounting, connecting and coupling. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings, and can include direct or indirect connections or couplings.

[0027] Unless otherwise defined, all the terms (including technical and scientific terms) used herein have the

same meaning as commonly understood by one having ordinary skill in the art to which this present teaching belongs.

[0028] It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0029] In describing the present teaching, it will be understood that a number of techniques and steps are disclosed. Each of these has individual benefit and each can also be used in conjunction with one or more, or in some cases all, of the other disclosed techniques.

[0030] Accordingly, for the sake of clarity, this description will refrain from repeating every possible combination of the individual steps in an unnecessary fashion. Nevertheless, the specification and claims should be read with the understanding that such combinations are entirely within the scope of the present teaching.

[0031] In the following description, numerous specific examples are set forth in order to provide a thorough understanding of the present teaching. It will be evident, however, to one skilled in the art that the present teaching may be practiced without these specific examples.

[0032] Therefore, the following disclosure is to be considered as an exemplification of the present teaching, and is not intended to limit the present teaching to the specific embodiments illustrated by the figures or description below.

<Definition of Cranking>

[0033] Cranking herein refers to rotation of a crankshaft by applying an external force from outside an engine without using combustion in cylinders of an engine. In particular, cranking refers to the rotation of the crankshaft by using a motor for starting the engine in starting the engine. The term "cranking" includes application of an external force to the crankshaft while combustion occurs in cylinders of the engine.

<Definition of High-load Region>

[0034] The high-load region of the engine herein refers to a region where a torque necessary for compressing an in-cylinder gas is high in a compression stroke in an operation range of the engine. The high-load region of the engine includes the compression stroke.

<Definition of Low-load Region>

[0035] The low-load region of the engine herein refers to a region where the in-cylinder gas is not compressed in the operation range of the engine.

<Definition of Temperature of Four-stroke Engine>

[0036] The temperature of the four-stroke engine body herein refers to a temperature in a combustion chamber of the engine or a temperature detected by an engine temperature detector for detecting a temperature concerning a temperature in the combustion chamber. The temperature concerning the temperature in the combustion chamber refers to a temperature that varies depending on the temperature in the combustion chamber, such as a temperature of a coolant, temperatures of a cylinder and a crankcase body of the four-stroke engine body, a fuel temperature, an injector temperature, and an intake port temperature. This temperature may be a temperature of oil in an oil passage in the case of an air cooling engine, for example.

ADVANTAGEOUS EFFECTS OF INVENTION

[0037] An engine unit according to one embodiment of the present teaching can enhance startability of an engine.

BRIEF DESCRIPTION OF DRAWINGS

[0038]

[FIG. 1] FIG. 1 is a schematic view illustrating a configuration of an engine unit according to the first embodiment.

[FIG. 2] FIG. 2 is an illustration showing a relationship between a crank angle and a torque necessary for cranking in starting an engine.

[FIG. 3] FIG. 3 is a flowchart depicting an operation of rotation speed control of a permanent magnet starter motor by an ECU in starting the engine unit illustrated in FIG. 1.

[FIG. 4] FIG. 4 is a graph showing a relationship between an engine speed and a crank angle in starting the engine unit illustrated in FIG. 1.

[FIG. 5] FIG. 5 is a view illustrating an example of a motion of a crankshaft in starting the engine unit illustrated in FIG. 1.

[FIG. 6] FIG. 6 is a graph schematically showing a relationship between an opening degree of an exhaust valve and a crank angle in the engine unit illustrated in FIG. 1.

[FIG. 7] FIG. 7 is a graph showing engine speeds at a high engine temperature and a low engine temperature in starting the engine unit illustrated in FIG. 1.

[FIG. 8A] FIG. 8A is a graph showing an example of a relationship between an engine temperature and a rotation speed of the crankshaft in starting the engine.

[FIG. 8B] FIG. 8B is a graph showing another example of the relationship between the engine temperature and the rotation speed of the crankshaft in starting the engine.

[FIG. 9] FIG. 9 illustrates a schematic configuration of the engine unit, while showing an example of a relationship between an engine temperature and a rotation speed of the crankshaft in starting the engine and a relationship between a crank angle and a necessary torque in starting the engine.

[FIG. 10] FIG. 10 is a schematic view illustrating a configuration of an engine unit according to the second embodiment.

[FIG. 11] FIG. 11 is a graph showing an example of a comparison with the cases of a different fuel injection position in the relationship between the engine temperature and the rotation speed of the crankshaft in starting the engine.

DESCRIPTION OF EMBODIMENTS

First Embodiment

[0039] The embodiments will be described hereinafter with reference to the drawings. In the drawings, the same parts are denoted by the same reference numerals, and the description thereof will not be repeated. The dimensions of the components in the drawings do not strictly represent actual dimensions of the components and dimensional proportions of the components.

<Configuration of Engine Unit>

[0040] A configuration of an engine unit 100 will be described. The engine unit 100 is provided in a motorcycle, which is an example of a vehicle. FIG. 1 is a view schematically illustrating a configuration of the engine unit 100. The following description will be directed to a case where the engine unit 100 includes a single-cylinder four-stroke engine body 10 (hereinafter referred to simply as an engine 10). In FIG. 1, the components of the engine unit 100 are simplified. The engine unit 100 according to this embodiment is an engine unit including a four-stroke engine 10 in which an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke are included in one cycle.

[0041] As illustrated in FIG. 1, the engine unit 100 includes the engine 10, an air cleaner 12, an intake pipe 14a, an intake pipe 14b, an exhaust pipe 16, a throttle device 20, a throttle position sensor (hereinafter referred to as a TPS) 22, a pressure sensor 24, a crank angle sensor 26 (crank angle detector), an engine temperature sensor 28 (engine temperature detector), a permanent magnet starter motor 30, an engine control device (control unit, hereinafter referred to as an ECU) 32, an inverter 62, a battery 64, and a start switch 66. First, the components except for the engine 10 will be briefly described.

[0042] The air cleaner 12 takes air in the atmosphere (air outside the vehicle including the engine 10) and purifies the intake air. An end of the intake pipe 14a is connected to the air cleaner 12. The other end of the intake pipe 14a is connected to a throttle body 20c described

later of the throttle device 20. An end of the intake pipe 14b is connected to the throttle body 20c of the throttle device 20. The other end of the intake pipe 14b is connected to a passage 34a formed in a cylinder head 34 described later. An end of the exhaust pipe 16 is connected to the passage 34b formed in the cylinder head 34 described later. In this embodiment, an intake passage 33a is formed by, for example, a space inside the intake pipe 14a, a space inside the throttle body 20c, a space inside the intake pipe 14b, and the passage 34a. In this embodiment, an exhaust passage 33b is formed by, for example, the passage 34b and a space inside the exhaust pipe 16.

[0043] The intake passage 33a guides air in the atmosphere purified by the air cleaner 12 into a combustion chamber 36 described later of the engine 10 through an intake port 35a described later. On the other hand, the exhaust passage 33b exhausts air in the combustion chamber 36 to the atmosphere (outside the vehicle) through an exhaust port 35b described later.

[0044] The configuration of the intake passage 33a is not limited to the configuration illustrated in FIG. 1, and only needs to guide air in the atmosphere to the combustion chamber 36 described later. The configuration of the exhaust passage 33b is not limited to the configuration illustrated in FIG. 1, and only needs to discharge a gas in the combustion chamber 36 to the atmosphere. In the following description, the terms of "upstream" and "downstream" refer to "upstream" and "downstream" with respect to an airflow direction from the air cleaner 12 to the exhaust passage 33b through the intake passage 33a and the engine 10.

[0045] The throttle device 20 includes a throttle valve 20a, a driving device 20b for driving the throttle valve 20a, and a throttle body 20c. The throttle valve 20a and the driving device 20b are disposed in the throttle body 20c. As the driving device 20b, an electric motor may be used, for example.

[0046] The throttle valve 20a is driven by the driving device 20b to thereby adjust an opening area of the intake passage 33a. That is, in this embodiment, the throttle valve 20a serves as a regulating valve that adjusts the opening area of the intake passage 33a. As will be described later, the driving device 20b is controlled by an ECU 32.

[0047] The TPS 22 detects a position of the throttle valve 20a as a throttle opening angle. The TPS 22 outputs a signal indicating the detected throttle opening angle to the ECU 32.

[0048] The pressure sensor 24 detects a pressure (intake pressure) of a space downstream of the throttle valve 20a in the intake passage 33a. That is, the pressure sensor 24 detects a pressure of a space between the throttle valve 20a and the combustion chamber 36 described later in the intake passage 33a. In the following description, the intake pressure refers to a pressure of a space between the throttle valve 20a and the combustion chamber 36 in the intake passage 33a. The pressure

sensor 24 outputs a signal concerning the detected pressure to the ECU 32. In this embodiment, the pressure sensor 24 is a pressure detector.

[0049] The crank angle sensor 26 detects a rotation position (hereinafter referred to as a crank angle) of a crankshaft 46 described later of the engine 10. The crank angle sensor 26 outputs a signal indicating the detected crank angle (crank pulse signal) to the ECU 32.

[0050] Based on the signal output from the crank angle sensor 26, the ECU 32 ignites an air mixture in the combustion chamber 36 by an ignition plug 56 described later of the engine 10.

[0051] The configuration and operation of the ECU 32 described above are similar to those of a conventional ECU, and will not be described in detail.

[0052] The ECU 32 performs operation control in starting the engine. Specifically, the ECU 32 includes a rotation speed calculator 70, a crank angle determiner 71, a fuel injection time determiner 72, a motor controller 73, a fuel injection controller 74, an ignition controller 75, and a memory 76.

[0053] The rotation speed calculator 70 calculates a rotation speed of the engine 10, that is, a rotation speed of the crankshaft 46, based on the crank pulse signal output from the crank angle sensor 26. The rotation speed of the crankshaft 46 calculated by the rotation speed calculator 70 is input to the motor controller 73 and is used for feedback control of the permanent magnet starter motor 30.

[0054] The crank angle determiner 71 determines whether the crank angle obtained based on the crank pulse signal output from the crank angle sensor 26 is larger than a predetermined angle or not, and determines whether the crank angle is larger than a specified angle at which fuel injection starts or not. The determination result by the crank angle determiner 71 is input to the motor controller 73 and used for driving control of the permanent magnet starter motor 30. The determination result by the crank angle determiner 71 is input to the fuel injection controller 74, and used for driving control of a fuel injection device 54 described later of the engine 10. The predetermined angle is an angle smaller than the specified angle.

[0055] Based on engine temperature information output from the engine temperature sensor 28, the fuel injection time determiner 72 obtains a fuel injection time in accordance with an engine temperature from injection time data previously stored in the memory 76. In injecting fuel from the fuel injection device 54, the fuel injection time determiner 72 calculates a cumulative time of fuel injection (cumulative fuel injection time), and determines whether the calculated cumulative fuel injection time is longer than a default value (predetermined time) or not.

[0056] The engine temperature sensor 28 is, for example, a sensor for measuring a temperature of a coolant of the engine 10. The engine temperature sensor 28 may directly measure a temperature in the combustion chamber 36 or may measure a temperature in a cylinder 40 or

a crankcase 44, for example, of the engine 10. That is, the engine temperature sensor 28 may be disposed at any position as long as the engine temperature sensor 28 can measure a temperature concerning the combustion chamber 36 of the engine 10.

[0057] The motor controller 73 controls driving of the permanent magnet starter motor 30 in starting the engine, based on the rotation speed of the crankshaft 46 output from the rotation speed calculator 70 and the determination result output from the crank angle determiner 71. Specifically, the motor controller 73 performs rotation speed control of the permanent magnet starter motor 30 in accordance with the determination result output from the crank angle determiner 71, and performs feedback control of the permanent magnet starter motor 30 by using the rotation speed of the crankshaft 46.

[0058] If the crank angle determiner 71 determines that the crank angle is larger than the specified angle at which fuel injection starts, the fuel injection controller 74 causes the fuel injection device 54 to inject fuel. On the other hand, if the fuel injection time determiner 72 determines that the cumulative fuel injection time is longer than the default value, the fuel injection controller 74 stops fuel injection by the fuel injection device 54.

[0059] The ignition controller 75 ignites the ignition plug 56 at the time when the crank angle obtained based on the crank pulse signal output from the crank angle sensor 26 reaches an ignition timing of the ignition plug 56.

[0060] The permanent magnet starter motor 30 is a motor that cranks the crankshaft 46 to start the engine 10. In this embodiment, the permanent magnet starter motor 30 is a DC brushless motor. The permanent magnet starter motor 30 has a characteristic that the torque increases as the rotation speed decreases.

[0061] As the DC brushless motor, a DC brushless motor of a type that detects an electrical angle by using a Hall sensor or a DC brushless motor of a type that detects a mechanical angle by using a crank pulse can be used.

[0062] An output shaft of the permanent magnet starter motor 30 is connected to the crankshaft 46 of the engine 10 to rotate the crankshaft 46. In this embodiment, the output shaft of the permanent magnet starter motor 30 is connected to the crankshaft 46 through no power transmission mechanism (e.g. a belt, a chain, a gear, a speed reducer, or a speed-up gear). It should be noted that the permanent magnet starter motor 30 only needs to be connected to the crankshaft 46 of the engine 10 such that the crankshaft 46 can rotate in the normal direction. Thus, the permanent magnet starter motor 30 may be connected to the crankshaft 46 through the power transmission mechanism. The rotation axis of the permanent magnet starter motor 30 may substantially coincide with a rotation axis of the crankshaft 46.

[0063] The inverter 62 controls a current to be supplied from the battery 64 to the permanent magnet starter motor 30 to thereby control the rotation speed of the permanent magnet starter motor 30. The inverter 62 is controlled by the motor controller 73 of the ECU 32.

[0064] The battery 64 supplies electric power to the permanent magnet starter motor 30 through the inverter 62.

[0065] At startup of the engine 10, the start switch 66 outputs an ON signal in accordance with an operation of a driver or in the case where conditions for engine start are satisfied in an idling stop system described later. When the ON signal is output from the start switch 66, the ECU 32 starts rotation speed control of the permanent magnet starter motor 30 in order to start the engine 10.

[0066] The configuration of the engine 10 will now be described. As the configuration of the engine 10, various known engine configurations may be employed, and thus, the components of the engine will not be described in detail.

[0067] The engine 10 includes the cylinder head 34, the cylinder 40, a piston 42, the crankcase 44, the crankshaft 46, a connecting rod 48, an intake valve 50, an exhaust valve 52, the fuel injection device 54, and the ignition plug 56 (ignition device).

[0068] The piston 42 is movable to and fro in the cylinder 40. The crankshaft 46 is rotatable in the crankcase 44. The piston 42 and the crankshaft 46 are coupled to each other by the connecting rod 48. The to-and-fro movement of the piston 42 is transferred to the crankshaft 46 through the connecting rod 48. Accordingly, the crankshaft 46 rotates.

[0069] In the engine 10, the combustion chamber 36 is formed by the cylinder head 34, the cylinder 40, and the piston 42. The combustion chamber 36 includes the intake port 35a and the exhaust port 35b. The cylinder head 34 includes the passage 34a to be connected to the intake port 35a and the passage 34b to be connected to the exhaust port 35b. In this embodiment, the passage 34a connects the intake pipe 14b and the combustion chamber 36 to each other. The passage 34b connects the combustion chamber 36 and the exhaust pipe 16 to each other.

[0070] The intake valve 50 opens and closes the intake port 35a. The exhaust valve 52 opens and closes the exhaust port 35b. The intake valve 50 is driven by an unillustrated known valve mechanism. Similarly, the exhaust valve 52 is driven by an unillustrated valve mechanism.

[0071] In one cycle, the intake valve 50 is opened before the exhaust valve 52 is closed, and the intake valve 50 is closed before the exhaust valve 52 is opened. In other words, at least in the low-load operation range, the intake stroke is started before the exhaust stroke is finished.

[0072] Specifically, the intake valve 50 is open at a crank angle of, for example, 344 degrees to 576 degrees. The crank angle while the intake valve 50 is open is not limited to the range described above, and the intake valve 50 may be open with a crank angle of 360 degrees to 540 degrees at minimum and 326 degrees to 610 degrees at maximum.

[0073] The exhaust valve 52 is open at least in the

exhaust stroke. Specifically, the exhaust valve 52 is open at a crank angle of, for example, 64 degrees to 378 degrees. The crank angle while the exhaust valve 52 is open is not limited to the range described above, and the exhaust valve 52 may be open with a crank angle of 180 degrees to 360 degrees at minimum and 70 degrees to 390 degrees at maximum.

[0074] The fuel injection device 54 injects fuel into the intake passage 33a. In this embodiment, the fuel injection device 54 injects fuel toward the intake valve 50. Fuel supplied into the intake passage 33a is sent to the combustion chamber 36 as an air-fuel mixture together with air. The ignition plug 56 ignites the air-fuel mixture in the combustion chamber 36.

[0075] The fuel injection device 54 and the ignition plug 56 perform fuel injection and ignition by control of the ECU 32 at appropriate timings in accordance with the strokes in one cycle of the engine 10.

[0076] A decompression mechanism 58 is provided near an unillustrated camshaft for driving the exhaust valve 52. The decompression mechanism 58 reduces an increase in resistance to the rotation of the crankshaft 46 caused by compression of air in the cylinder in the compression stroke of the engine. That is, the decompression mechanism 58 is a mechanism that opens the exhaust valve 52 at a predetermined timing in order to reduce the pressure in the cylinder in the compression stroke in starting the engine.

<Start Operation of Engine Unit>

[0077] First, a torque necessary for cranking in starting the engine will be described. FIG. 2 is an illustration showing a relationship between a crank angle and a torque necessary for cranking in starting the engine.

[0078] The engine 10 of the engine unit 100 includes, in four strokes, a high-load region TH where a load for rotating the crankshaft 46 is high and a low-load region TL where the load for rotating the crankshaft 46 is lower than the load in the high-load region TH. In the crank angle of the crankshaft 46, the low-load region TL is equal to or wider than the high-load region TH. More specifically, the low-load region TL is wider than the high-load region TH. In other words, a rotation angle region corresponding to the low-load region TL is wider than a rotation angle region corresponding to the high-load region TH.

[0079] More specifically, the engine 10 repeats four strokes of the intake stroke, the compression stroke, the expansion stroke, and the exhaust stroke. As illustrated in FIG. 2, the compression stroke is included in the high-load region TH but is not included in the low-load region TL. In the engine 10 according to this embodiment, the high-load region TH is a region substantially overlapping the compression stroke, and the low-load region TL is a region substantially overlapping the intake stroke, the expansion stroke, and the exhaust stroke. It should be noted that the edge of each of the high-load region TH and the low-load region TL does not need to coincide with the

edge of each of the strokes.

[0080] In the compression stroke, an air-fuel mixture in the combustion chamber 36 is compressed by the piston 42 so that a reaction force is generated by the compression. Thus, in the compression stroke, a torque necessary for cranking is larger than those in the other strokes. The decompression mechanism 58 is actuated in the compression stroke to thereby reduce the pressure in the combustion chamber 36.

[0081] The decompression mechanism 58 operates to open the exhaust valve 52 with a crank angle of around 630 degrees. A period in which the exhaust valve 52 is opened by the decompression mechanism 58 is a short period in the compression stroke. In addition, as illustrated in FIG. 6, the timing at which the exhaust valve 52 is opened by the decompression mechanism 58 is immediately before the intake valve 50 is closed or after the intake valve 50 is closed. As illustrated in FIG. 6, the timing when the exhaust valve 52 is opened by the decompression mechanism 58 is adjustable within the compression stroke. The valve lift amount of the exhaust valve 52 in an actuation period of the decompression mechanism 58 is smaller than the valve lift amount of the intake valve 50. The valve lift amount is a distance in which the valve moves away from the valve seat in an axial direction.

[0082] A start operation of the engine unit 100 will now be described. In this embodiment, in starting the engine 10, cranking is performed by the starter motor 30. The start of the engine 10 includes a case where the engine 10 starts from a state where the engine temperature is lower than a temperature in operation of the engine 10 and a case where the engine 10 starts again from an engine stopped state in an idling stop system. The idling stop system has a configuration similar to a known configuration, and thus, detailed description and illustration of the idling stop system will be omitted.

[0083] FIG. 3 is a flowchart depicting an operation of rotation speed control of the permanent magnet starter motor 30 by the ECU 32 in starting the engine unit 100. FIG. 4 is a graph showing a relationship between an engine speed and a crank angle in starting the engine unit 100. FIG. 5 is a view illustrating an example of a motion of the crankshaft 46 in starting the engine unit 100.

[0084] First, when the start switch 66 turns on and a startup request flag is set (step S1), the motor controller 73 of the ECU 32 drives and rotates the permanent magnet starter motor 30.

[0085] The engine 10 stops combustion by a combustion stop instruction by the ECU 32. The crankshaft 46 rotates with an inertial force after stopping of combustion in the engine 10. When the inertial force becomes smaller than a compression reaction force in the compression stroke of the engine 10, the crankshaft 46 rotates in the reverse direction by the compression reaction force and stops. Thus, as illustrated in FIG. 5, the stop position of the crankshaft 46 is often at a crank angle P0 of the intake stroke that is a stroke before the compression stroke.

[0086] Based on a signal output from the crank angle sensor 26, the ECU 32 acquires information on the crank angle and the rotation speed of the engine 10. In the case where the crank angle of the crankshaft 46 is not at a specified position, the motor controller 73 of the ECU 32 rotates the permanent magnet starter motor 30 in the reverse direction, as indicated by broken lines in FIGS. 4 and 5. The reverse rotation of the permanent magnet starter motor 30 continues until the crank angle reaches the specified position P1 in the expansion stroke.

[0087] Subsequently, the crank angle determiner 71 of the ECU 32 determines whether the crank angle of the crankshaft 46 is larger than a predetermined angle or not (step S2). The predetermined angle is an angle smaller than a crank angle (specified angle) at which fuel injection occurs.

[0088] If the crank angle of the crankshaft 46 is larger than the predetermined angle (YES in step S2), the motor controller 73 of the ECU 32 controls driving of the permanent magnet starter motor 30 such that the rotation speed of the crankshaft 46 is a target rotation speed A (step S3). Control of the rotation speed of the permanent magnet starter motor 30 may be torque control using a duty ratio, or speed control in which feedback control is performed by detecting the rotation speed of the permanent magnet starter motor 30.

[0089] The upper limit of the target rotation speed A is a speed at which a fuel injection time obtained from the engine temperature measured by the engine temperature sensor 28 as described later can be obtained, and the lower limit of the target rotation speed A is a speed at which the engine can pass over a maximum load in the high-load region TH.

[0090] If the rotation speed of the crankshaft 46 is low, vaporized fuel cannot be compressed in the high-load region TH, and the engine 10 is stopped.

[0091] On the other hand, if the rotation speed of the crankshaft 46 is high, the time for evaporation of the injected fuel cannot be sufficiently obtained. In this case, a fuel concentration in the combustion chamber 36 of the engine 10 becomes insufficient, which might cause a failure in increasing the rotation speed of the engine 10 and an accidental fire, for example.

[0092] That is, when the rotation speed of the crankshaft 46 in cranking increases excessively, after a lapse of a fuel injection time FI (see FIG. 4), fuel is insufficiently evaporated in the passage 34a of the intake passage 33a. Consequently, an air-fuel ratio in the combustion chamber 36 is not an appropriate value in some cases.

[0093] The target rotation speed A of the crankshaft 46 is determined within the range between the upper and lower limits in consideration of the phenomenon as described above. The target rotation speed A is obtained based on the temperature of the engine 10, which will be described later.

[0094] If the crank angle of the crankshaft 46 is less than or equal to the predetermined angle (NO in step S2), the crank angle determiner 71 repeats the determi-

nation of step S2 until the crank angle of the crankshaft 46 exceeds the predetermined angle.

[0095] After the permanent magnet starter motor 30 is driven and controlled at the target rotation speed A, the crank angle determiner 71 determines whether the crank angle of the crankshaft 46 is larger than a specified angle at which fuel injection starts (step S4). If the crank angle of the crankshaft 46 is larger than the specified angle for fuel injection start (YES in step S4), the fuel injection controller 74 of the ECU 32 causes the fuel injection device 54 to inject fuel (step S5). On the other hand, if the crank angle of the crankshaft 46 is less than or equal to the specified angle for fuel injection start (NO in step S4), the determination of step S4 is repeated until the crank angle of the crankshaft 46 exceeds the specified angle for fuel injection start.

[0096] In this embodiment, the specified angle for fuel injection start by fuel injection device 54 is, for example, 300°. Alternatively, the specified angle for fuel injection start may be an angle other than 300°. As described above, the fuel injection time is determined by the fuel injection time determiner 72 based on injection time data previously determined based on an engine temperature. The injection time data is stored in the memory 76 of the ECU 32. Fuel injection needs to be finished within a period from when fuel injection starts to when the intake valve 50 is closed (within a period FI shown in FIG. 4) at the latest.

[0097] After fuel injection has started by the fuel injection device 54, the fuel injection time determiner 72 of the ECU 32 determines whether the cumulative fuel injection time as a cumulative time of fuel injection is larger than a default value (predetermined time) of the fuel injection time or not (step S6). If the cumulative fuel injection time is determined to be larger than the default value (YES in step S6), fuel injection by the fuel injection device 54 is stopped (step S7). Thereafter, rotation speed control in which the target rotation speed has been set at A in step S3 is canceled (step S8), and a flow of the rotation speed control in starting the engine is finished (end). The default value is determined depending on the engine temperature by using injection time data.

[0098] On the other hand, if the cumulative fuel injection time is determined to be less than or equal to the default value (NO in step S6), fuel injection by the fuel injection device 54 continues until the cumulative fuel injection time exceeds the default value.

[0099] After the rotation speed control of the permanent magnet starter motor 30 by the ECU 32 described above, when the intake valve 50 is closed, in the following compression stroke, the compressed pressure in the combustion chamber 36 serves as a rotation load of the crankshaft 46. Thus, as shown in FIG. 4, the rotation speed of the crankshaft 46 decreases. After the crankshaft 46 has passed through a position corresponding to a compression top dead point in the compression stroke, the ignition controller 75 of the ECU 32 causes the ignition plug 56 to ignite an air-fuel mixture in the combustion

chamber 36 so that initial combustion occurs. In this embodiment, the crank angle at ignition of the ignition plug 56 is 715 degrees, but is not limited to this example.

[0100] With the initial combustion, a rotary force is exerted on the crankshaft 46, and the strokes in the four cycles are intermittently performed in the engine 10 so that start of the engine 10 by cranking is completed.

<Determination Procedure of Target Rotation Speed>

[0101] Next, a procedure of determining the target rotation speed A of the crankshaft 46 in starting the engine 10 will be described.

[0102] Based on the temperature of the engine 10 measured by the engine temperature sensor 28, the fuel injection time determiner 72 of the ECU 32 refers to injection time data previously stored in the memory 76 of the ECU 32, and determines a fuel injection time for the first combustion in starting the engine 10.

[0103] The injection time data is, for example, a table in which an engine temperature is associated with the fuel injection time. The injection time data is set such that the fuel injection time increases as the engine temperature decreases. The injection time may be calculated such that the injection time increases with a decrease in temperature in accordance with a predetermined relational expression, or may be set such that the injection time is constant within a predetermined range and decreases when the engine temperature increases across the predetermined range. An example of the injection time is indicated by solid arrow in FIG. 2. As shown in FIG. 2, the injection time at an engine temperature of -5°C is longer than the injection time at an engine temperature of 80°C. FIG. 2 shows only a first stroke for the injection time and does not show the subsequent strokes.

[0104] The injection time data varies depending on the position to which the fuel injection device 54 injects fuel, the injection direction, and the size of liquid droplets of the injected fuel. This is performed in order to obtain an appropriate air-fuel ratio at ignition by sufficiently evaporating the injected fuel even at low temperatures of the engine 10. Thus, the injection time data is set such that the fuel injection time is long at a low engine temperature. In general, the injection time decreases as the size of liquid droplets of the injected fuel decreases and the expansion angle of spraying increases.

[0105] The fuel injection by the fuel injection device 54 starts at a predetermined crank angle (e.g., 300 degrees), and finishes until the intake valve 50 is closed in the intake stroke of the engine 10. Thus, the rotation speed of the crankshaft 46 needs to be determined such that the fuel injection finishes before the intake valve 50 is opened. In this embodiment, the timing of fuel injection start is fixed at a crank angle of 300 degrees, independently of the engine temperature.

[0106] Accordingly, to obtain a fuel injection time at low temperatures, the target rotation speed A of the crankshaft 46 needs to be set depending on the time from the

fuel injection start to closing of the intake valve 50. Thus, as shown in FIG. 7, as the injection time increases, the target rotation speed A is set lower. As described above, the fuel injection time needs to be increased as the engine temperature decreases. Thus, as shown in FIG. 7, a target rotation speed A' at a low engine temperature is lower than the target rotation speed A at a high engine temperature.

[0107] FIG. 8A shows an example of a relationship between an engine temperature and a rotation speed of the crankshaft 46 in starting the engine. As described above, the target rotation speed A of the crankshaft 46 decreases as the temperature of the engine 10 decreases. As an example, as shown in FIG. 8A, in temperatures of the engine 10 at any two points on the graph (referred to as a first temperature and a second temperature, respectively), the ECU 32 controls the rotation speed of the permanent magnet starter motor 30 such that the rotation speed of the crankshaft 46 at the relatively low first temperature is lower than the rotation speed at the second temperature higher than the first temperature.

[0108] The rotation speed of the crankshaft 46 does not continuously change in accordance with the temperature of the engine 10 as described above, but as shown in FIG. 8B, control may be performed such that the temperature of the engine 10 is constant to a predetermined temperature and when the temperature of the engine 10 decreases below the predetermined temperature, the rotation speed is reduced.

[0109] As described above, the fuel injection only needs to be finished within a period from when the fuel injection starts to when the intake valve 50 is closed (fuel injection time FI). Thus, the fuel injection time of the injection time data may be shorter than the fuel injection time FI.

[0110] When the target rotation speed of the crankshaft 46 is increased in accordance with the fuel injection time, power consumption of the permanent magnet starter motor 30 increases, and accordingly, power consumption of the battery 64 increases. On the other hand, the target rotation speed A of the crankshaft 46 may be reduced to a rotation speed at which a necessary fuel injection time can be obtained in accordance with the engine temperature. This can reduce power consumption of the permanent magnet starter motor 30 so that an increase in power consumption of the battery 64 can be suppressed.

[0111] In the engine unit 100 according to this embodiment, the permanent magnet starter motor 30 that can obtain a higher output torque at a lower rotation speed is used as a starter motor. In addition, in the engine 10 in which the high-load region TH and the low-load region TL are present in four strokes, as shown in FIG. 5, in the low-load region TL after the crankshaft 46 rotates from the stopped state to the first combustion, the target rotation speed A of the crankshaft 46 is set in accordance with the engine temperature. Thus, a time for vaporization of fuel supplied into the intake passage 33a can be obtained. As a result, energy obtained by the first com-

bustion can be sufficiently increased so that startability of the engine 10 can be enhanced.

[0112] In this embodiment, the decompression mechanism 58 is actuated in the compression stroke in starting the engine so that the pressure in the combustion chamber 36 can be reduced. However, the actuation of the decompression mechanism 58 in the compression stroke might cause the possibility that sufficient energy cannot be obtained in the first compression in starting the engine so that the rotation speed of the crankshaft 46 cannot be increased. On the other hand, in the engine unit 100 according to this embodiment, in the low-load region TL after the rotation of the crankshaft 46 from the stopped state to the first combustion, the target rotation speed A of the crankshaft 46 is set in accordance with the engine temperature so that the time for vaporization of fuel supplied into the intake passage 33a can be obtained. Thus, energy obtained by the first combustion can be sufficiently enhanced, and as a result, startability of the engine 10 can be enhanced.

Second Embodiment

[0113] FIG. 10 is a schematic view illustrating a configuration of an engine unit 101 according to the second embodiment. The engine unit 101 according to this embodiment is different from the engine unit 100 according to the first embodiment in that an ECU 80 sets a rotation speed of the crankshaft 46 in accordance with the temperature of the engine 10 by using rotation speed data as map data of the engine temperature and a target rotation speed A.

[0114] Specifically, the ECU 80 includes a rotation speed calculator 70, a crank angle determiner 71, a motor controller 73, a fuel injection controller 74, an ignition controller 75, a memory 76, and a rotation speed determiner 81.

[0115] In this embodiment, the memory 76 stores rotation speed data as map data in which the temperature of the engine 10 and the target rotation speed A of the crankshaft 46 in starting the engine are associated with each other beforehand, in addition to injection time data similar to that in the first embodiment.

[0116] The rotation speed determiner 81 determines, by using the rotation speed data stored in the memory 76, the target rotation speed A of the crankshaft 46 in starting the engine in accordance with an engine temperature measured by the engine temperature sensor 28. The motor controller 73 controls an inverter 62 by using the target rotation speed A determined by the rotation speed determiner 81 to thereby drive a permanent magnet starter motor 30 such that the crankshaft 46 reaches the target rotation speed A.

[0117] The fuel injection controller 74 determines, by using the rotation speed data stored in the memory 76, a fuel injection time in accordance with the engine temperature measured by the engine temperature sensor 28. The method for determining the fuel injection time is

similar to that in the first embodiment. The fuel injection time may be determined in accordance with the rotation speed of the crankshaft 46.

[0118] Part of the configuration of the ECU 80 except for the configuration described above is similar to that of the ECU 32 of the first embodiment, and detailed description of the ECU 80 will be omitted.

[0119] The configuration of this embodiment can also obtain the time for vaporization of fuel supplied into an intake passage 33a. As a result, energy obtained by the first combustion can be sufficiently increased so that startability of the engine 10 can be enhanced.

Other Embodiments

[0120] The embodiments of the present teaching have been described above, but the embodiments are merely examples for carrying out the present teaching. Thus, the present teaching is not limited to the embodiments, and the embodiments may be modified as necessary within a range not departing from the gist of the present teaching.

[0121] The embodiments described above have been directed to the engine units using single-cylinder four-stroke engines. The engines, however, may be parallel-twin cylinder or a V-twin cylinder four-stroke engine.

[0122] The embodiments described above have been directed to the case where the crankshaft 46 rotates in the reverse direction in starting the engine. However, the present teaching is not limited to these embodiments, and the crankshaft 46 may not rotate in the reverse direction and may rotate in the normal direction in starting the engine.

[0123] The permanent magnet starter motor 30 used in each embodiment may be a motor with a brush or a brushless motor. The starter motor may be a starter motor generator also serving as an electric generator.

[0124] In the embodiments described above, the fuel injection device 54 injects fuel toward the intake valve 50, but may inject fuel toward another position in the intake passage 33a. For example, the fuel injection device 54 may inject fuel toward a position upstream of the intake valve 50 and located on an inner surface of the wall constituting the intake passage 33a.

[0125] In this case, the injection time data can be set such that the injection time is longer than that in the case of injecting fuel toward the intake valve 50. That is, as shown in FIG. 11, a target rotation speed A of the crankshaft 46 in the case of injecting fuel toward the inner surface of the wall constituting the intake passage 33a is lower than that in the case of injecting fuel toward the intake valve 50.

[0126] The embodiments described above are directed to the configurations in which the engine units 100 and 101 are applied to motorcycles. Alternatively, the engine units 100 and 101 may be applied to other vehicles such as tricycles or four-wheel vehicles.

[0127] In the embodiments described above, the tem-

perature of an engine coolant is measured as the temperature of the engine 10. In the case of an air cooling engine, for example, the temperature of oil in an oil passage in which lubricating oil flows may be measured as the temperature of the engine.

[0128] Although the engine 10 uses the TPS 22 in the above embodiments, the engine 10 may use an accelerator position sensor instead of the TPS 22.

[0129] In the first embodiment, the engine unit 100 includes the decompression mechanism 58. The engine unit 101 in the second embodiment may also include a decompression mechanism. The engine unit 100 may not include a decompression mechanism.

15 DESCRIPTION OF REFERENCE CHARACTERS

[0130]

10	four-stroke engine body
20 12	air cleaner
14a, 14b	intake pipe
16	exhaust pipe
20	throttle device
22	TPS
25 24	pressure sensor
26	crank angle sensor (crank angle detector)
28	engine temperature sensor (engine temperature detector)
30	permanent magnet starter motor
30 32, 80	ECU (control device)
33a	intake passage
33b	exhaust passage
35a	intake port
35b	exhaust port
35 34	cylinder head
36	combustion chamber
40	cylinder
42	piston
44	crankcase
40 46	crankshaft
48	connecting rod
50	intake valve
52	exhaust valve
54	fuel injection device
45 56	ignition plug (ignition device)
58	decompression mechanism
62	inverter
64	battery
66	start switch
50 70	rotation speed calculator
71	crank angle determiner
72	fuel injection time determiner
73	motor controller
74	fuel injection time controller
55 75	ignition controller
76	memory
81	rotation speed determiner
100, 101	engine unit

Claims

1. An engine unit comprising:

a four-stroke engine body including

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a combustion chamber having an intake port and an exhaust port,
 an intake valve configured to open and close the intake port,
 an exhaust valve configured to open and close the exhaust port,
 an intake passage connected to the intake port and configured to guide air in the atmosphere into the combustion chamber through the intake port,
 an exhaust passage connected to the exhaust port,
 a fuel injection device configured to inject fuel into the intake passage,
 an ignition device configured to ignite an air-fuel mixture including fuel and air in the combustion chamber,
 a piston configured to move to and fro in the combustion chamber, and
 a crank shaft connected to the piston to rotate in accordance with the to-and-fro movement of the piston, a high-load region where the load for rotating the crank shaft is high and a low-load region where the load for rotating the crank shaft is low being present in four strokes:

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a permanent magnet starter motor that includes a permanent magnet and is configured to rotate the crank shaft;
 a control device that controls the permanent magnet starter motor, the fuel injection device, and the ignition device;
 an engine temperature detector that detects a temperature of the four-stroke engine body; and
 a crank angle detector that detects a crank angle, the crank angle being a position of a rotation angle of the crank shaft, wherein the control device

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drives the permanent magnet starter motor to rotate the crank shaft from a stopped state,
 controls the fuel injection device while a crank angle of the crank shaft is in the low-load region, thereby injecting fuel into the intake passage,
 controls a rotation speed of the permanent magnet starter motor so that an increase in a rotation speed of the crank shaft is suppressed, based on the temperature of the four-stroke engine body detected by the en-

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gine temperature detector while the crank angle of the crank shaft is in the low-load region and from when the fuel injection device injects fuel into the intake passage to when the intake valve is closed, and starts the four-stroke engine body by igniting the air-fuel mixture in the combustion chamber by using the ignition device while the crank angle of the crank shaft is in the high-load region.

- 2. The engine unit according to claim 1, wherein the control device controls the rotation speed of the permanent magnet starter motor such that a rotation speed of the crank shaft obtained when the temperature of the four-stroke engine body detected by the engine temperature detector is a first temperature is lower than a rotation speed of the crank shaft obtained when the temperature of the four-stroke engine body detected by the engine temperature detector is a second temperature higher than the first temperature.
- 3. The engine unit according to claim 1 or 2, wherein the fuel injection device injects fuel toward the intake valve.
- 4. The engine unit according to any one of claims 1 to 3, wherein the control device determines a rotation speed of the crank shaft in accordance with a fuel injection time determined based on the temperature of the four-stroke engine body detected by the engine temperature detector.
- 5. The engine unit according to any one of claims 1 to 4, wherein the engine temperature detector is a sensor that detects a temperature of a coolant of the four-stroke engine body or a temperature of oil in an oil passage.
- 6. The engine unit according to any one of claims 1 to 5, wherein the control device causes the fuel injection device to inject fuel until the fuel injection time exceeds a predetermined time in which fuel necessary for engine start is allowed to be supplied.
- 7. The engine unit according to any one of claims 1 to 6, wherein the control device controls the rotation speed of the motor such that as the temperature of the four-stroke engine body detected by the engine temperature detector decreases, the rotation speed of the crank shaft in the fuel injection time decreases.
- 8. The engine unit according to any one of claims 1 to 7, wherein

the four-stroke engine body further includes a de-compression mechanism that temporarily opens the exhaust valve in order to eject the air-fuel mixture in the combustion chamber while the crank angle of the crank shaft is in the high-load region.

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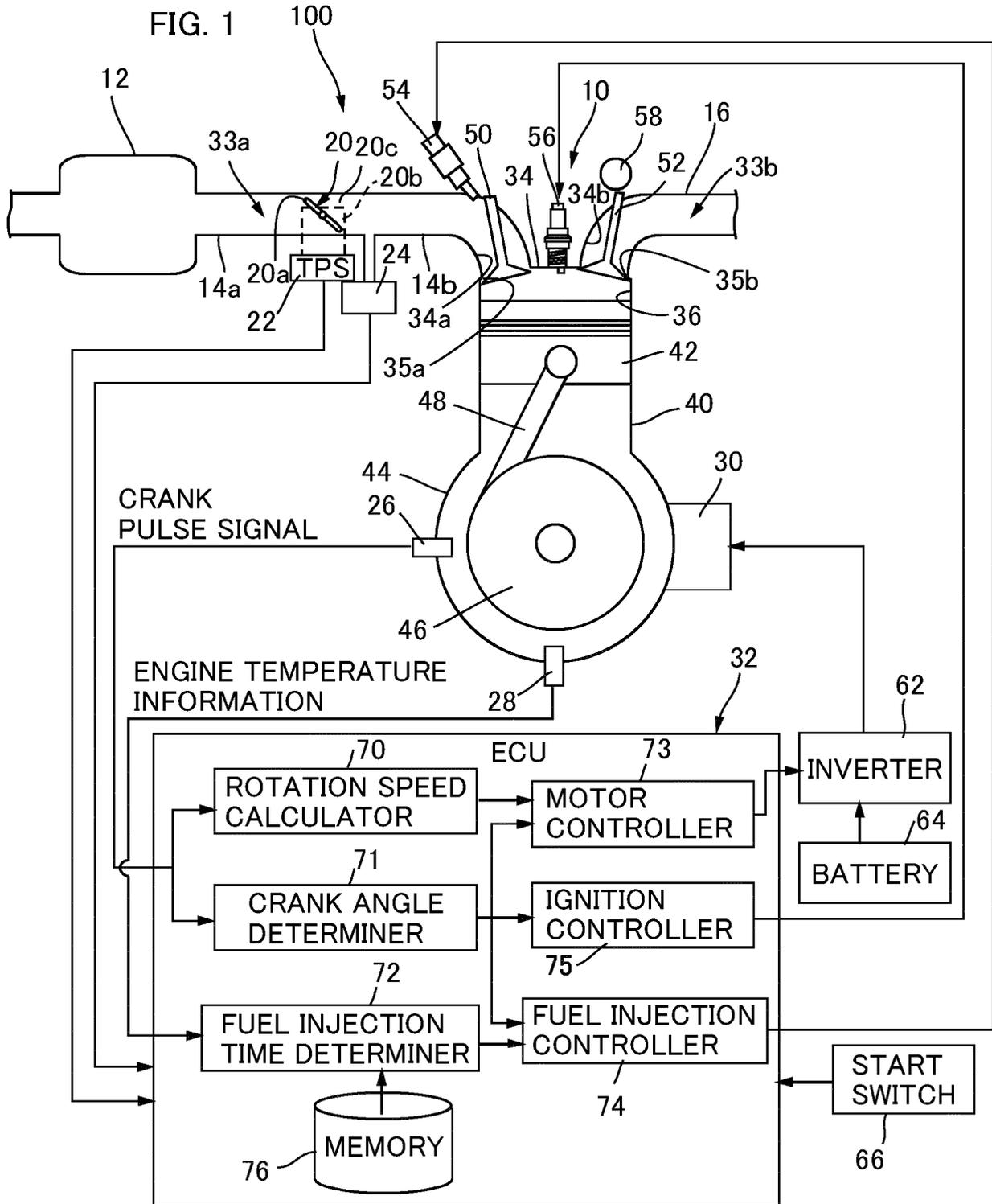
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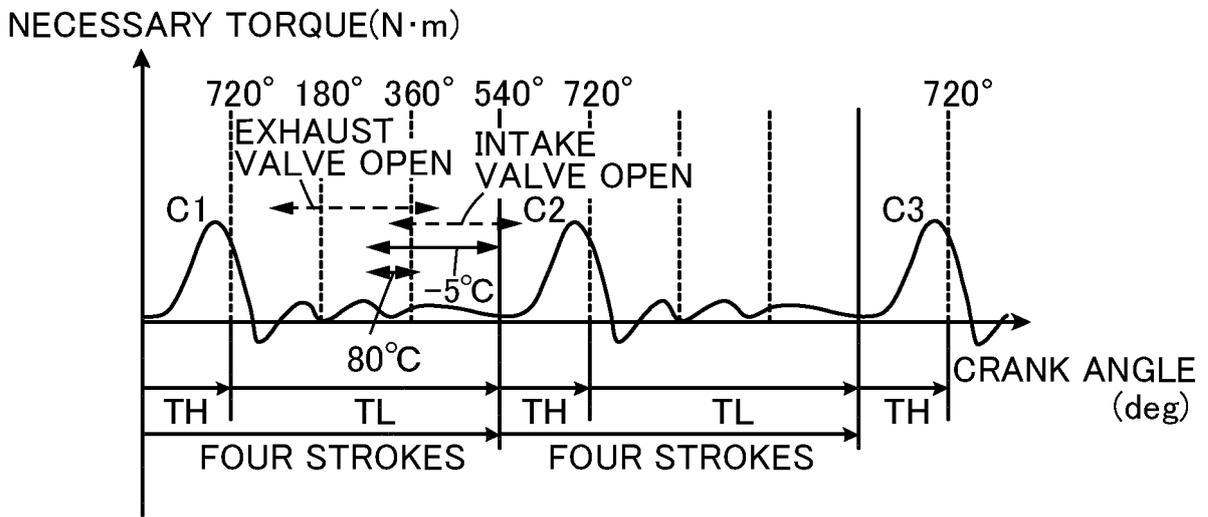


FIG. 2

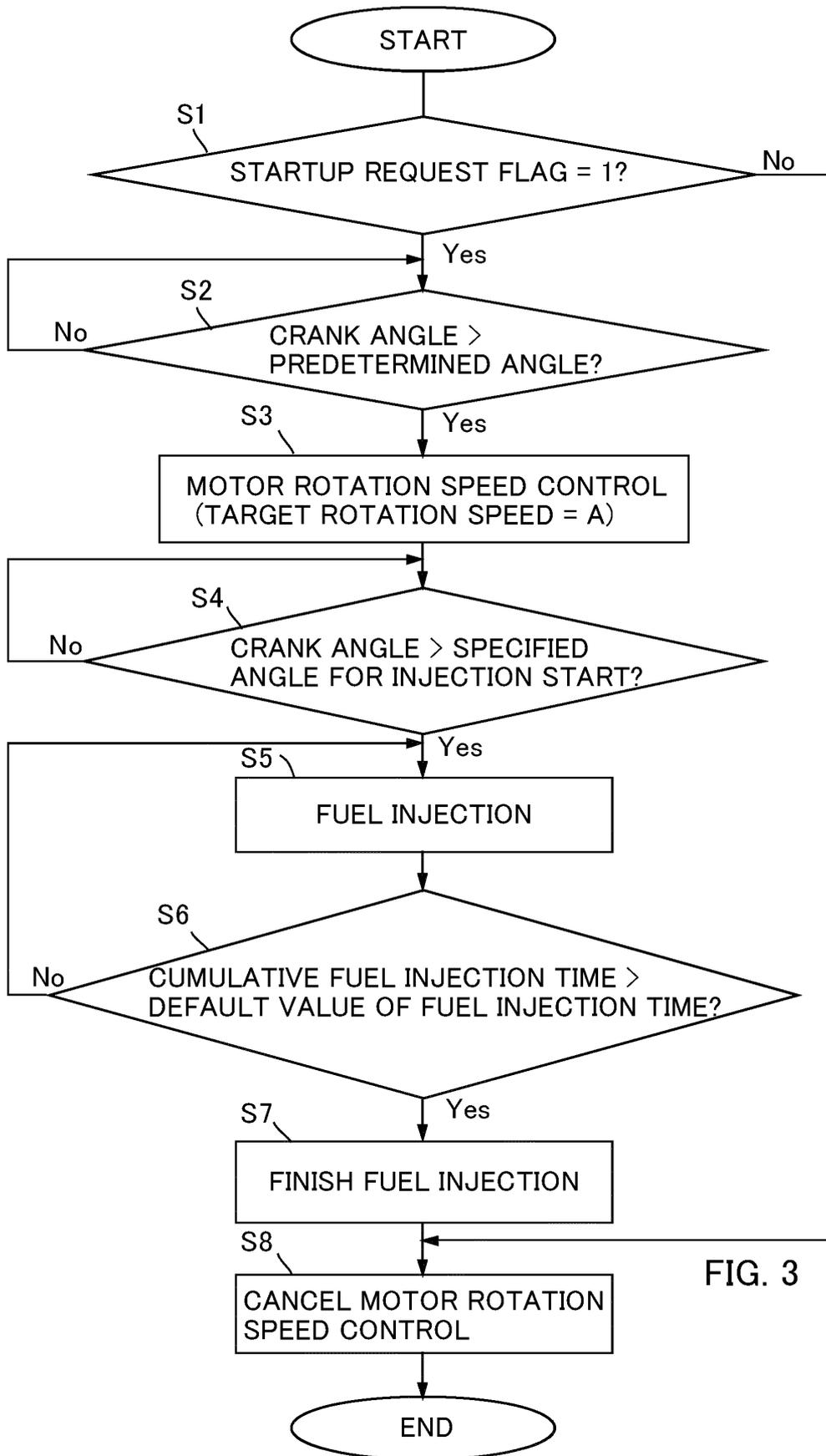


FIG. 3

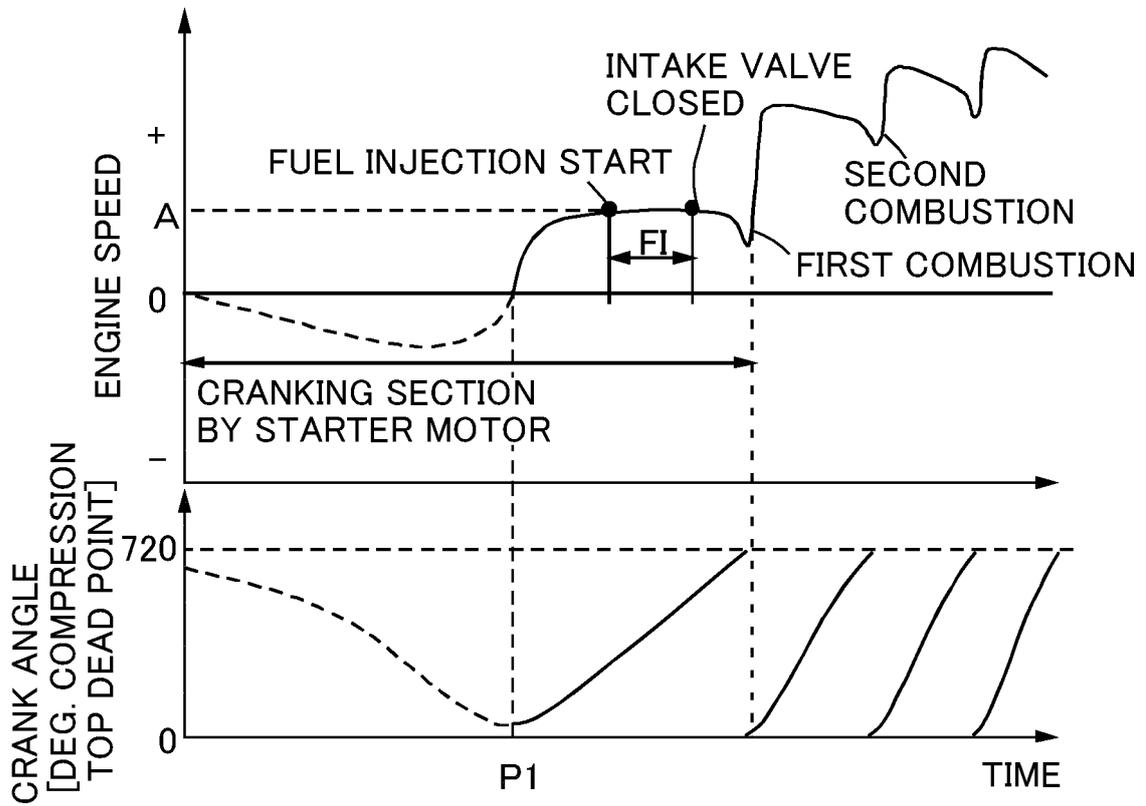


FIG. 4

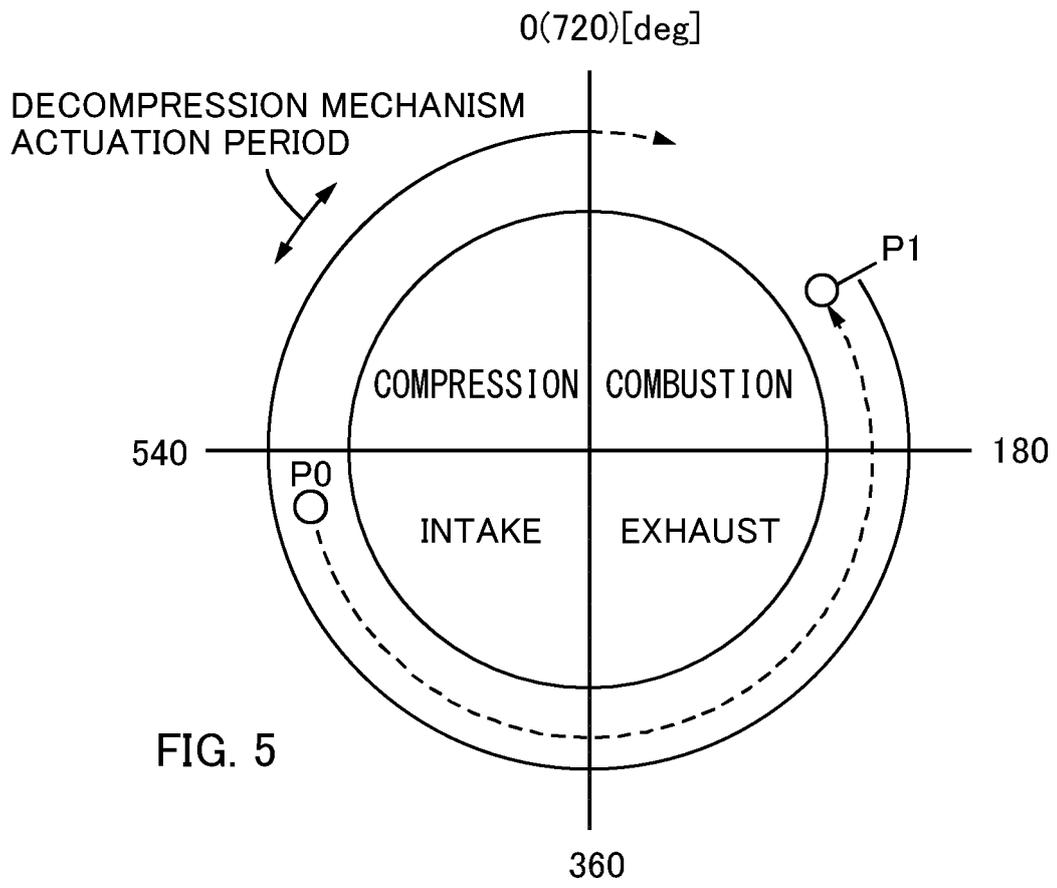
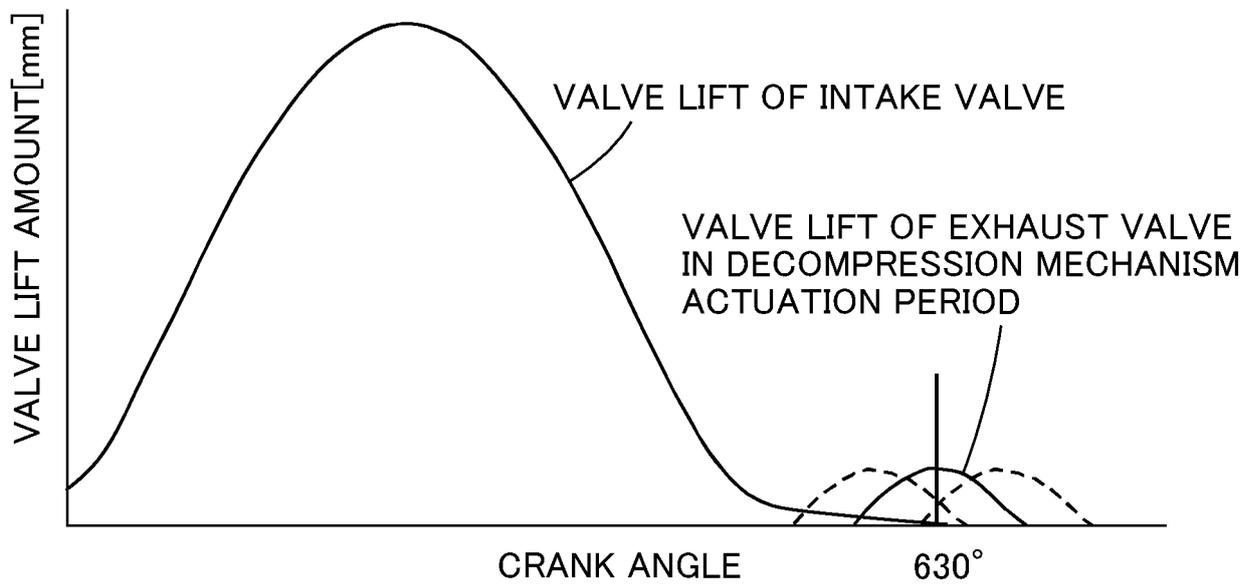


FIG. 6



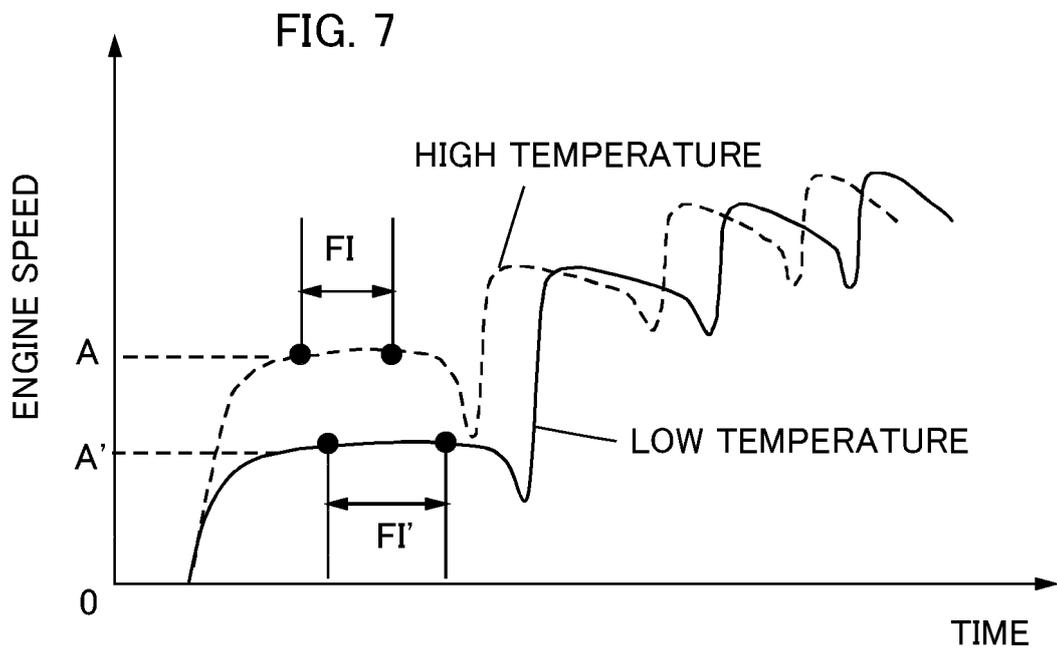


FIG. 8A

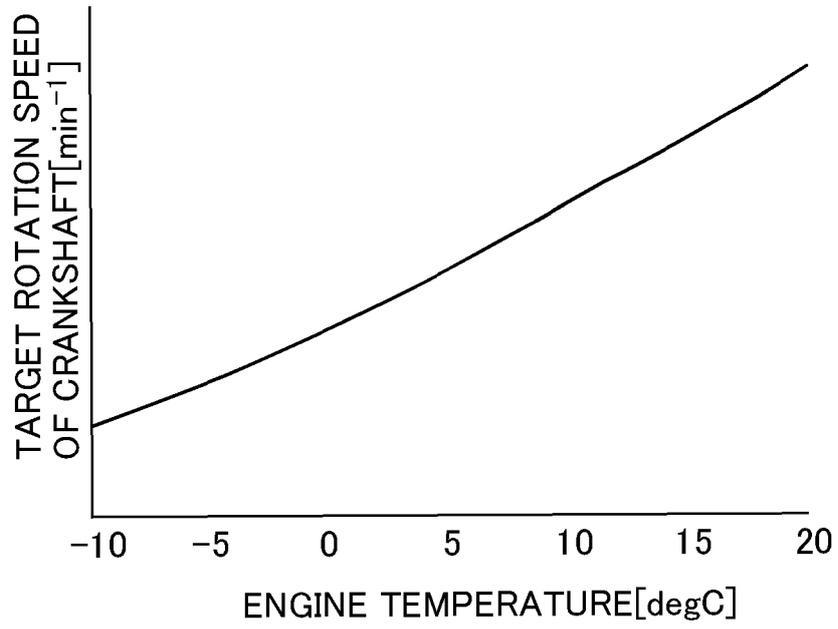
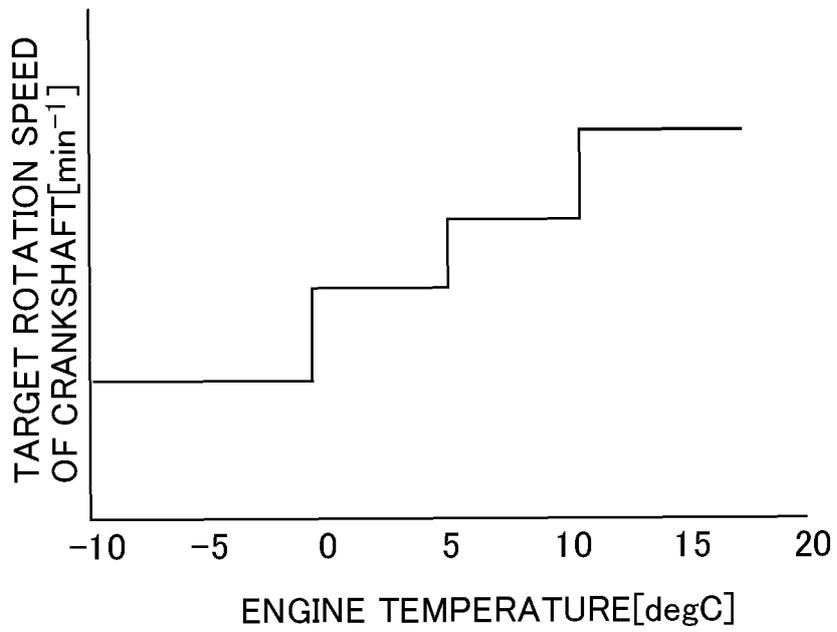
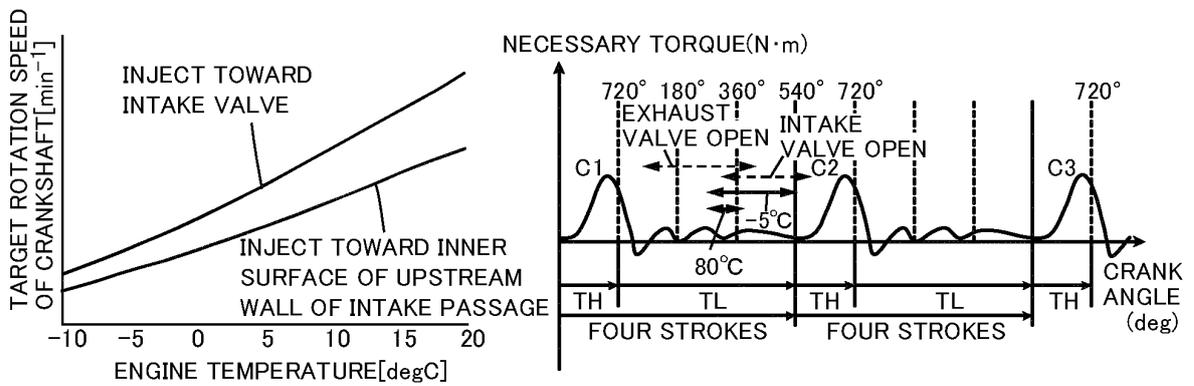
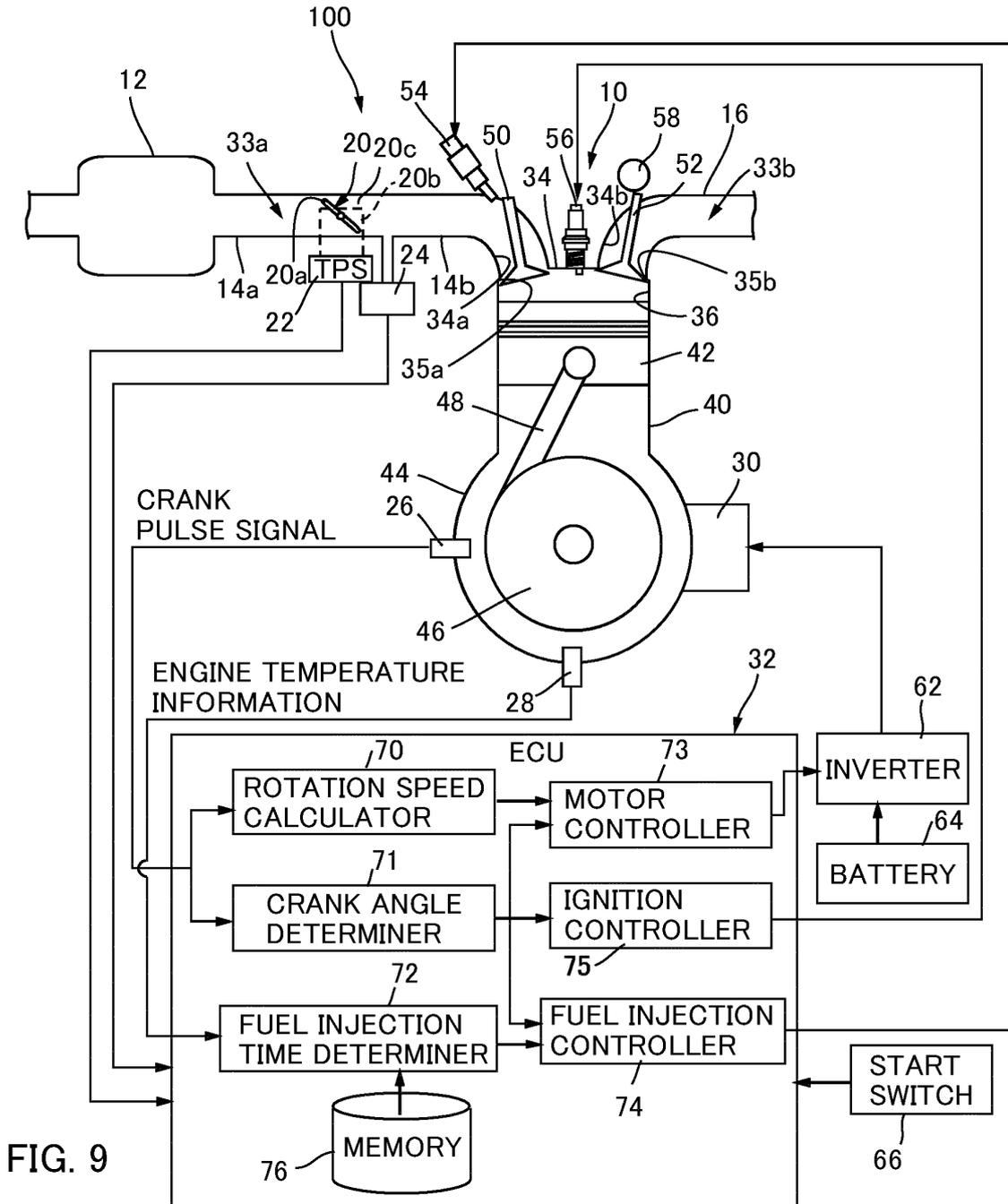


FIG. 8B





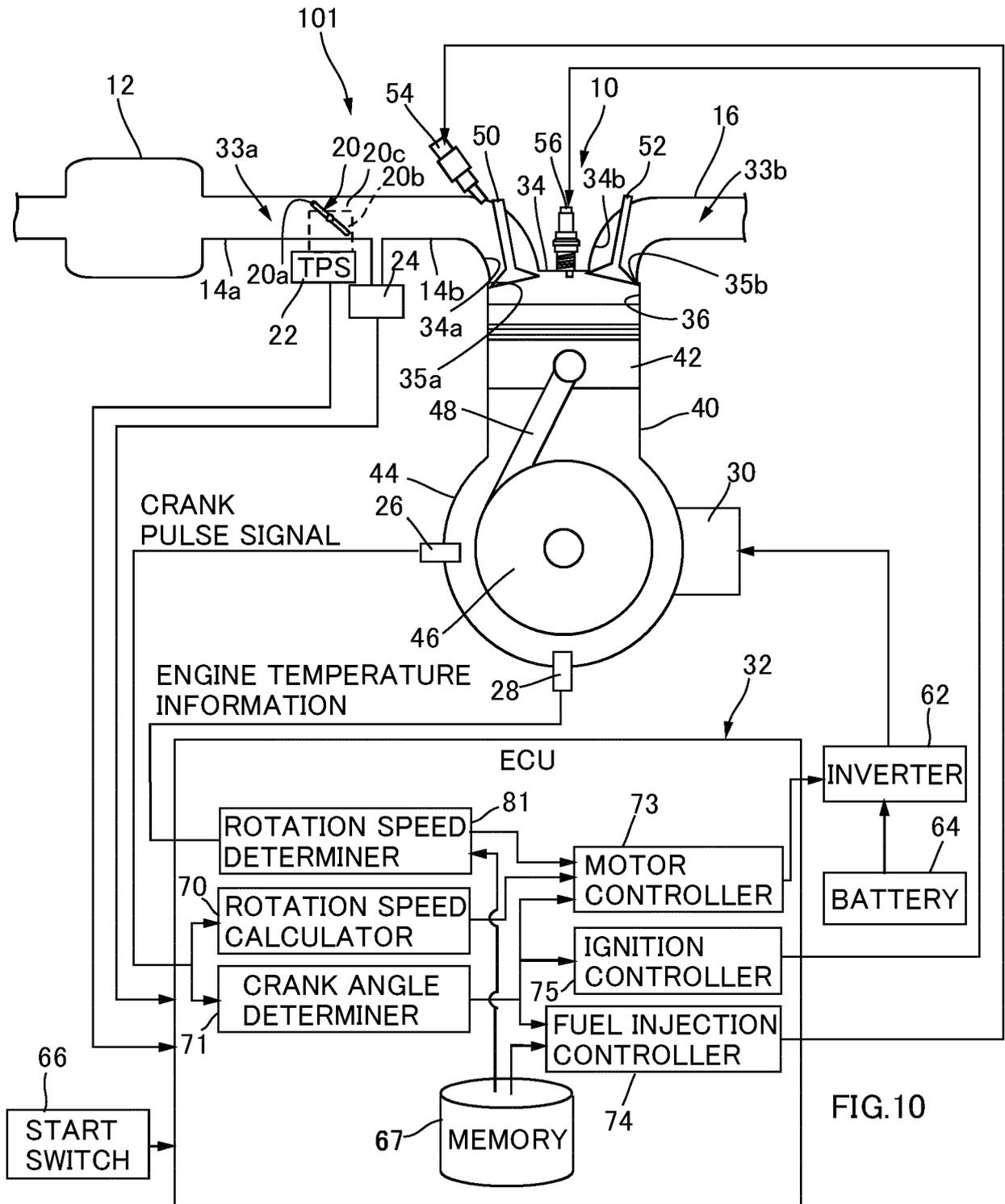
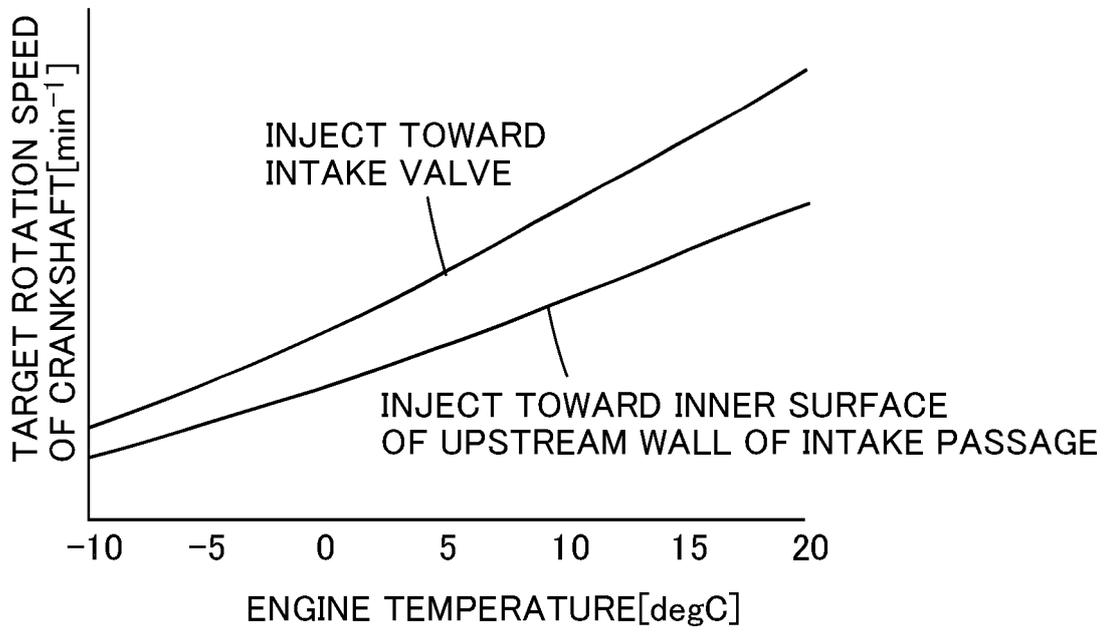


FIG.10

FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/018340

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A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F02D43/00(2006.01)i, F02D45/00(2006.01)i, F02N11/08(2006.01)i,
F02D29/02(2006.01)i, F02D41/06(2006.01)i, F02P5/15(2006.01)i,
F02D13/02(2006.01)i, F02D13/08(2006.01)i

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

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B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F02D41/00-45/00, F02N11/08, F02D29/00-29/02, F02P5/145-5/155,
F02D13/00-13/08

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-161754 A (TOYOTA MOTOR CORP.) 07 June 2002, entire text & US 6739299 B2, entire text & EP 1209355 A2 & DE 60110528 T2	1-8
A	JP 2016-46906 A (MITSUBISHI ELECTRIC CORP.) 04 April 2016, entire text (Family: none)	1-8
A	JP 11-153075 A (TOYOTA MOTOR CORP.) 08 June 1999, entire text & US 2001/0022166 A1, entire text & US 6247437 B1 & EP 0903492 A2	1-8
A	JP 2000-282909 A (EQUOS RESEARCH CO., LTD.) 10 October 2000, entire text (Family: none)	1-8

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

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance	"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

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Date of the actual completion of the international search 30 July 2018 (30.07.2018)	Date of mailing of the international search report 07 August 2018 (07.08.2018)
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Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/018340

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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 2007-182855 A (TOYOTA MOTOR CORP.) 19 July 2007, entire text (Family: none)	8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003343404 A [0003] [0010]
- WO 2015093576 A [0006] [0010]