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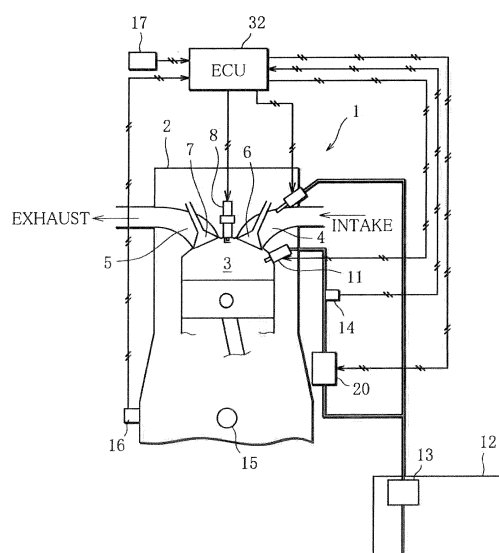
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(54) **FUEL-INJECTION CONTROLLER FOR ENGINE**

(57) There is provided a fuel-injection controller for an engine (1) that includes an air intake passage fuel injection valve (10) for injecting fuel to an intake port (4), and an inside cylinder fuel injection valve (11) for injecting fuel pressurized by a high pressure pump (20) into a combustion chamber (3). The high pressure pump (20) includes a plunger that reciprocates four times in a compressing chamber per one rotation of a drive shaft driven by the engine (1) to pressurize fuel in the compressing chamber, and a spill valve that opens and closes a supply passage of fuel to the compressing chamber. In addition, the fuel-injection controller for an engine includes a control unit (32) that controls driving of the spill valve. When the inside cylinder fuel injection valve (11) injects fuel, the control unit (32) changes the control of the spill valve to be driven twice per one rotation of the drive shaft during middle load driving with a load lower than a load during high load driving from four times per one rotation of the drive shaft during the high load driving.

FIG. 1



Description

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Technical Field

[0001] The present invention relates to a fuel injection control technique of an engine, capable of inside cylinder fuel injection and air intake passage fuel injection.

Background Art

[0002] There is known an engine that includes an inside cylinder fuel injection valve for injecting fuel into a combustion chamber, and an air intake passage fuel injection valve for injecting fuel into an air intake passage, and that controls the amount of fuel injection in each of the fuel injection valves in response to a rotational speed and a load of the engine.

[0003] Fuel pressurized highly by a high pressure pump is supplied to the inside cylinder fuel injection valve, so that the fuel can be injected into a combustion chamber in which pressure becomes high.

[0004] The high pressure pump is provided with a cam in a drive shaft that is driven by a crankshaft and a camshaft of the engine, for example. In the high pressure pump, drive of the cam with rotation of the drive shaft allows a plunger to reciprocate in a compressing chamber to pressurize fuel introduced in the compressing chamber and discharge the fuel under high pressure.

[0005] The high pressure pump includes a spill valve that is an opening/closing valve of an electromagnetic drive type, and that is provided between a supply passage through which fuel is supplied to the compressing chamber, and the compressing chamber. In addition, the high pressure pump is generally configured to provide a plurality of cam ridges in the cam provided in the drive shaft to allow the plunger to reciprocate multiple times per one rotation of the drive shaft, in order to ensure the amount of fuel injection.

[0006] Further, there is proposed a control technique in which operation and stop of a spill valve are switched on the basis of a driving state of an engine so that discharge pressure of fuel from a high pressure pump can be changed (refer to Patent Document 1).

[0007] In Patent Document 1, the spill valve is operated in an idle state on a low load side so that only an inside cylinder fuel injection valve directly injects fuel under high pressure into the inside of a cylinder to enable stable fuel injection. In an idle state on a high load side, the spill valve is stopped so that the inside cylinder fuel injection valve and an air intake passage fuel injection valve inject fuel under low pressure, at a predetermined sharing rate, to enable the spill valve to reduce an operation sound.

Prior Art Document**Patent Document**

[0008] Patent Document 1: Japanese Patent No.

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

[0009] Unfortunately, in Patent Document 1 described above, the spill valve is operated to enable stable fuel injection on the low load side in the idle state, the spill valve is stopped only on the high load side in the idle state. Thus, a range in which the operation sound of the spill valve can be reduced is limited to a part of the idle state, so that it is desired that the operation sound of the spill valve is reduced in a wider driving range of the engine. In addition, it is difficult to reduce an operation sound of the spill valve by only switching operation and stop of the spill valve, while fuel is appropriately supplied in a wider engine driving range of the engine including fuel injection by combination of the air intake passage fuel injection valve and the inside cylinder fuel injection valve, and stable combustion is achieved.

[0010] The present invention has been made to solve the problem to be solved described above, and an object of the present invention is to provide a fuel-injection controller for an engine, capable of reducing an operation sound of a spill valve of a high pressure pump in a wide driving range.

Means for Solving the Problems

[0011] In order to achieve the object described above, the invention according to Claim 1 is a fuel-injection controller for an engine, the engine including a high pressure pump, an air intake passage fuel injection device configured to inject fuel into an air intake passage, and an inside cylinder fuel injection device configured to inject fuel pressurized by a high pressure pump into a combustion chamber. The high pressure pump includes a plunger that moves in a compressing chamber to pressurize fuel in the compressing chamber, and a spill valve that opens and closes a supply passage of fuel to the compressing chamber. And the fuel-injection controller includes control device that controls fuel injection by the air intake passage fuel injection device, and fuel injection by the inside cylinder fuel injection device on the basis of a driving state of the engine, as well as that controls drive of the spill valve with drive of the plunger, in order to control a discharge state of fuel from the high pressure pump. At the time of fuel injection by the inside cylinder fuel injection device, the control device controls the spill valve to reduce an operation frequency thereof as a load of the engine decreases.

[0012] In the invention according to Claim 2, the control device controls the spill valve to stop driving during low load driving of the engine to stop fuel injection from the inside cylinder fuel injection device to allow the air intake passage fuel injection device to inject fuel, controls the spill valve to be driven during high load driving with a load

higher than a load during the low load driving to allow the inside cylinder fuel injection device to inject fuel, and controls the spill valve to be driven during middle load driving, which is a driving range between a driving range during the low load driving and a driving range during the high load driving, at a frequency less than a frequency of operation during the high load driving to allow the inside cylinder fuel injection device as well as the air intake passage fuel injection device to inject fuel.

[0013] In the invention according to Claim 3, in a case where discharge pressure of fuel from the high pressure pump is less than a specified value during the middle load driving, the control device controls the air intake passage fuel injection device to inject fuel to replenish a shortage of fuel that is a difference between the amount of fuel injection from the inside cylinder fuel injection device and the necessary amount of fuel injection set on the basis of at least a load of the engine.

[0014] In the invention according to Claim 4, the control device sets the amount of fuel injection by the air intake passage fuel injection device at a specified value during the high load driving, and controls the inside cylinder fuel injection device to inject fuel for a shortage of fuel that is a difference between the amount of fuel injection from the air intake passage fuel injection device and the necessary amount of fuel injection set on the basis of at least a load of the engine.

[0015] In the invention according to Claim 5, the control device sets the amount of fuel injection from the air intake passage fuel injection device at more than the amount of fuel injection from the inside cylinder fuel injection device during the middle load driving.

[0016] In the invention according to Claim 6, the control device sets the amount of fuel injection from the inside cylinder fuel injection device at more than the amount of fuel injection from the air intake passage fuel injection device during the high load driving.

[0017] In the invention according to Claim 7, the control device further controls valve closing timing of the spill valve in a variable manner on the basis of a driving state of the engine at the time of fuel injection by the inside cylinder fuel injection device.

Advantageous Effects of the Invention

[0018] According to the invention of Claim 1, at the time of fuel injection by the inside cylinder fuel injection device, an operation frequency of the spill valve is reduced with a decrease in a load of the engine, so that an operation sound of the spill valve can be reduced during the low load driving. In addition, in a state where a load of the engine rises, it is possible to highly maintain discharge pressure of fuel from the high pressure pump while an operation frequency of the spill valve is ensured. As a result, output power can be increased while the amount of fuel injection from the inside cylinder fuel injection device is ensured.

[0019] As above, in a state where a load of the engine

is high, while an operation frequency of the spill valve is increased to ensure discharge pressure of the high pressure pump, an operation frequency of the spill valve is reduced with a decrease in a load of the engine. As a result, a range of reducing the operation frequency of the spill valve is set to a wide range without limiting to an idle state so that the operation sound of the spill valve can be reduced.

[0020] According to the invention of Claim 2, during the low load driving, the spill valve is controlled so that drive of the spill valve is stopped to stop fuel injection from the inside cylinder fuel injection device to allow the air intake passage fuel injection device to inject fuel. As a result, the operation sound of the spill valve in the high pressure pump can be eliminated. During the high load driving, the inside cylinder fuel injection device injects fuel, so that filling efficiency is improved by an intake cooling effect to enable output power to increase. In addition, during the middle load driving, while output power is ensured by fuel injection from the inside cylinder fuel injection device and fuel injection from the air intake passage fuel injection device, the operation sound can be reduced by reducing the operation frequency of the spill valve.

[0021] According to the invention of Claim 3, even if the amount of fuel injection from the inside cylinder fuel injection device lacks during the middle load driving, the shortage of fuel is replenished by injection fuel from the air intake passage fuel injection device. As a result, the necessary amount of fuel injection can be filled without increasing the number of drives of the spill valve, so that the operation sound of the spill valve can be reduced.

[0022] According to the invention of Claim 4, during the high load driving, the amount of fuel injection by the air intake passage fuel injection device is set at a specified value, and the inside cylinder fuel injection device injects fuel for a shortage of fuel. As a result, it is possible to further obtain an intake cooling effect inside the cylinder by actively using fuel injection from the inside cylinder fuel injection device, so that output power of the engine can be increased.

[0023] According to the invention of Claim 5, during the middle load driving, the amount of fuel injection from the air intake passage injection device is set at more than the amount of fuel injection from the inside cylinder fuel injection device, so that it is possible to promote atomization of fuel to improve fuel consumption.

[0024] According to the invention of Claim 6, during the high load driving, the amount of fuel injection from the inside cylinder fuel injection device is set at more than the amount of fuel injection from the air intake passage fuel injection device, so that it is possible to improve an intake cooling effect to increase output power.

[0025] According to the invention of Claim 7, an operation frequency of the spill valve is not only controlled but valve closing timing thereof is controlled, in a variable manner on the basis of a driving state of the engine, so that it is possible to minutely control discharge pressure

of the high pressure pump. Thus, discharge pressure of the high pressure pump is minutely controlled in accordance with the amount of fuel injection from the inside cylinder fuel injection device, so that it is possible to reduce friction of the plunger at the time of operation to further improve fuel consumption.

Brief Description of the Drawings

[0026]

FIG. 1 is a schematic structural view of a fuel supply system of an engine provided with a fuel-injection controller of one embodiment of the present invention.

FIG. 2 is a schematic structural view of high pressure pump in accordance with the present embodiment.

FIG. 3 is a flow chart showing a drive control procedure of a fuel injection control and a spill valve in a control unit.

FIG. 4 is a flow chart showing a drive control procedure of a fuel injection control and a spill valve in a control unit.

FIG. 5 is a map for determining a fuel injection mode.

Mode for Carrying out the Invention

[0027] Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings.

[0028] FIG. 1 is a schematic structural view of a fuel supply system of an engine 1 provided with a fuel-injection controller of one embodiment of the present invention. FIG. 2 is a schematic structural view of a high pressure pump 20.

[0029] The engine 1 in accordance with one embodiment of the present invention is an engine for traveling drive of an automobile, for example. As shown in FIG. 1, the engine 1 is provided with a cylinder head 2 that includes: an intake port 4 (air intake passage) and an exhaust port 5 that communicate with a combustion chamber 3; an intake valve 6 for opening and closing a portion between the intake port 4 and the combustion chamber 3; an exhaust valve 7 for opening and closing a portion between the exhaust port 5 and the combustion chamber 3; and an ignition plug 8 provided with an electrode facing to the combustion chamber 3.

[0030] Further, the cylinder head 2 of the engine 1 of the present embodiment includes an air intake passage fuel injection valve 10 for injecting fuel into the intake port 4, and an inside cylinder fuel injection valve 11 for injecting fuel into the combustion chamber 3.

[0031] The air intake passage fuel injection valve 10 is provided with an injection port arranged in the intake port 4, and injects fuel under low pressure supplied from a fuel tank 12 by a feed pump 13 into the intake port 4. Fuel injection by the air intake passage fuel injection valve 10 is indicated as air intake passage fuel injection

(PI).

[0032] The inside cylinder fuel injection valve 11 is provided with an injection port arranged in the combustion chamber 3, and injects fuel under high pressure supplied from the high pressure pump 20 into the combustion chamber 3. The high pressure pump 20 pressurizes fuel under low pressure supplied from the feed pump 13 and supplies the fuel to the inside cylinder fuel injection valve 11. Fuel injection by the inside cylinder fuel injection valve 11 is indicated as inside cylinder fuel injection (DI).

[0033] In addition, in a fuel supply passage between the high pressure pump 20 and the inside cylinder fuel injection valve 11, a pressure sensor 14 is provided to detect discharge pressure of fuel from the high pressure pump 20 indicated as delivery fuel pressure Pd.

[0034] As shown in FIG. 2, the high pressure pump 20 is provided with a plunger 22 that is allowed to reciprocate in a cylindrical cylinder 21. The plunger 22 is moved by a cam 24 provided in a drive shaft 23. The drive shaft 23 is coupled to an intake cam shaft (not shown) of the engine 1, for example, and therefore the plunger 22 is reciprocated in the cylinder 21 by drive of the engine 1 to change the volume of a compressing chamber 25 in the cylinder 21. The present embodiment is configured so that the cam 24 is formed into a substantially square plate shape with smoothed corners 24a, and is arranged so as to press the plunger 22 with the four corners 24a to reduce the volume of the compressing chamber 25, and the plunger 22 reciprocates four times per one rotation of the drive shaft 23.

[0035] The cylinder 21 includes a supply passage 26 through which fuel is supplied to the compressing chamber 25, and a discharge passage 27 through which fuel is discharged from the compressing chamber 25. Further, the cylinder 21 includes a spill valve 28 that opens and closes the supply passage 26, and a discharge valve 29 that opens and closes the discharge passage 27. The supply passage 26 and the discharge passage 27 are connected to the feed pump 13 and the inside cylinder fuel injection valve 11, respectively.

[0036] The spill valve 28 is urged by a spring 30 so as to be opened, as well as is configured to be closed by energizing a solenoid 31. The solenoid 31 receives electric power as a spill valve driving signal from a control unit (ECU) 32 to close the spill valve 28.

[0037] The discharge valve 29 is urged by a spring 33 so as to be closed, and is configured to be opened in a case where a differential pressure between a pressure in the compressing chamber 25 and a pressure in the discharge passage 27 is equal to or more than a specified value, that is, the discharge valve 29 is set to be opened when a pressure in the compressing chamber 25 rises to a setting supply pressure to the inside cylinder fuel injection valve 11 or more.

[0038] When the plunger 22 moves downward, namely the volume of the compressing chamber 25 increases, the spill valve 28 opens as shown in FIG. 2 so that fuel is supplied into the compressing chamber 25 from the

supply passage 26. When the plunger 22 moves upward, namely the volume of the compressing chamber 25 decreases, a spill valve driving signal of closing the spill valve 28 is temporarily supplied to the solenoid 31. Subsequently, when the plunger 22 moves upward, the spill valve 28 is maintained at a valve-closed state to pressurize fuel in the compressing chamber 25.

[0039] Thus, in the high pressure pump 20, a spill valve driving signal of closing the spill valve 28 is inputted into the solenoid 31 each time when the plunger 22 starts moving upward from bottom dead center of the plunger 22, so that the spill valve 28 repeatedly opens and closes, and fuel is repeatedly pressurized in accordance with vertical motion of the plunger 22. As a result, fuel under high pressure can be discharged.

[0040] The control unit 32 is composed of an input-output device, a storage device (such as a ROM, a RAM, and a nonvolatile RAM), and a central processing unit (CPU), and the like. The control unit 32 controls the air intake passage fuel injection valve 10 and the inside cylinder fuel injection valve 11 on the basis of accelerator operation, engine rotational speed, and the like, to control the amount of fuel injection, as well as controls operation of the ignition plug 8, and the like to control operation of the engine 1. In addition, the control unit 32 has a function in which the delivery fuel pressure P_d is received from the pressure sensor 14, and a crank angle is received from a crank angle sensor 16 of the engine 1 to control drive of the spill valve 28 of the high pressure pump 20 on the basis of a load and a rotational speed of the engine 1. The load of the engine 1 may be acquired on the basis of an accelerator manipulated variable received from an accelerator position sensor 17, for example, and the rotational speed of the engine 1 may be acquired by measuring a change of crank angles received from the crank angle sensor 16.

[0041] Each of FIGS. 3 and 4 is a flow chart showing a drive control procedure of a fuel injection control and the spill valve 28 in the control unit 32. FIG. 5 is a map for determining a fuel injection mode.

[0042] The present routine starts at the time of operation of starting the engine 1 with a key switch, and the like.

[0043] As shown in FIG. 3, in the present embodiment, first in step S10, the engine 1 is started by controlling operation of the inside cylinder fuel injection valve 11 or the air intake passage fuel injection valve 10, the ignition plug 8, and a starter motor (not shown), and processing proceeds to step S20.

[0044] In step S20, drive of the spill valve 28 is started. That is, a spill valve driving signal is outputted to the solenoid 31 each time when the plunger 22 of the high pressure pump 20 starts moving upward from bottom dead center of the plunger 22, as described above, in accordance with a crank angle received from the crank angle sensor 16, so that fuel is pressurized, and the processing proceeds to step S30.

[0045] In step S30, a fuel injection mode is determined on the basis of a rotational speed and a load of the engine

1. The fuel injection mode is determined by using a fuel injection mode map, such as shown in FIG. 5. As shown in FIG. 5, a fuel injection mode during low load and low rotational speed driving (corresponding to during low load driving in the invention of the present application, including an idle state) is determined as a PI mode, a fuel injection mode during middle load driving is determined as a "DI + PI (1)" mode, and a fuel injection mode during high load driving is determined as a "DI + PI (2)" mode. In the PI mode, the inside cylinder fuel injection valve 11 does not inject fuel, and only the air intake passage fuel injection valve 10 injects fuel, and in the "DI + PI (1)" and "DI + PI (2)" modes, both of the inside cylinder fuel injection valve 11 and the air intake passage fuel injection valve 10 inject fuel. In addition, it is determined whether the PI mode is determined, and if the PI mode is determined, the processing proceeds to step S40.

[0046] In step S40, the delivery fuel pressure P_d is inputted from the pressure sensor 14 so that it is determined whether the delivery fuel pressure P_d is equal to or more than a specified value P_{d1} ($P_d \geq P_{d1}$). The specified value P_{d1} may be set at a fuel pressure sufficient for injecting fuel from the inside cylinder fuel injection valve 11 into the combustion chamber 3. If the delivery fuel pressure P_d is equal to or more than the specified value P_{d1} , the processing proceeds to step S50.

[0047] In step S50, output of a spill valve driving signal is stopped. That is, drive of the spill valve 28 is stopped so that the spill valve 28 is opened to stop pressurizing fuel in the high pressure pump 20, and the processing returns to step S30.

[0048] In step S40, if it is determined that the delivery fuel pressure P_d is less than the specified value P_{d1} , the processing proceeds to step S60.

[0049] In step S60, the spill valve 28 is driven as with step S20. That is, if the spill valve 28 is driven, the spill valve 28 is continuously driven, and if the spill valve 28 is not driven, drive of the spill valve 28 is started, and the processing returns to step S30.

[0050] In step S30, if the PI mode is not determined, namely the "DI + PI (1)" mode or the "DI + PI (2)" mode is determined, the processing proceeds to step S70, as shown in FIG. 4.

[0051] In step S70, the spill valve 28 is driven as with step S60 to pressurize fuel in the high pressure pump 20, and the processing proceeds to step S80.

[0052] In step S80, operation of the inside cylinder fuel injection valve 11 is controlled to start an inside cylinder fuel injection, and the processing proceeds to step S90.

[0053] In step S90, a fuel injection mode is determined as with step S30 to determine whether the fuel injection mode is the "DI + PI (1)" mode. If it is determined that the fuel injection mode is the "DI + PI (1)" mode, the processing proceeds to step S100.

[0054] In step S100, the drive of the spill valve 28 is set so as to be driven twice per one rotation of the drive shaft 23 in the high pressure pump 20. That is, although the high pressure pump 20 is configured so that the

plunger 22 reciprocates four times per one rotation of the drive shaft, as described above, a spill valve driving signal is outputted every other reciprocation in the four reciprocations. Thus, fuel is pressurized in a volume in which the plunger reciprocates twice per one rotation of the drive shaft, so that the amount of discharge is halved as compared with a case where a spill valve driving signal is outputted every reciprocation of the plunger 22 to reduce discharge pressure, and the processing proceeds to step S110.

[0055] In step S110, the delivery fuel pressure Pd is inputted from the pressure sensor 14 as with step S40, and it is determined whether the delivery fuel pressure Pd is equal to or more than the specified value Pd1 ($Pd \geq Pd1$). If the delivery fuel pressure Pd is equal to or more than the specified value Pd1, the processing returns to step S90. If the delivery fuel pressure Pd is less than the specified value Pd1, the processing proceeds to step S120.

[0056] In step S120, a shortage of fuel is replenished by the air intake passage fuel injection (PI). That is, the amount of fuel injection from the inside cylinder fuel injection valve 11 is set at a relatively small amount, and the air intake passage fuel injection valve 10 is controlled to inject fuel for a shortage of fuel that is a difference between the amount of fuel injection from the inside cylinder fuel injection valve 11 and the necessary amount of fuel injection set on the basis of an engine rotational speed and an engine load, and the processing returns to step S90.

[0057] In step S90, if it is determined that a fuel injection mode is not the "DI + PI (1)" mode, the processing proceeds to step S130.

[0058] In step S130, a fuel injection mode is determined as with step S30 to determine whether the fuel injection mode is the "DI + PI (2)" mode. If it is determined that the fuel injection mode is the "DI + PI (2)" mode, the processing proceeds to step S140.

[0059] In step S140, the drive of the spill valve 28 is set so as to be driven four times per one rotation of the drive shaft 23. The setting is normal setting during operation of the high pressure pump 20, in which a spill valve driving signal is outputted every reciprocation of the plunger 22 in the high pressure pump 20 in which the plunger 22 reciprocates four times per one rotation of the drive shaft 23, and the processing proceeds to step S150.

[0060] In step S150, the amount of fuel injection into the air intake passage, which is the amount of fuel injection by the air intake passage fuel injection valve 10, is set at a specified value Vpi1 of a relatively small value, and the processing proceeds to step S160.

[0061] In step S160, a shortage of fuel is replenished by the inside cylinder fuel injection. That is, the inside cylinder fuel injection valve 11 is controlled to inject fuel for a shortage of fuel that is a difference between the specified value Vpi1 described above and the necessary amount of fuel injection set on the basis of an engine rotational speed and an engine load, and the processing

proceeds to step S130.

[0062] In step S130, if it is determined that a fuel injection mode is not the "DI + PI (2)" mode, the processing proceeds to step S170.

5 **[0063]** In step S170, it is determined whether the engine 1 is stopped or not. If the engine 1 is stopped, the present routine is finished, and if the engine 1 is not stopped, the processing returns to step S30 shown in FIG. 3.

10 **[0064]** In accordance with the control described above, in the present embodiment, it is possible to change drive of the spill valve 28 to two stages of two drives and four drives, per one rotation of the drive shaft 23. As a result, discharge performance of the high pressure pump 20 can be changed to two stages.

15 **[0065]** In addition, the PI mode is selected during low load and low rotational speed driving of the engine 1 to stop drive of the spill valve 28, so that it is possible to eliminate an operation sound of the spill valve 28. Since the necessary amount of fuel injection is small during low load and low rotational speed driving, only the air intake passage fuel injection without the inside cylinder fuel injection can sufficiently fill the necessary amount even if the maximum amount of fuel injection of the air intake passage fuel injection valve 10 is small.

20 **[0066]** The "DI + PI (1)" mode is selected during middle load driving of the engine 1, so that fuel injection is performed by both of the inside cylinder fuel injection and the air intake passage fuel injection. Accordingly, the amount of the fuel injection can be increased as compared with the PI mode, so that it is possible to sufficiently fill the amount of fuel injection required during the middle load driving. In addition, since drive of the spill valve 28 is set at two drives in the range, it is possible to reduce an operation sound as compared with four drives of a normal drive of the spill valve 28.

25 **[0067]** In the "DI + PI (1)" mode, or during middle load driving, the amount of inside cylinder fuel injection is less set, and a shortage of fuel is replenished by the air intake passage fuel injection. Thus, the amount of the air intake passage fuel injection is set to be more than the amount of the inside cylinder fuel injection. Accordingly, since the air intake passage fuel injection allows fuel to be easily atomized until the fuel reaches to the combustion chamber 3 after fuel injection, it is possible to improve fuel consumption. In addition, the number of drives of the spill valve 28 is reduced, so that friction of the spill valve 28 during operation can be reduced, as well as the number of drives of the solenoid 31 can be reduced. As a result, fuel consumption can be improved due to the points above.

30 **[0068]** In a range of the "DI + PI (1)" mode, when even a small amount of the inside cylinder fuel injection is performed, it is possible to reduce a deposit adhering to an injection port of the inside cylinder fuel injection valve 11.

35 **[0069]** The "DI + PI (2)" mode is selected during high load driving of the engine 1, so that fuel injection is performed by both of the inside cylinder fuel injection and

the air intake passage fuel injection, as well as the drive of the spill valve 28 is set at four drives. Accordingly, the high pressure pump 20 is allowed to exert its capability as much as possible, so that it is possible to sufficiently ensure fuel required during high load driving. In the "DI + PI (2)" mode, the number of operations of the spill valve 28 becomes twice as many as those in the "DI + PI (1)" mode, so that an operation sound of the spill valve 28 is not reduced. However, an engine sound increases during high load driving, so that an operation sound of the spill valve 28 does not easily become a problem.

[0070] In the "DI + PI (2)" mode, or during high load driving, the amount of the air intake passage fuel injection is less set, and a shortage of fuel is replenished by the inside cylinder fuel injection. Thus, the amount of the inside cylinder fuel injection is set to be more than the amount of the air intake passage fuel injection. Thus, it is possible to sufficiently acquire an intake cooling effect caused by a fuel injection into the combustion chamber 3 in the inside cylinder fuel injection. As a result, it is possible to improve filling efficiency and increase output power.

[0071] As above, in the present embodiment, the inside cylinder fuel injection is not performed during low load driving (during low load and low rotational speed) including an idle state to stop operation of the spill valve 28 to reduce a noise from the high pressure pump 20, as well as during middle load driving, the number of operations of the spill valve 28 is halved as compared with that during high load driving to reduce an operation sound. As a result, it is possible to reduce the operation sound in a wide driving range, such as during low load driving and during middle load driving.

[0072] The invention of the present application is not limited to the embodiment above. In the embodiment above, for example, in a case where the number of operations of the spill valve 28 during middle load driving is set at two drives, the spill valve 28 is controlled to alternately perform a stop and an operation one by one, but each of the stop and the operation may be performed twice alternately in four operations per one rotation of the drive shaft 23, for example. However, when the stop and the operation of the spill valve 28 is alternately performed one by one as with the embodiment above, change of the delivery fuel pressure Pd from the high pressure pump 20 can be reduced as compared with those performed for each multiple times. As a result, it is possible to more accurately control fuel injection.

[0073] In addition, in the embodiment above, although both of the inside cylinder fuel injection and the air intake passage fuel injection are performed in the "DI + PI (2)" mode, only the inside cylinder fuel injection may be performed.

[0074] Further, in the "DI + PI (1)" mode or the "DI + PI (2)" mode of the embodiment above, valve closing timing of the spill valve 28 may be controlled in a variable manner in accordance with the necessary amount of fuel injection from the inside cylinder fuel injection valve 11.

If the valve closing timing of the spill valve 28 is set at a time when the plunger 22 is positioned at its bottom dead center, the delivery fuel pressure Pd, which is discharge pressure from the high pressure pump 20, can be set high. On the other hand, if the valve closing timing of the spill valve 28 is set at a time when the plunger 22 moves to a position above its bottom dead center to form lag setting, it is possible to reduce the delivery fuel pressure Pd. In addition, when the lag setting is applied to the valve closing timing of the spill valve 28 in accordance with a driving state of the engine 1, where the necessary amount of fuel injection from the inside cylinder fuel injection valve 11 is reduced, it is possible to reduce friction of the plunger 22 at the time of operation to further improve fuel consumption.

[0075] The invention of the present application is widely applicable to an engine which includes air intake passage fuel injection device configured to inject fuel into an air intake passage, and inside cylinder fuel injection device configured to inject fuel into a combustion chamber, and in which a high pressure pump with a spill valve supplies fuel under high pressure to the inside cylinder fuel injection device.

Explanation of Reference Signs

[0076]

- 1 engine
- 10 air intake passage fuel injection valve (air intake passage fuel injection device)
- 11 inside cylinder fuel injection valve (inside cylinder fuel injection device)
- 20 high pressure pump
- 22 plunger
- 25 compressing chamber
- 28 spill valve
- 32 control unit (control device)

Claims

1. A fuel-injection controller for an engine, the engine including a high pressure pump, an air intake passage fuel injection device configured to inject fuel into an air intake passage, and an inside cylinder fuel injection device configured to inject fuel pressurized by the high pressure pump into a combustion chamber;
the high pressure pump including a plunger that moves in a compressing chamber to pressurize fuel in the compressing chamber, and a spill valve that opens and closes a supply passage of fuel to the compressing chamber;
the fuel-injection controller comprising:

a control device that controls fuel injection by the air intake passage fuel injection device, and

- fuel injection by the inside cylinder fuel injection device on a basis of a driving state of the engine, as well as that controls drive of the spill valve with drive of the plunger, in order to control a discharge state of fuel from the high pressure pump, the control device controlling the spill valve to reduce an operation frequency thereof as a load of the engine decreases, at the time of fuel injection by the inside cylinder fuel injection device.
2. The fuel-injection controller for an engine according to Claim 1, wherein the control device controls the spill valve to stop driving during low load driving of the engine to stop fuel injection from the inside cylinder fuel injection device to allow the air intake passage fuel injection device to inject fuel, controls the spill valve to be driven during high load driving with a load higher than a load during the low load driving to allow the inside cylinder fuel injection device to inject fuel, and controls the spill valve to be driven during middle load driving, which is a driving range between a driving range during the low load driving and a driving range during the high load driving, at a frequency less than a frequency of operation during the high load driving to allow the inside cylinder fuel injection device as well as the air intake passage fuel injection device to inject fuel.
 3. The fuel-injection controller for an engine according to Claim 2, wherein in a case where discharge pressure of fuel from the high pressure pump is less than a specified value during the middle load driving, the control device controls the air intake passage fuel injection device to inject fuel to replenish a shortage of fuel that is a difference between the amount of fuel injection from the inside cylinder fuel injection device and the necessary amount of fuel injection set on a basis of at least a load of the engine.
 4. The fuel-injection controller for an engine according to Claim 2 or 3, wherein the control device sets the amount of fuel injection by the air intake passage fuel injection device at a specified value during the high load driving, and controls the inside cylinder fuel injection device to inject fuel for a shortage of fuel that is a difference between the amount of fuel injection from the air intake passage fuel injection device and the necessary amount of fuel injection set on the basis of at least a load of the engine.
 5. The fuel-injection controller for an engine according to any one of Claims 2 to 4, wherein the control device sets the amount of fuel injection from the air intake passage fuel injection device at more than the amount of fuel injection from the inside cylinder fuel injection device during the middle load driving.

6. The fuel-injection controller for an engine according to any one of Claims 2 to 5, wherein the control device sets the amount of fuel injection from the inside cylinder fuel injection device at more than the amount of fuel injection from the air intake passage fuel injection device during the high load driving.
7. The fuel-injection controller for an engine according to any one of Claims 1 to 6, wherein the control device further controls valve closing timing of the spill valve in a variable manner on the basis of a driving state of the engine at the time of fuel injection by the inside cylinder fuel injection device.

Amended claims under Art. 19.1 PCT

1. A fuel-injection controller for an engine, the engine including a high pressure pump, an air intake passage fuel injection device configured to inject fuel into an air intake passage, and an inside cylinder fuel injection device configured to inject fuel pressurized by the high pressure pump into a combustion chamber;

the high pressure pump including a plunger that is moved in a compressing chamber by drive of a cam with rotation of a drive shaft to pressurize fuel in the compressing chamber, and a spill valve that opens and closes a supply passage of fuel to the compressing chamber;

the fuel-injection controller comprising:

a control device that controls fuel injection by the air intake passage fuel injection device, and fuel injection by the inside cylinder fuel injection device on a basis of a driving state of the engine, as well as that controls drive of the spill valve with drive of the plunger, in order to control a discharge state of fuel from the high pressure pump, the control device controlling the spill valve to reduce an operation frequency thereof by reducing the number of drives of the spill valve as compared with the number of drives of the plunger per one rotation of the drive shaft, as a load of the engine decreases, at the time of fuel injection by the inside cylinder fuel injection device.

2. The fuel-injection controller for an engine according to Claim 1, wherein the control device controls the spill valve to stop driving during low load driving of the engine to stop fuel injection from the inside cylinder fuel injection device to allow the air intake passage fuel injection device to inject fuel, controls the spill valve to be driven during high load driving with a load higher than a load during the low load driving to allow the inside cylinder fuel injection device to inject fuel, and controls the spill valve to be

driven during middle load driving, which is a driving range between a driving range during the low load driving and a driving range during the high load driving, at a frequency less than a frequency of operation during the high load driving to allow the inside cylinder fuel injection device as well as the air intake passage fuel injection device to inject fuel.

3. The fuel-injection controller for an engine according to Claim 2, wherein in a case where discharge pressure of fuel from the high pressure pump is less than a specified value during the middle load driving, the control device controls the air intake passage fuel injection device to inject fuel to replenish a shortage of fuel that is a difference between the amount of fuel injection from the inside cylinder fuel injection device and the necessary amount of fuel injection set on a basis of at least a load of the engine.

4. The fuel-injection controller for an engine according to Claim 2 or 3, wherein the control device sets the amount of fuel injection by the air intake passage fuel injection device at a specified value during the high load driving, and controls the inside cylinder fuel injection device to inject fuel for a shortage of fuel that is a difference between the amount of fuel injection from the air intake passage fuel injection device and the necessary amount of fuel injection set on the basis of at least a load of the engine.

5. The fuel-injection controller for an engine according to any one of Claims 2 to 4, wherein the control device sets the amount of fuel injection from the air intake passage fuel injection device at more than the amount of fuel injection from the inside cylinder fuel injection device during the middle load driving.

6. The fuel-injection controller for an engine according to any one of Claims 2 to 5, wherein the control device sets the amount of fuel injection from the inside cylinder fuel injection device at more than the amount of fuel injection from the air intake passage fuel injection device during the high load driving.

7. The fuel-injection controller for an engine according to any one of Claims 1 to 6, wherein the control device further controls valve closing timing of the spill valve in a variable manner on the basis of a driving state of the engine at the time of fuel injection by the inside cylinder fuel injection device.

1 of the present application and the invention disclosed in Document 1 (JP2007-9815A).

According to the amendment, Claim 1 of the present application defines that the spill valve is allowed to reduce an operation frequency thereof by reducing the number of drives of the spill valve as compared with the number of drives of the plunger per one rotation of the drive shaft, as a load of the engine decreases, at the time of fuel injection by the inside cylinder fuel injection device.

In accordance with Claim 1 of the present application, it is possible not only to naturally reduce the operation frequency of the spill valve with decrease in a rotation speed of the engine, but also to reduce the operation frequency to an operation frequency of the spill valve that is arbitrarily set in accordance with a rotation speed of the engine. As a result, it is possible to effectively reduce an operation sound of the spill valve.

Statement under Art. 19.1 PCT

The amendment of Claim 1 of the present application is defined on the basis of the description of paragraphs [0023], [0032], and the like of the specification to clarify the difference between the invention according to Claim

FIG. 1

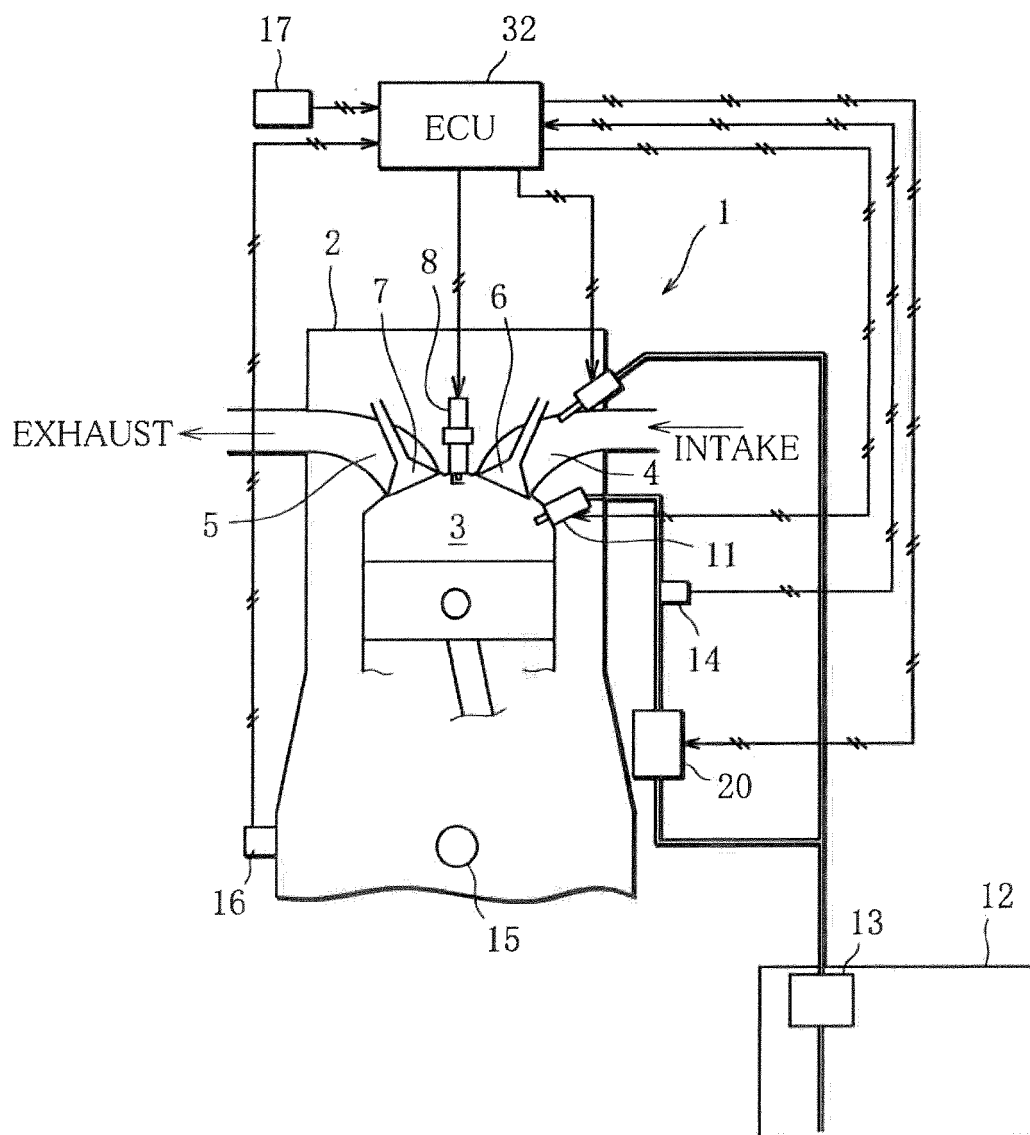


FIG. 2

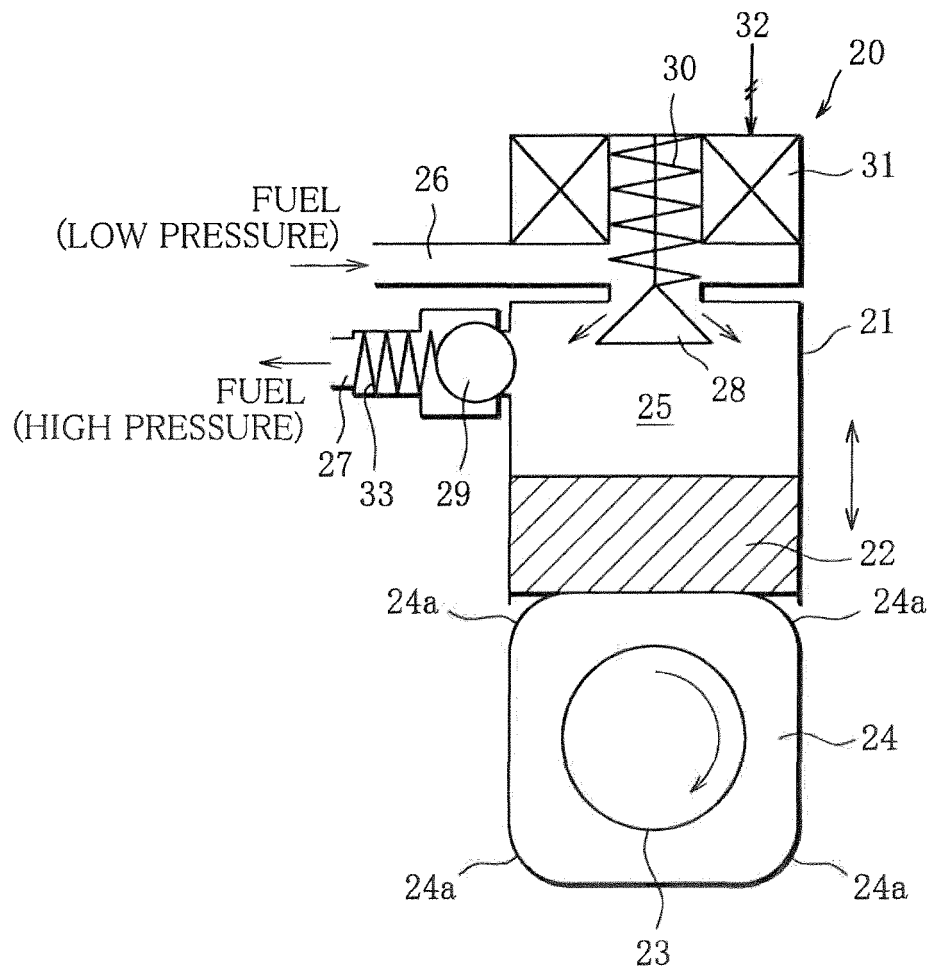


FIG. 3

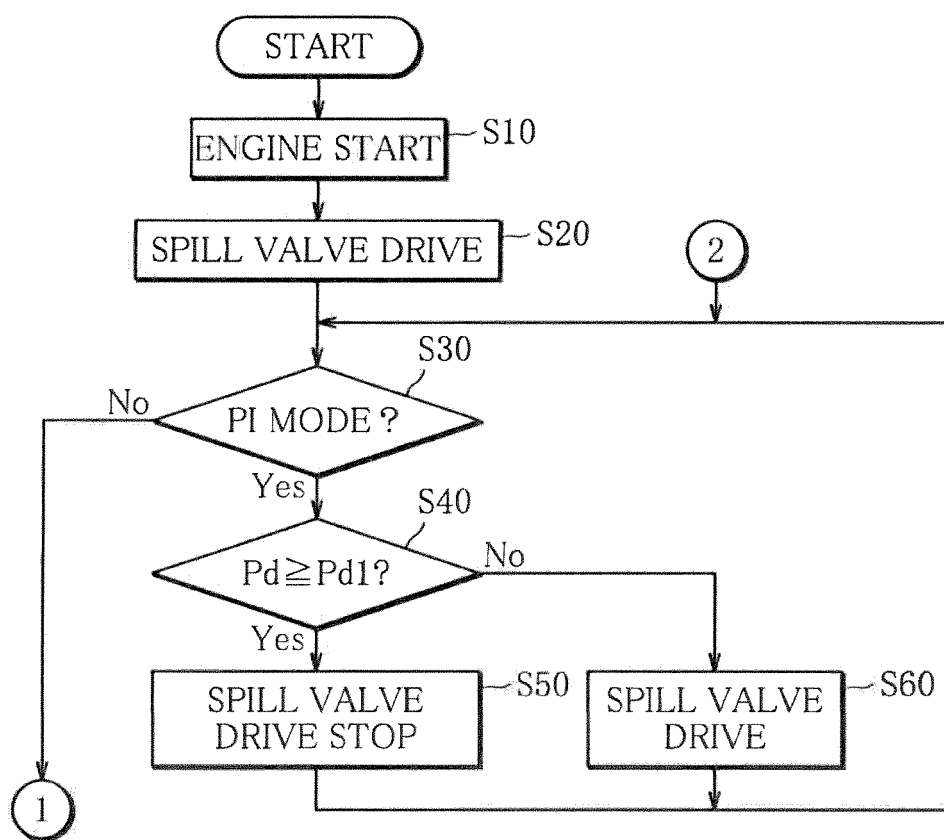


FIG. 4

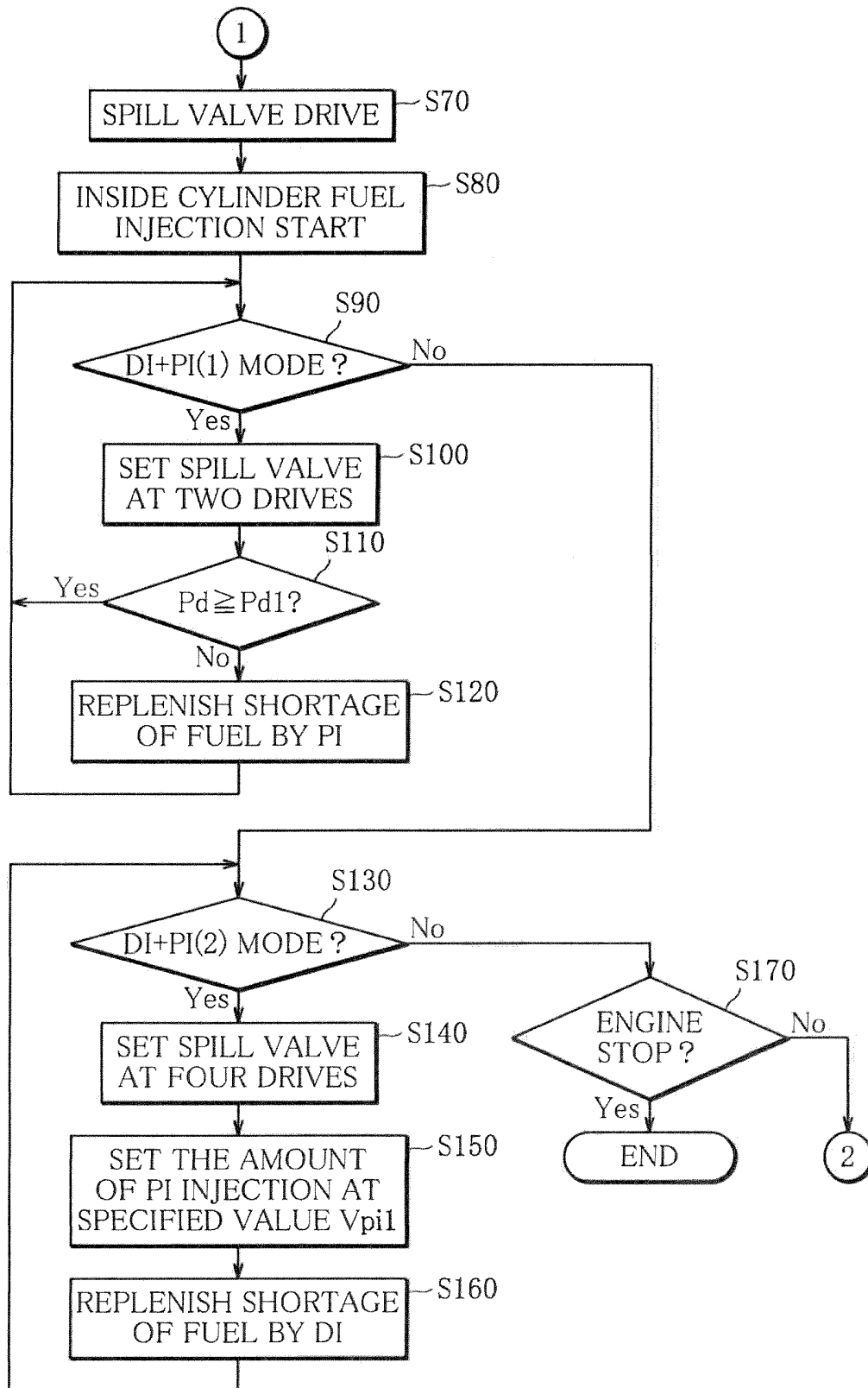
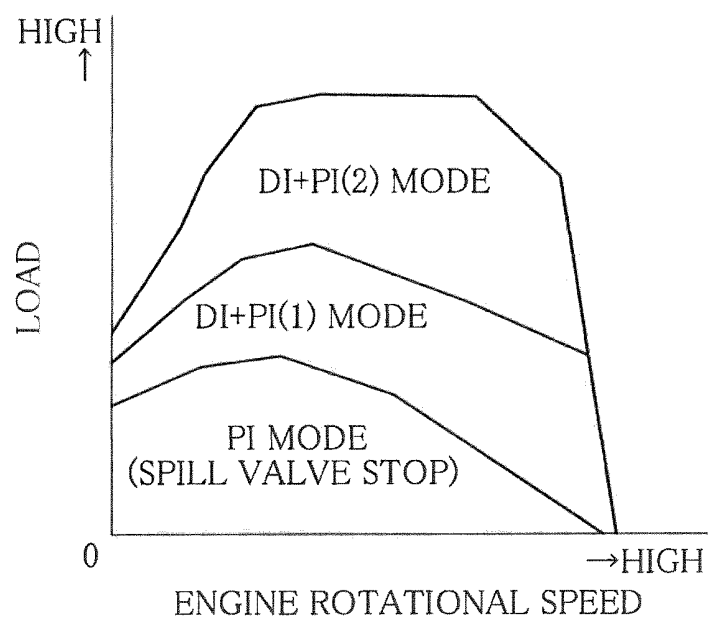


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/058065

A. CLASSIFICATION OF SUBJECT MATTER

F02M55/02(2006.01)i, F02M59/34(2006.01)i, F02M59/36(2006.01)i, F02M59/46(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)
F02M55/02, F02M59/34, F02M59/36, F02M59/46

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 1996-2013
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
X Y	JP 2007-9815 A (Toyota Motor Corp.), 18 January 2007 (18.01.2007), paragraphs [0103] to [0112]; fig. 12 & US 2007/0000478 A1 & EP 1896711 A1 & WO 2007/004596 A1	1-2, 5-6 7
Y	JP 2005-207374 A (Toyota Motor Corp.), 04 August 2005 (04.08.2005), paragraphs [0032] to [0034]; fig. 2 (Family: none)	7
A	JP 2011-202587 A (Daihatsu Motor Co., Ltd.), 13 October 2011 (13.10.2011), paragraph [0035] (Family: none)	1-7

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

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Date of the actual completion of the international search
11 June, 2013 (11.06.13)

Date of mailing of the international search report
25 June, 2013 (25.06.13)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/058065

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 2008-255980 A (Toyota Motor Corp.), 23 October 2008 (23.10.2008), paragraph [0038] (Family: none)	1-7
A	WO 2006/100938 A1 (Toyota Motor Corp.), 28 September 2006 (28.09.2006), paragraph [0023] & US 2006/0207568 A1 & EP 1860318 A1	1-7

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4428293 B [0008]