(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2013 (02.05.2013)

(10) International Publication Number
WO 2013/061123 A1

(51) International Patent Classification:
F02D 41/38 (2006.01)

(21) International Application Number:
PCT/IB2012/002003

(22) International Filing Date:
10 October 2012 (10.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2011-233287 24 October 2011 (24.10.2011) JP

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: METHOD AND APPARATUS FOR CONTROLLING THE FUEL SUPPLY OF AN INTERNAL COMBUSITON ENGINE

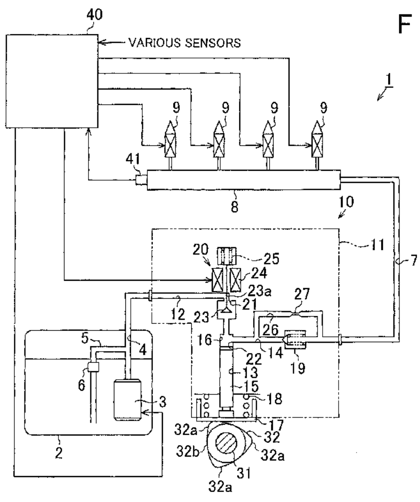

FIG. 1

(57) Abstract: A control device for an internal combustion engine including: a high-pressure pump pressurizing and discharging fuel, from a fuel tank, by lifting a plunger with cam noses of a cam that rotates with rotation of an engine output shaft; and fuel injection valves provided for corresponding cylinders and injecting and supplying fuel, fed under pressure from the high-pressure pump through a high-pressure passage, into the corresponding cylinders includes: a control unit controlling a fuel injection mode by each fuel injection valve based on a fuel pressure in the high-pressure passage in a period immediately before fuel injection, wherein the control unit executes pressure feed limiting control in which, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, feeding fuel under pressure by the high-pressure pump during the lift duration is limited.

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METHOD AND APPARATUS FOR CONTROLLING THE FUEL SUPPLY OF AN INTERNAL COMBUSITON ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an internal combustion engine that injects and supplies fuel, fed under pressure through a high-pressure passage from a cam-driven high-pressure pump, into a cylinder via a fuel injection valve, and a control device and control method that control a mode in which fuel is injected by the fuel injection valve on the basis of a fuel pressure in the high-pressure passage immediately before fuel injection.

2. Description of Related Art

[0002] An internal combustion engine control device of this type is, for example, a device described in Japanese Patent Application Publication No. 2009-215909 (JP 2009-215909 A). In the internal combustion engine described in JP 2009-215909 A, fuel stored in a fuel tank is drawn by a feed pump, and is supplied to a high-pressure pump. The fuel supplied to the high-pressure pump is further pressurized by the high-pressure pump, and is fed under pressure through a high-pressure passage to a fuel injection valve provided for corresponding cylinders. The fuel fed under pressure in this way is injected and supplied from each fuel injection valve into a corresponding one of the cylinders.

[0003] The high-pressure pump is a cam-driven pump. For example, a plunger provided in a cylinder of the high-pressure pump is lifted by cam noses of a cam provided on an intake camshaft of the internal combustion engine. By so doing, the fuel supplied from the fuel tank is pressurized.

[0004] In addition, at the time of fuel injection, a fuel injection mode, such as a valve open duration of each fuel injection valve, is controlled on the basis of a fuel pressure in the high-pressure passage immediately before fuel injection. Here, for example, a cam having two cam noses is employed in the case of a four-cylinder internal combustion engine, and a cam having three cam noses is employed in the case of a six-cylinder internal combustion engine. Fluctuations in fuel pressure immediately before fuel injection reduce by carrying out fuel injection between a duration during which one cam nose is lifted by the plunger (hereinafter, lift duration) and a subsequent lift duration.

[0005] Incidentally, when a cam having three cam noses is also employed for, for example, a four-cylinder internal combustion engine as a cam that drives the high-pressure pump, it is possible to commonalize a cam between a four-cylinder internal combustion engine and a six-cylinder internal combustion engine. In this case, in the four-cylinder internal combustion engine, there occurs a situation that the lift duration of the plunger by any one of the cam noses overlaps with a period during which a fuel pressure is detected for fuel injection or a valve open duration of each fuel injection valve. That is, when an excessive amount of fuel is injected from that fuel injection valve, variations in fuel injection amount among the cylinders cannot be ignored. As a result, engine torque fluctuations increase, and engine vibrations cannot be ignored.

SUMMARY OF THE INVENTION

[0006] The invention provides an internal combustion engine control device, internal combustion engine control method and internal combustion engine that are able to appropriately reduce variations in fuel injection amount among cylinders when a lift duration of a plunger by any one of cam noses overlaps with an injection control period in any one of fuel injection valves.

[0007] A first aspect of the invention provides an internal combustion engine control device for an internal combustion engine that includes: a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, by lifting a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft; and fuel injection valves that are provided for corresponding cylinders and that inject and supply fuel, fed under pressure from the high-pressure pump through a high-pressure passage, into the corresponding cylinders. The internal combustion engine control device includes: a control unit that controls a mode in which fuel is injected by each of the fuel injection valves on the basis of a fuel pressure in the high-pressure passage in a period immediately before fuel injection, wherein the control unit executes pressure feed limiting control in which, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, feeding fuel under pressure by the high-pressure pump during the lift duration is limited.

[0008] With the above configuration, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, that is, the plunger is lifted in a period during which the fuel pressure is detected for fuel injection or a valve open duration of the fuel injection valve and, therefore, the fuel pressure does not change in a desired mode, feeding fuel under pressure by the high-pressure pump during the lift duration is limited. Therefore, it is possible to suppress an excessive amount of injected fuel when the injection control duration overlaps with the lift duration. Thus, it is possible to appropriately reduce variations in fuel injection amount among the cylinders when a lift duration of the plunger by any one of the cam noses overlaps with an injection control period in any one of the fuel injection valves.

[0009] In the above internal combustion engine control device, the control unit may stop feeding fuel under pressure by the high-pressure pump in the pressure feed limiting control.

[0010] With this configuration, it is possible to avoid an excessive amount of injected fuel when an injection control duration overlaps with a lift duration of the plunger by any one of the cam noses.

[0011] In the above internal combustion engine control device, the number of cylinders of the internal combustion engine may be not a natural number multiple of the cam noses.

[0012] With the above configuration, at least a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves. Specifically, for example, there are a four-cylinder internal combustion engine that includes a cam having three cam noses and a six-cylinder internal combustion engine that includes a cam having four cam noses. For example when a cam having three cam noses is employed for a four-cylinder internal combustion engine, it is possible to appropriately suppress variations in fuel injection amount among the cylinders by applying the invention. On the other hand, when the cam having three cam noses is employed for a six-cylinder internal combustion engine, existing high-pressure pump control just needs to be applied. Therefore, the common cam is employed for internal combustion engines having a different number of cylinders, while it is possible to appropriately suppress variations in fuel injection amount among the cylinders.

[0013] In the above internal combustion engine control device, the control unit may feed fuel under pressure by the high-pressure pump only during one lift duration, which does not overlap with any injection control durations in the fuel injection valves, among lift durations of the plunger by the plurality of cam noses in the pressure feed limiting control.

[0014] With the above configuration, when a feed amount of fuel under pressure in the one lift duration is increased as compared with that of a control configuration that feeds fuel under pressure during all the lift durations while the cam rotates one revolution, it is possible to appropriately suppress shortage of fuel at the time of each fuel injection.

[0015] In the above internal combustion engine control device, the control unit may limit feeding fuel under pressure by the high-pressure pump only during a lift duration, which overlaps with an injection control duration in any one of the fuel injection valves, among lift durations of the plunger by the plurality of cam noses in the pressure feed limiting control.

[0016] In the above internal combustion engine control device, the control unit may execute the pressure feed limiting control during low-load operation.

[0017] When there are large variations in fuel injection amount among the cylinders, engine torque fluctuations increase, so engine vibrations increase. Particularly, during low-load operation of the internal combustion engine in which the engine vibration level is low, such increasing of the engine vibrations cannot be ignored. Thus, by applying the above-described aspect during low-load operation, it is possible to appropriately suppress occurrence of such an inconvenience.

[0018] In addition, the amount of fuel injected by each fuel injection valve per injection is small during low-load operation of the internal combustion engine, so the width of decrease in fuel pressure per injection is small. Therefore, even when feeding fuel under pressure is limited by applying the above aspect and, therefore, the fuel pressure cannot be temporarily increased, it is possible to suppress occurrence of an inconvenience that injected fuel becomes insufficient by applying the above aspect as much as possible.

[0019] In the above internal combustion engine control device, the control unit may execute the pressure feed limiting control during idle operation. During idle operation of the internal combustion engine, a driver tends to experience discomfort from, particularly, engine vibrations. In this respect, with the above configuration, pressure feed limiting control is executed during idle operation, so it is possible to appropriately suppress occurrence of engine vibrations during idle operation.

[0020] In the above internal combustion engine control device, the control unit may execute the pressure feed limiting control when a fuel pressure in the high-pressure passage is a target fuel pressure.

[0021] In the above internal combustion engine control device, the control unit may set one lift duration at the time when the pressure feed limiting control is executed such that the one lift duration is longer than one lift duration at the time when the pressure feed limiting control is not executed.

[0022] A second aspect of the invention provides an internal combustion engine. The internal combustion engine includes: a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, by lifting a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft; fuel injection valves that are provided for corresponding cylinders and that inject and supply fuel, fed under pressure from the high-pressure pump through a high-pressure passage, into the corresponding cylinders; the cam of which the number of the cam noses is not a natural number multiple of the number of the cylinders of the internal combustion engine; and a drain mechanism that, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, drains fuel compressed by the plunger toward the fuel tank during the lift duration.

[0023] With the above configuration, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, fuel compressed by the plunger is drained toward the fuel tank through the drain mechanism. By so doing, feeding fuel under pressure by the high-pressure pump during the lift duration is limited. Therefore, it is possible to suppress an excessive amount of injected fuel when the injection control duration overlaps with the lift duration. Thus, it is possible to appropriately reduce variations in fuel injection amount among the cylinders when a lift duration of the plunger by any one of the cam noses overlaps with an injection control period in any one of the fuel injection valves.

[0024] A third aspect of the invention provides an internal combustion engine control method. The internal combustion engine control method includes: causing a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, to lift a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft; injecting and supplying fuel, fed under pressure from the high-pressure pump through a high-pressure passage, from fuel injection valves provided for corresponding cylinders; controlling a mode, in which fuel is injected by the fuel injection valves, on the basis of a fuel pressure in the high-pressure passage during a period immediately before fuel injection; and, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, limiting fuel pressure feed by the high-pressure pump during the lift duration.

[0025] The above internal combustion engine control method may further include, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, draining fuel compressed by the plunger toward the fuel tank during the lift duration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic view that shows the schematic configuration of a fuel supply system in an internal combustion engine and an internal combustion engine control device according to an embodiment of the invention;

FIG. 2 is a flowchart that shows the procedure of drive control over a high-pressure pump in the embodiment;

FIG. 3A is a timing chart that shows a change of an injection state of each fuel injection valve in the embodiment;

FIG. 3B is a timing chart that shows a change of a pressure feed state of the high-pressure pump during idle operation in the embodiment;

FIG. 3C is a timing chart that shows a change of a fuel pressure during idle operation in the embodiment;

FIG. 3D is a timing chart that shows a change of a pressure feed state of a high-pressure pump in a comparative embodiment to the embodiment; and

FIG. 3E is a timing chart that shows a change of a fuel pressure in the comparative embodiment to the embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0027] Hereinafter, an embodiment in which the internal combustion engine and the internal combustion engine control device according to the invention are respectively applied to a direct-injection in-line four-cylinder internal combustion engine and a control device therefor will be described with reference to FIG. 1 to FIG. 3E.

[0028] FIG. 1 shows the schematic configuration of a fuel supply system in an internal combustion engine according to the present embodiment. As shown in FIG. 1, in the fuel supply system of the internal combustion engine 1, an electric feed pump 3 is arranged in a fuel tank 2, and a low-pressure supply pipe 4 is connected to the feed pump 3. Fuel stored in the fuel tank 2 is drawn by the feed pump 3, pressurized up to a predetermined feed pressure (for example, several hundreds of kPa) and fed to the low-pressure supply pipe 4 under pressure. The feed pump 3 is a pump that is able to change its fuel discharge capacity. A return pipe 5 is connected in the middle of the low-pressure supply pipe 4 so as to form a branch path. A pressure regulating valve 6 is provided in the middle of the return pipe 5. When a fuel pressure in the low-pressure supply pipe 4 is higher than or equal to the feed pressure, the pressure regulating valve 6 opens. By so doing, part of fuel discharged from the feed pump 3 is returned to the fuel tank 2 via the return pipe 5, and the pressure of fuel in the low-pressure supply pipe 4 is kept at the feed pressure.

[0029] A high-pressure pump 10 is connected to the downstream side of the low-pressure supply pipe 4. An introducing passage 12, a cylinder 13 and a discharge passage 14 are formed inside a pump housing 11 of the high-pressure pump 10. The introducing passage 12 is connected to the downstream side of the low-pressure supply pipe 4. The cylinder 13 of the high-pressure pump 10 is connected to the downstream side of the introducing passage 12. The discharge passage 14 is connected to the downstream side of the cylinder 13 of the high-pressure pump 10.

[0030] An introducing port 21 is formed at an upstream-side end portion (upper end portion in FIG. 1) of the cylinder 13. The introducing port 21 draws low-pressure fuel from the feed pump 3. A discharge port 22 is formed at a side face (right side face in FIG. 1) of the cylinder 13. The discharge port 22 discharges fuel toward the discharge passage 14. A plunger 15 is provided in the cylinder 13 so as to be reciprocally movable. A pressure chamber 16 is defined by the inner wall of the cylinder 13 and the top face of the plunger 15. The discharge port 22 is in fluid communication with the pressure chamber 16.

[0031] A valve element 23 of a spill valve 20 is accommodated in the cylinder 13. The spill valve 20 opens or closes the introducing port 21. The valve element 23 is provided so as to be movable via a needle 23a along an axial direction of the needle 23a. The spill valve 20 is a so-called normally open valve, and the valve element 23 is constantly urged by the urging force of a spring 25 in a direction to open the introducing port 21. The needle 23a is attracted by energizing a solenoid 24, and the spill valve 20 closes the introducing port 21.

[0032] The plunger 15 is driven by the rotation of a crankshaft (not shown) that is an engine output shaft. Specifically, an intake camshaft 31 rotates with the rotation of the crankshaft, and the plunger 15 reciprocates inside the cylinder 13 as the plunger 15 is lifted by a cam 32 provided on the intake camshaft 31. The cam 32 has three cam noses 32a that radially protrude from a base circle 32b. These cam noses 32a have mutually the same shape, and the cam noses 32a are provided at equal angular intervals in the circumferential direction. A lifter 17 is provided below the plunger 15, and the lifter 17 is kept in a state where the lifter 17 is in contact with a cam face of the cam 32 by the urging force of the spring 18.

[0033] In the high-pressure pump 10, when supply of current to the solenoid 24 is stopped at the time when the plunger 15 moves downward and the volume of the pressure chamber 16 increases, the introducing port 21 is opened and fuel is drawn from the introducing passage 12 into the pressure chamber 16.

[0034] When current is supplied to the solenoid 24 at the time when the plunger 15 moves upward and the volume of the pressure chamber 16 reduces, the introducing port 21 is closed, fuel in the pressure chamber 16 is pressurized and is discharged from the discharge port 22 to the discharge passage 14.

[0035] By adjusting a duration during which current is supplied to the solenoid

24, that is, a duration during which the introducing port 21 is closed, it is possible to adjust the amount of fuel drawn into the pressure chamber 16. A discharge valve 19 is provided in the middle of the discharge passage 14. When the fuel pressure applied from the pressure chamber 16 to the discharge valve 19 is higher than or equal to a predetermined discharge pressure, the discharge valve 19 opens. By so doing, fuel is allowed to be fed under pressure toward fuel injection valves 9.

[0036] The discharge passage 14 is provided with a relief passage 26 that bypasses the discharge valve 19. An orifice portion 27 is provided in the middle of the relief passage 26. A high-pressure supply pipe 7 is connected to the downstream side of the discharge passage 14 in the pump housing 11, and a delivery pipe 8 is connected to the downstream side of the high-pressure supply pipe 7. The fuel injection valves 9 are connected to the delivery pipe 8. The fuel injection valves 9 are used to inject and supply fuel into the corresponding cylinders of the internal combustion engine. Drive control over the fuel injection valves 9 is executed by an electronic control unit 40.

[0037] Such various controls over the internal combustion engine 1 are executed by the electronic control unit 40. The electronic control unit 40 is formed of a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), and the like. The CPU executes arithmetic processings related to various controls. The ROM stores programs and data for various controls. The RAM temporarily stores results of arithmetic processings, and the like. The electronic control unit 40 loads signals detected by various sensors, executes various arithmetic processings, and comprehensively controls the internal combustion engine 1 on the basis of the results.

[0038] The various sensors include a crank angle sensor, a cam angle sensor, an air flow meter, a throttle sensor, a coolant temperature sensor, and the like. The crank angle sensor detects a rotational phase of the crankshaft. The cam angle sensor detects a rotational phase of the intake camshaft. The air flow meter detects an intake air flow rate. The throttle sensor detects a throttle opening degree. The coolant temperature sensor detects the temperature of engine coolant. In addition, a fuel pressure sensor 41 is provided. The fuel pressure sensor 41 detects a fuel pressure Pr in the delivery pipe 8.

An accelerator sensor, a brake sensor, a vehicle speed sensor, and the like, are provided. The accelerator sensor detects an accelerator operation amount. The brake sensor detects a brake operation amount. The vehicle speed sensor detects a vehicle speed that is a travel speed of the vehicle. These various sensors are electrically connected to the electronic control unit 40.

[0039] The electronic control unit 40 controls an injection mode, such as the valve open duration of each fuel injection valve 9, on the basis of the fuel pressure Pr in the delivery pipe 8 in a period immediately before fuel injection. That is, when the valve open duration of each fuel injection valve 9 is constant, the amount of fuel actually injected from each fuel injection valve 9 increases as the fuel pressure Pr in the delivery pipe 8 increases. Thus, the valve open duration of each fuel injection valve 9 is set to be shorter as the fuel pressure Pr in the delivery pipe 8 increases such that a set fuel injection amount is injected.

[0040] In the present embodiment, by providing the camshaft 31 that has the cam 32 having the three cam noses 32a for the four-cylinder internal combustion engine 1, it is possible to utilize the cam 32 used in a six-cylinder internal combustion engine. That is, the cam 32 is commonalized between the four-cylinder internal combustion engine 1 and the six-cylinder internal combustion engine.

[0041] In this case, as described above, in the four-cylinder internal combustion engine 1, there occurs a situation that a period during which the fuel pressure Pr is detected for fuel injection and the valve open duration of any one of the fuel injection valves 9 (hereinafter, an injection control duration in any one of the fuel injection valves 9) overlap with a lift duration of the plunger 15 (hereinafter, simply referred to as lift duration) by any one of the cam noses 32a of the cam 32. Here, a lift duration is a duration during which the volume of the pressure chamber 16 reduces as the plunger 15 is lifted, and is a duration during which fuel in the pressure chamber 16 is discharged to the discharge passage 14 when current is supplied to the solenoid 24 during the lift duration. Therefore, when an excessive amount of fuel is injected from the fuel injection valve 9, variations in fuel injection amount occur among the cylinders cannot be ignored. As a result, engine torque fluctuations increase, and engine vibrations may not be ignored, particularly, during idle operation in which the engine vibration level is low.

[0042] In the present embodiment, when a lift duration overlaps with the injection control duration in any one of the fuel injection valves 9, the electronic control unit 40 executes pressure feed limiting control in which feeding fuel under pressure by the high-pressure pump 10 during the lift duration is stopped by opening the spill valve 20. Specifically, in the pressure feed limiting control, fuel is fed under pressure by the high-pressure pump 10 only during one lift duration that does not overlap with any injection control durations in the fuel injection valves 9 among the three lift durations during one revolution of the cam 32. By so doing, occurrence of the above-described inconvenience is suppressed.

[0043] Next, drive control over the high-pressure pump 10 in the present embodiment will be described with reference to FIG. 2. FIG. 2 shows the procedure of drive control over the high-pressure pump 10. The series of processes are repeatedly executed at each predetermined crank angle (°CA) during engine operation.

[0044] As shown in FIG. 2, in the series of processes, first, it is determined in step S1 whether the internal combustion engine 1 is in an idle operation state. When it is determined that the internal combustion engine 1 is not in the idle operation state (NO in step S1), the process subsequently proceeds to step S2. In step S2, a driving duty of the spill valve 20 is calculated such that fuel is fed under pressure during all the lift durations (in this case, three lift durations) while the cam 32 rotates one revolution. Subsequently, the process proceeds to step S6, and energization control over the solenoid 24 is executed on the basis of the driving duty calculated in step S2. Then, the series of processes once end.

[0045] On the other hand, when it is determined in step S1 that the internal combustion engine 1 is in the idle operation state (YES in step S1), the process proceeds to step S3. In step S3, it is determined whether the fuel pressure Pr is a target fuel pressure. The target fuel pressure is set to a value at which, when fuel is fed under pressure by the high-pressure pump 10 only during the above-described one lift duration while the cam 32 rotates one revolution, a fuel pressure required for fuel injection at the last timing after the fuel has been fed under pressure can be ensured, and is preset through an experiment, or the like. When it is determined that the fuel pressure Pr is not the target fuel pressure (NO in step S3), the process sequentially proceeds to step S2 and step S6, and energization control over the solenoid 24 is executed, after which the series of processes once end.

[0046] On the other hand, when it is determined in step S3 that the fuel pressure Pr is the target fuel pressure (YES in step S3), the process proceeds to step S4. In step S4, a lift duration during which feeding fuel under pressure is stopped (hereinafter, pressure feed stop lift duration) is derived. Subsequently, the process proceeds to step S5, and the driving duty of the spill valve 20 is calculated such that feeding fuel under pressure is stopped during the derived pressure feed stop lift duration and fuel is fed under pressure during the other lift durations. After that, the process proceeds to step S6, and energization control over the solenoid 24 is executed, after which the series of processes once end. That is, pressure feed limiting control is executed when the fuel pressure in the high-pressure passage is the target fuel pressure.

[0047] Next, the operation in the present embodiment will be described with reference to FIG. 3A to FIG. 3E. FIG. 3A shows a change of an injection state of each fuel injection valve. FIG. 3B shows a change of a pressure feed state of the high-pressure pump 10 during idle operation. FIG. 3C shows a change of a fuel pressure Pr during idle operation. FIG. 3D shows a change of a pressure feed state of the high-pressure pump 10 in a comparative embodiment. FIG. 3E shows a change of a fuel pressure Pr in the comparative embodiment. In FIG. 3A to FIG. 3E, the abscissa axis represents a crank angle (°CA).

[0048] As shown in FIG. 3A, the internal combustion engine 1 according to the present embodiment has four cylinders, so fuel is injected by the fuel injection valves at intervals of 180°CA. That is, in this case, fuel is injected into the fourth cylinder (#4) at 30°CA, and fuel is injected into the second cylinder (#2) at 210°CA. After that, fuel is injected into the first cylinder (#1) at 390°CA, and fuel is injected into the third cylinder

(#3) at 570°CA.

[0049] In the comparative embodiment, fuel is fed under pressure during all the lift durations while the cam 32 rotates one revolution. As shown by the comparative embodiment in FIG. 3D and FIG. 3E, fuel is fed under pressure by closing the spill valve 20 during a period from about -30°CA (690°CA) to 0°CA, a period from about 210°CA to 240°CA and a period from about 450°CA to 480°CA.

[0050] As shown by the comparative embodiment in FIG. 3E, during the period from about -30°CA (690°CA) to 0°CA, the fuel pressure Pr is increased by feeding fuel under pressure, and, at following 30°CA, the fuel pressure Pr is decreased by opening the fuel injection valve 9.

[0051] During the period from about 210°CA to 240°CA, the lift duration (also the pressure feed duration in the present embodiment) overlaps with the injection control duration of the fuel injection valve 9 (the period during which the fuel pressure Pr is detected, the valve open duration of the fuel injection valve 9), so, as shown in FIG. 3E, the fuel pressure Pr increases although the fuel injection valve 9 is opened. Thus, an excessive amount of fuel is injected from the opened fuel injection valve 9.

[0052] When the fuel injection valve 9 is opened at following 390°CA in FIG. 3E, the fuel pressure Pr decreases. Then, fuel is fed under pressure during the period from about 450°CA to 480°CA, so the fuel pressure Pr increases. The fuel injection valve 9 is opened at following 570°CA, so the fuel pressure Pr decreases.

[0053] In contrast to this, in the present embodiment, as also shown in FIG. 3B and FIG. 3C, only during a period from about -90°CA to 0°CA (that is, from 630°CA to 720°CA), the spill valve 20 is closed, and fuel is fed under pressure. By so doing, the fuel pressure Pr increases, the fuel injection valve 9 is opened at 30°CA after fuel is fed under pressure, and then the fuel pressure Pr decreases.

[0054] In the period from about 210°CA to 240°CA, different from the above-described comparative embodiment, the spill valve 20 is opened, so fuel compressed by the plunger 15 is drained toward the fuel tank 2 through the introducing port 21. In this way, when a lift duration overlaps with an injection control duration in any one of the fuel injection valves 9, that is, the plunger 15 is lifted in a period in which the fuel pressure Pr is detected for fuel injection or a valve open duration of any one of the fuel injection valves 9 and, therefore, the fuel pressure Pr does not change in a desired mode, feeding fuel under pressure by the high-pressure pump 10 during the lift duration is stopped. Therefore, it is possible to avoid an excessive amount of injected fuel when the injection control duration overlaps with the lift duration.

[0055] In the period from about 450°CA to 480°CA, feeding fuel under pressure is stopped through drive control over the spill valve 20 in the present embodiment, while fuel is fed under pressure in this period in the above-described comparative embodiment. In the present embodiment, the duration during which the spill valve 20 is closed in order to feed fuel under pressure (duration from about -90°CA to 0°CA) is about three times as long as the duration (from about -30°CA (690°CA) to 0°CA) in the above-described comparative embodiment. That is, one lift duration at the time when pressure feed limiting control is executed is set so as to be longer than one lift duration at the time when no pressure feed limiting control is executed. This is because the amount of fuel fed under pressure once is increased and, by so doing, shortage of fuel at the time of each following fuel injection is appropriately suppressed.

[0056] The spill valve 20 in the present embodiment functions as a drain mechanism according to the invention. With the above-described internal combustion engine control device and internal combustion engine according to the present embodiment, the following operations and advantageous effects are obtained.

[0057] The internal combustion engine 1 includes the high-pressure pump 10 that pressurizes and discharges fuel, supplied from the fuel tank 2, by lifting the plunger 15 with the use of the three cam noses 32a of the cam 32 of the intake camshaft 31. The internal combustion engine 1 includes the fuel injection valves 9 respectively provided in the four cylinders. The fuel injection valves 9 inject and supply fuel, fed under pressure from the high-pressure pump 10 through the high-pressure passage (the discharge passage 14, the high-pressure supply pipe 7 and the delivery pipe 8), into the corresponding cylinders. That is, the number of cylinders "4" of the internal combustion engine 1 is not a natural number multiple of the number of the cam noses 32a "3". The electronic control unit 40 controls a mode in which fuel is injected by each fuel injection valve 9 on the basis of the fuel pressure Pr in the delivery pipe 8 in a period immediately before fuel injection. When a lift duration of the plunger 15 by the cam 32 overlaps with an injection control duration in any one of the fuel injection valves 9, the electronic control unit 40 executes pressure feed limiting control in which feeding fuel under pressure by the high-pressure pump 10 during the lift duration is stopped by opening the spill valve 20. Specifically, in the pressure feed limiting control, fuel is fed under pressure by the high-pressure pump 10 only during one lift duration that does not overlap with any injection control durations in the fuel injection valves 9 among the lift durations of the plunger 15 by the three cam noses 32a.

[0058] With the above configuration, when a lift duration of the plunger 15 by the cam 32 overlaps with an injection control duration in any one of the fuel injection valves 9, it is possible to appropriately reduce variations in fuel injection amount among the cylinders.

[0059] With the above configuration, when the cam 32 having the three cam noses 32a is employed in the four-cylinder internal combustion engine 1 as well, it is possible to appropriately suppress variations in fuel injection amount among the cylinders. When the cam 32 having the three cam noses 32a is employed in the six-cylinder internal combustion engine, existing high-pressure pump control may be applied. Therefore, the common cam 32 is allowed to be employed for internal combustion engines having a different number of cylinders, while it is possible to appropriately suppress variations in fuel injection amount among the cylinders.

[0060] The electronic control unit 40 executes pressure feed limiting control during idle operation. When there are large variations in fuel injection amount among the cylinders, engine torque fluctuations increase, so engine vibrations increase. Particularly, during idle operation of the internal combustion engine 1 in which the engine vibration level is low, such increasing of the engine vibrations cannot be ignored. Thus, by executing the above-described pressure feed limiting control during idle operation, it is possible to appropriately suppress occurrence of such an inconvenience.

[0061] The amount of fuel injected by each fuel injection valve 9 per injection is small during idle operation of the internal combustion engine 1, so the width of decrease in fuel pressure per injection is small. Therefore, even when feeding fuel under pressure is limited through pressure feed limiting control and, therefore, the fuel pressure cannot be temporarily increased, it is possible to suppress occurrence of an inconvenience that injected fuel becomes insufficient through pressure feed limiting control as much as possible.

[0062] The internal combustion engine control device and the internal combustion engine according to the invention are not limited to the configuration illustrated in the above-described embodiment, but they may be, for example, modified into the following alternative embodiments as needed.

[0063] In the above-described embodiment, the above-described pressure feed limiting control is executed during idle operation; instead, pressure feed limiting control may be executed during low-load operation other than during idle operation. In the above-described embodiment, fuel is fed under pressure by the high-pressure pump 10 only during one lift duration that does not overlap with any injection control durations in the fuel injection valves 9 among the lift durations of the plunger 15 by the three cam noses 32a. The mode in which pressure feed limiting control is executed according to the invention is not limited to this configuration. It is also applicable that feeding fuel under pressure by the high-pressure pump 10 is limited only during a lift duration that overlaps with an injection control duration in any one of the fuel injection valves 9 (period from about 210°CA to 240°CA in the above-described embodiment) among the lift durations of the plunger 15 by the three cam noses 32a.

[0064] In the above-described embodiment, the four-cylinder internal combustion engine 1 that includes the cam 32 having the three cam noses 32a is illustrated; however, the internal combustion engine according to the invention is not limited to this configuration. For example, it is also applicable that a six-cylinder internal combustion engine includes a cam having four cam noses. In this case, the number of cylinders "6" of the internal combustion engine is not a natural number multiple of the number of the cam noses "4", and at least a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves. By applying the invention to the thus configured internal combustion engine, it is possible to appropriately suppress variations in fuel injection amount among the cylinders.

[0065] In the above-described embodiment, feeding fuel under pressure by the high-pressure pump 10 is stopped in pressure feed limiting control; however, the pressure feed limiting control according to the invention is not always limited to the configuration that feeding fuel under pressure is stopped. That is, for example, when a lift duration overlaps with an injection control duration in any one of the fuel injection valves, the amount of fuel fed under pressure by the high-pressure pump is reduced as compared with the case where a lift duration does not overlap with any injection control durations. Thus, feeding fuel under pressure just needs to be limited.

CLAIMS:

1. An internal combustion engine control device for an internal combustion engine that includes: a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, by lifting a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft; and fuel injection valves that are provided for corresponding cylinders and that inject and supply fuel, fed under pressure from the high-pressure pump through a high-pressure passage, into the corresponding cylinders, comprising:

a control unit that controls a mode in which fuel is injected by each of the fuel injection valves on the basis of a fuel pressure in the high-pressure passage in a period immediately before fuel injection, wherein

the control unit executes pressure feed limiting control in which, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, feeding fuel under pressure by the high-pressure pump during the lift duration is limited.

2. The internal combustion engine control device according to claim 1, wherein

the control unit stops feeding fuel under pressure by the high-pressure pump in the pressure feed limiting control.

3. The internal combustion engine control device according to claim 1 or 2, wherein

the number of the cylinders of the internal combustion engine is not a natural number multiple of the number of the cam noses.

4. The internal combustion engine control device according to any one of claims 1 to 3, wherein

the control unit feeds fuel under pressure by the high-pressure pump only during one lift duration, which does not overlap with any injection control durations in the fuel injection valves, among lift durations of the plunger by the plurality of cam noses in the pressure feed limiting control.

5. The internal combustion engine control device according to any one of claims 1 to 3, wherein

the control unit limits feeding fuel under pressure by the high-pressure pump only during a lift duration, which overlaps with an injection control duration in any one of the fuel injection valves, among lift durations of the plunger by the plurality of cam noses in the pressure feed limiting control.

6. The internal combustion engine control device according to any one of claims 1 to 5, wherein

the control unit executes the pressure feed limiting control during low-load operation.

7. The internal combustion engine control device according to claim 6, wherein

the control unit executes the pressure feed limiting control during idle operation.

8. The internal combustion engine control device according to any one of claims 1 to 7, wherein

the control unit executes the pressure feed limiting control when a fuel pressure in the high-pressure passage is a target fuel pressure.

9. The internal combustion engine control device according to any one of claims 1 to 8, wherein

the control unit sets one lift duration at the time when the pressure feed limiting control is executed such that the one lift duration is longer than one lift duration at the time when the pressure feed limiting control is not executed.

10. An internal combustion engine comprising:

a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, by lifting a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft;

fuel injection valves that are provided for corresponding cylinders and that inject and supply fuel, fed under pressure from the high-pressure pump through a high-pressure passage, into the corresponding cylinders;

the cam of which the number of the cam noses is not a natural number multiple of the number of the cylinders of the internal combustion engine; and

a drain mechanism that, when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, drains fuel compressed by the plunger toward the fuel tank during the lift duration.

11. An internal combustion engine control method comprising:

causing a high-pressure pump that pressurizes and discharges fuel, supplied from a fuel tank, to lift a plunger with the use of a plurality of cam noses of a cam that rotates with rotation of an engine output shaft;

injecting and supplying fuel, fed under pressure from the high-pressure pump through a high-pressure passage, from fuel injection valves provided for corresponding cylinders;

controlling a mode, in which fuel is injected by the fuel injection valves, on the basis of a fuel pressure in the high-pressure passage during a period immediately before fuel injection; and

when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, limiting feeding fuel under pressure by the high-pressure pump during the lift duration.

12. The internal combustion engine control method according to claim 11, further comprising:

when a lift duration of the plunger by any one of the cam noses overlaps with an injection control duration in any one of the fuel injection valves, draining fuel compressed by the plunger toward the fuel tank during the lift duration.

FIG. 1

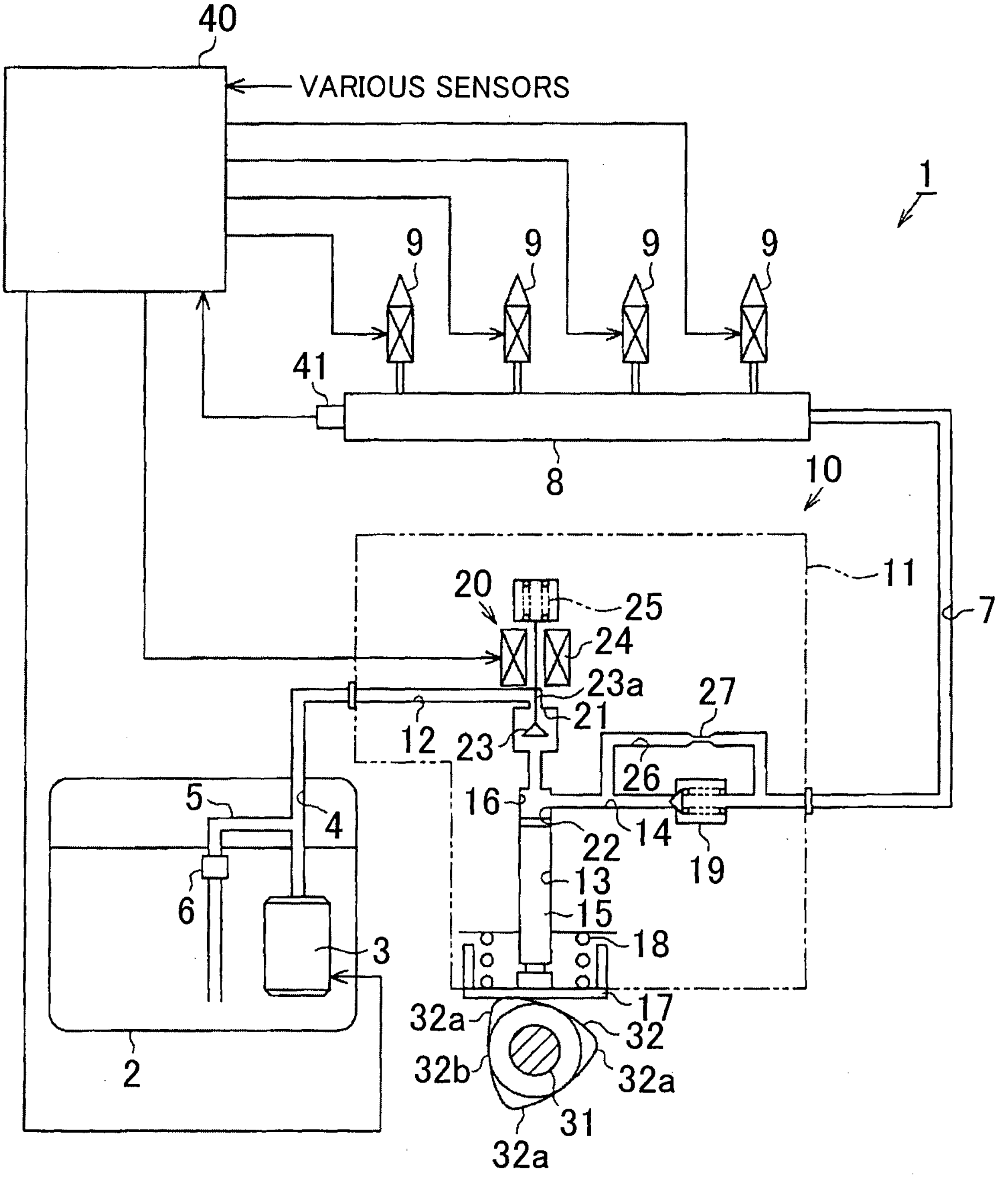
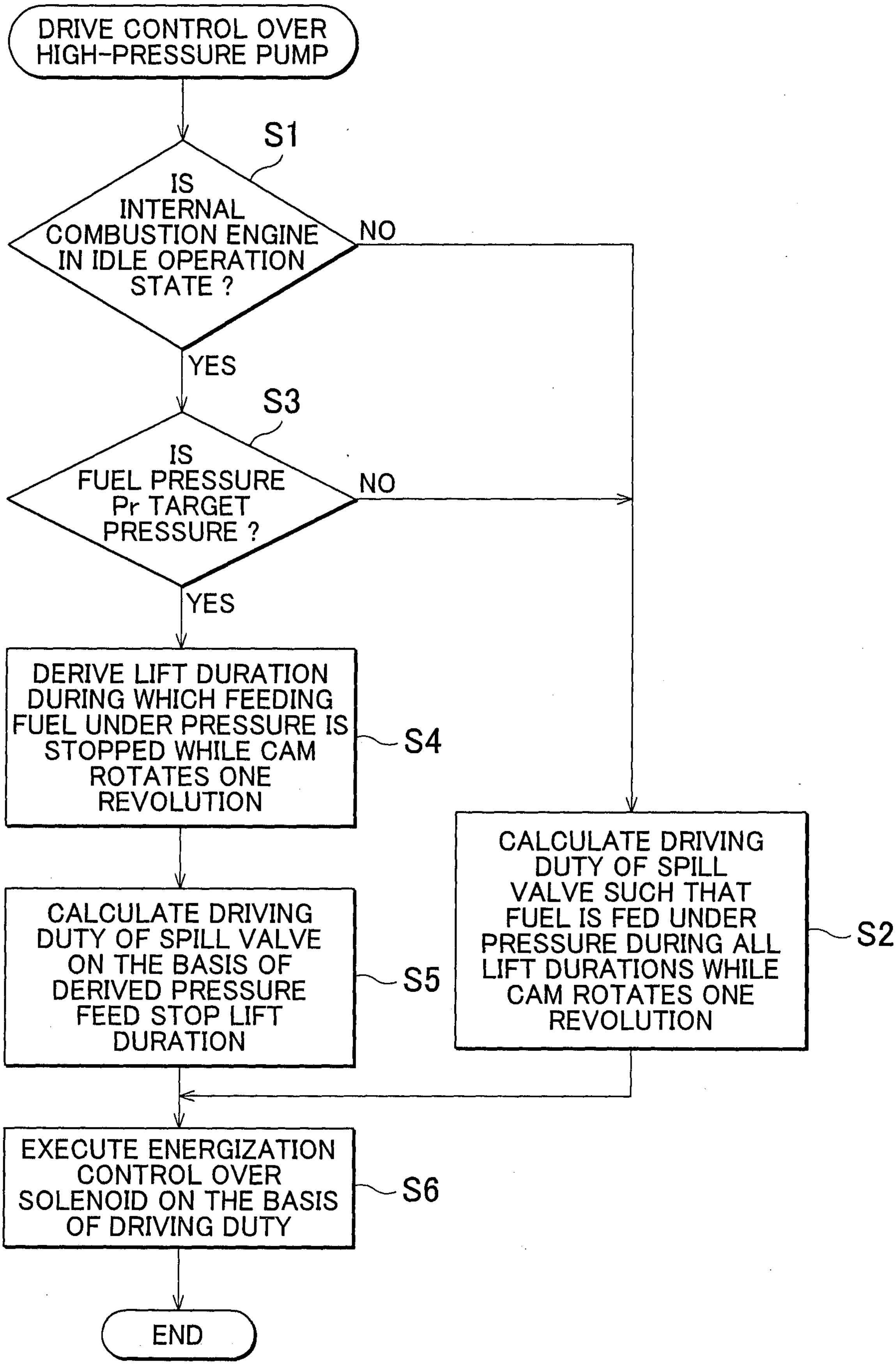

40
VARIOUS SENSORS
1
9
9
9
9
41
8
10
11
20
25
24
23a
27
21
12
23
26
5
16
4
14
22
19
13
6
15
3
18
17
32a
32
32b
32a
2
31
32a
7

FIG. 2


DRIVE CONTROL OVER HIGH-PRESSURE PUMP
S1
IS INTERNAL COMBUSTION ENGINE IN IDLE OPERATION STATE ?
NO
YES
S3
IS FUEL PRESSURE Pr TARGET PRESSURE ?
NO
YES
DERIVE LIFT DURATION DURING WHICH FEEDING FUEL UNDER PRESSURE IS STOPPED WHILE CAM ROTATES ONE REVOLUTION
S4
CALCULATE DRIVING DUTY OF SPILL VALVE SUCH THAT FUEL IS FED UNDER PRESSURE DURING ALL LIFT DURATIONS WHILE CAM ROTATES ONE REVOLUTION
S2
CALCULATE DRIVING DUTY OF SPILL VALVE ON THE BASIS OF DERIVED PRESSURE FEED STOP LIFT DURATION
S5
EXECUTE ENERGIZATION CONTROL OVER SOLENOID ON THE BASIS OF DRIVING DUTY
S6
END

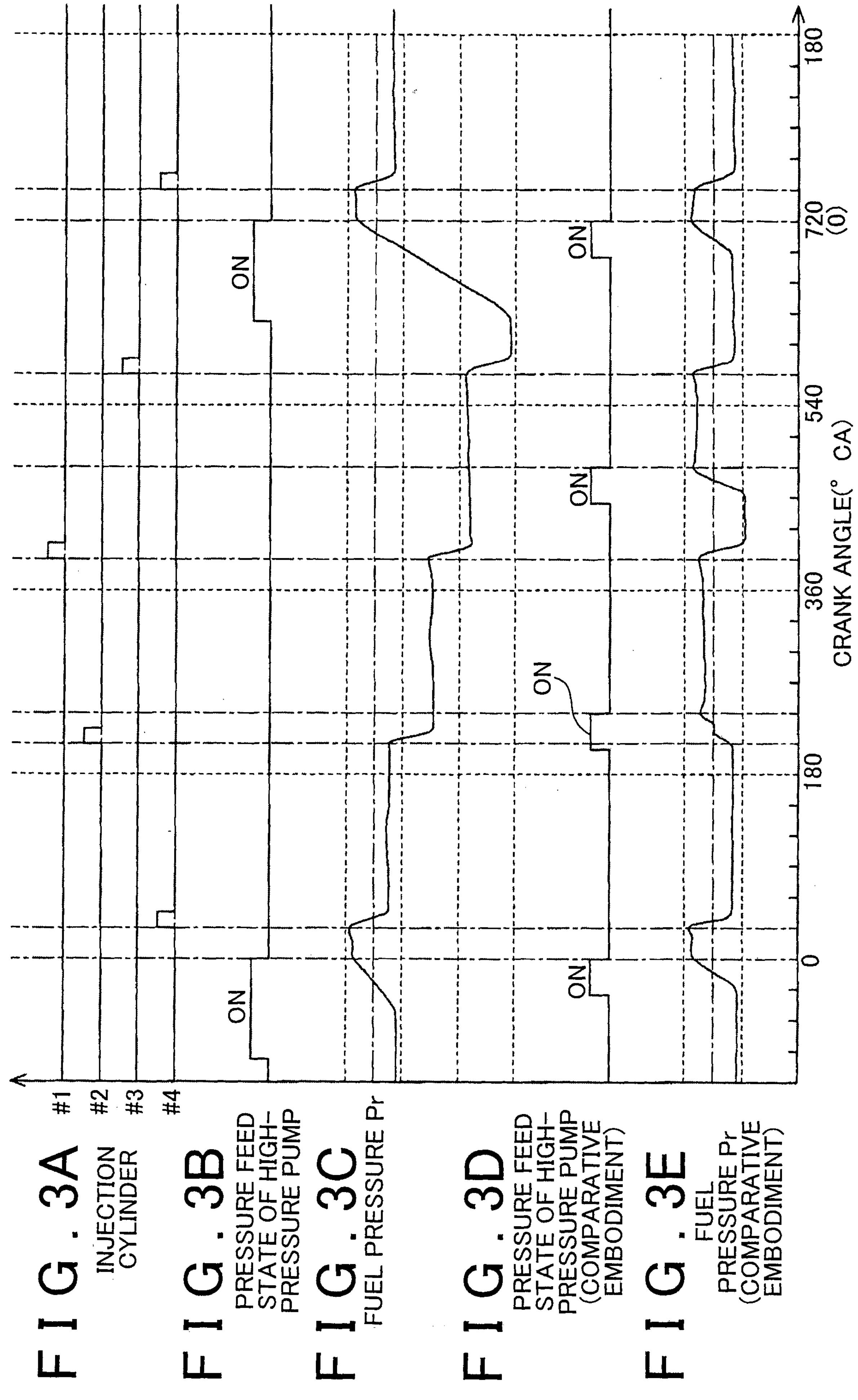


FIG. 3A
INJECTION CYLINDER
#1
#2
#3
#4
FIG. 3B
PRESSURE FEED STATE OF HIGH-PRESSURE PUMP
ON
FIG. 3C
FUEL PRESSURE Pr
FIG. 3D
PRESSURE FEED STATE OF HIGH-PRESSURE PUMP (COMPARATIVE EMBODIMENT)
ON
FIG. 3E
FUEL PRESSURE Pr (COMPARATIVE EMBODIMENT)
0
180
360
540
720 (0)
180
CRANK ANGLE(° CA)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/002003

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/38
ADD.

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)
F02D

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/111409 A1 (TOYOTA MOTOR CO LTD [JP]; KOJIMA SUSUMU [JP]; TOMODA TERUTOSHI [JP]) 24 November 2005 (2005-11-24) page 3, line 13 - line 23 page 4, line 3 - line 7 -----	1-12
X	US 5 526 790 A (AUGUSTIN ULRICH [DE] ET AL) 18 June 1996 (1996-06-18) column 1, line 30 - line 44 column 1, line 47 - line 64 -----	1-12

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" 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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 February 2013	15/02/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/002003

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