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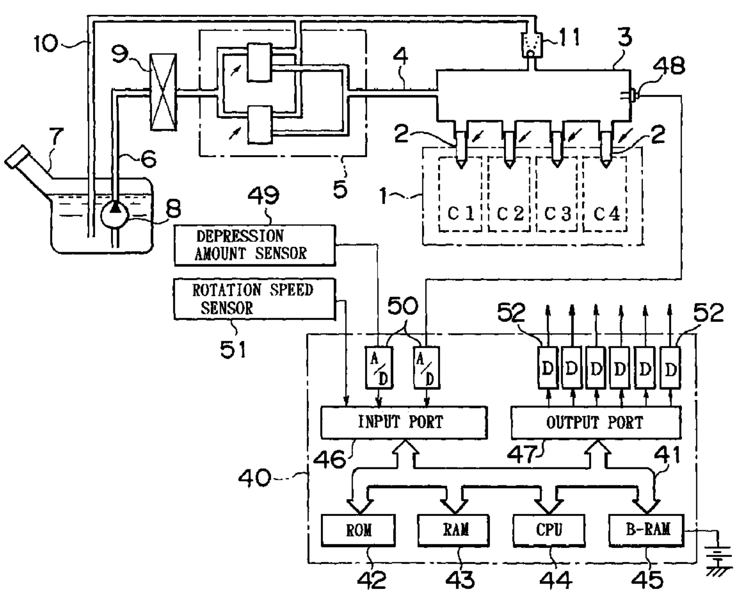
(54) Accumulator-type fuel injection apparatus and control method for the same

(57) An accumulator-type fuel injection apparatus has a plurality of fuel injection valves for corresponding individual cylinders of an engine. The fuel injection valves (2) are connected to a common pressure-accumulator chamber (3) that is connected to an ejection side of a fuel pump (5). Fuel is pumped from the fuel pump (5) into the pressure-accumulator chamber (3) and then supplied into the cylinders via the corresponding fuel injection valves (2). The fuel pumping timing of the fuel pump is set relative to the fuel injection timing so that a variation in fuel pressure in the pressure-accumulating chamber (3) at the time of start of a fuel injecting operation is smaller than a predetermined set value.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The present invention relates to an accumulator-type fuel injection apparatus equipped with an accumulator connected to a fuel injection valve, and a control method for the accumulator-type fuel injection apparatus.

2. Description of Related Art

[0002] In known accumulator-type fuel injection apparatuses, the fuel injection valves for the cylinders of an internal combustion engine are connected to a common pressure accumulator (pressure-accumulating chamber), and a fuel pump is connected at its ejection side to the accumulator. Fuel is pumped into the accumulator by the fuel pump, and then supplied from the accumulator to each cylinder via the corresponding fuel injection valve.

[0003] Normally, the fuel injection duration is set to the same value for all the fuel injection valves. Therefore, in order to reduce the variations in the amount of fuel supplied to the individual cylinders, it is necessary to reduce the variations in the fuel injection pressure, that is, the fuel pressure in the accumulator at the time of start of each fuel injecting operation.

[0004] The fuel pressure in the accumulator decreases when fuel injection is performed, and it increases when fuel pumping is performed. There is an accumulator-type fuel injection apparatus in JP-A-5-106495 that minimizes the variations in fuel injection pressure by causing the fuel pump to pump out fuel every time fuel injection is performed.

[0005] However, in order to perform fuel pumping every time fuel injection is performed, the fuel pump is required to be equipped with a plunger for every cylinder. Therefore, problems of an increased size of the fuel pump and an increased cost of the apparatus result may occur, The number of plungers can be reduced by increasing the operating speed, e.g., rotation speed, of the fuel pump or by increasing the number of fuel pumping operations per rotation of the fuel pump. However, such a measure reduces the durability of the fuel pump.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the invention to provide an accumulator-type fuel injection apparatus that reduces the variation in the fuel pressure in an accumulator at the starting time of each fuel injecting operation without a need to pump fuel from a fuel pump every time fuel is injected into a cylinder, It is also an object of the invention to provide a control method for the accumulator-type fuel injection apparatus.

[0007] The above object is solved by combination of features of the main claim, the sub-claim disclose further advantageous embodiments of the invention.

[0008] According to the invention, there is provided an accumulator-type fuel injection apparatus having a pressure-accumulating chamber that is connected to a plurality of fuel injection valves corresponding to cylinders of an engine, wherein fuel is supplied from the pressure-accumulating chamber into the cylinders via the corresponding fuel injection valves, The apparatus includes a fuel pump that pumps fuel into the pressure-accumulating chamber. The apparatus also includes a device for controlling the fuel pump so that fuel is pumped to the pressure-accumulating chamber during an earlier fuel injecting operation of at least two consecutive fuel injecting operations, instead of during fuel injecting operations for all the cylinders.

[0009] Since the pumping of fuel is performed during an earlier fuel injecting operation of at least two consecutive fuel injecting operations, rather than during the fuel injecting operations for all the cylinders, a minimum size of the fuel pump and a minimum cost thereof can be achieved while securing good durability of the fuel pump. Furthermore, by adjusting the fuel pumping timing of the fuel pump relative to the fuel injecting timing, the variation in the fuel injection pressure can be reduced.

[0010] This summary of the invention does not necessarily describe all necessary features so that the invention may also reside in a sub-combination of these described features.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing and further objects, features and advantages of the present invention will become apparent from the following description of a preferred embodiment with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

Fig. 1 is a schematic view of an internal combustion engine including an accumulator-type fuel injection apparatus, according to the invention;
Fig. 2 is a sectional view of a fuel pump used in the accumulator-type fuel injection apparatus shown in Fig. 1;
Fig. 3 is a time chart illustrating an example of an undesirable setting of fuel pumping timing; and
Fig. 4 is a time chart illustrating an example of a setting of fuel pumping timing for the accumulator-type fuel injection apparatus shown in Fig. 1, according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0012] A preferred embodiment of the present invention will be described in detail hereinafter with reference to the accompanying drawings.

[0013] Referring to Fig. 1, an internal combustion engine 1 has, for example, four cylinders C1, C2, C3, C4. Each cylinder of the engine 1 is provided with a fuel injection valve 2 that injects fuel directly into a combustion chamber defined in each cylinder. Each fuel injection valve 2 is formed by an electromagnetic fuel injection valve and is controlled in accordance with an output signal from an electronic control unit 40. In this embodiment, fuel injection into the cylinders C1-C4 is performed in the order of C1-C3-C4-C2.

[0014] Fuel passages connected to the fuel injection valves 2 are connected to a common pressure accumulator, that is, a common rail 3. The common rail 3 is connected to an ejection side of a fuel pump 5 by a high-pressure pipe 4. A suction-side of the fuel pump 5 is connected by a low-pressure pipe 6 to a feed pump 8 disposed in a fuel tank 7. A fuel filter 9 is disposed in the low-pressure pipe 6. The common rail 3 and the fuel tank 7 are also interconnected by a return pipe 10 in which a check valve 11 is disposed so as to allow fuel to flow only in the direction from the common rail 3 toward the fuel tank 7. The check valve 11 normally remains closed. When the fuel pressure in the common rail 3 becomes excessively high, the check valve 11 opens to reduce the fuel pressure in the common rail 3.

[0015] The fuel pump 5 is formed by an engine-driven in-line pump equipped with a pair of plungers, that is, first and second plungers. Referring to Fig. 2, which only illustrates the first plunger 22 for exemplary purposes, the plunger 22 is slidably disposed in a plunger insert hole 21 formed in a housing 20. The plunger 22 is driven by a cam 23 that has only one cam nose. A high-pressure chamber 24 is defined in the insert hole 21 by the plunger 22 and communicates with a low-pressure chamber 25 via a communication hole 26. The communication hole 26 is opened and closed by a fuel control valve 27 that is controlled by a solenoid coil 28. The high-pressure chamber 24 is connected to the high-pressure pipe 4 by a high-pressure passage 29. A check valve 30 is disposed in the fuel injection valve 2 so as to allow fuel flow only in a direction from the high-pressure chamber 24 toward the high-pressure pipe 4. The low-pressure chamber 25 is connected at one side thereof to the low-pressure pipe 6 by a low-pressure passage 31, and at another side thereof to the return pipe 10 by a return passage 32. A check valve 33 is disposed in the return passage 32 so as to allow fuel flow only in a direction from the low-pressure chamber 25 toward the return pipe 10. The solenoid coil 28 is controlled in accordance with an output signal from the electronic control unit 40.

[0016] When the solenoid coil 28 is energized, the fuel control valve 27 is raised, so that the fuel control valve 27 closes the communication hole 26. When the solenoid coil 28 is de-energized, the fuel control valve 27 is lowered by a compression spring 34, so that the fuel control valve 27 opens the communication hole 26.

[0017] When the plunger 22 starts to descend, fuel flows from the low-pressure chamber 25 into the high-pressure chamber 24 through the communication hole 26 since the fuel control valve 27 is open. When the plunger 22 starts to ascend after reaching bottom dead center, a pumping stroke starts. The fuel control valve 27 is kept in a lowered position for a predetermined time after the pumping stroke has started so that a certain amount of fuel returns from the high-pressure chamber 24 into the low-pressure chamber 25 through the communication hole 26. Subsequently, the fuel control valve 27 is raised, thereby closing the communication hole 26, to start pumping fuel from the high-pressure chamber 24 toward the common rail 3 through the high-pressure passage 29 and the high-pressure pipe 4. When the plunger 22 reaches top dead center, fuel pumping ends and, at this time point, the fuel control valve 27 is lowered again.

[0018] When the amount of fuel pumped from the fuel pump 5 toward the common rail 3 needs to be reduced, the lowering timing of the fuel control valve 27 is delayed. As a result, the amount of fuel that returns from the high-pressure chamber 24 to the low-pressure chamber 25 increases and, after a predetermined time, the amount of fuel pumped out of the high-pressure chamber 24 decreases. When the amount of fuel pumped from the fuel pump 5 toward the common rail 3 needs to be increased, the lowering timing of the fuel control valve 27 is advanced, As a result, the amount of fuel that returns from the high-pressure chamber 24 to the low-pressure chamber 25 decreases and, after some time, the amount of fuel pumped out of the high-pressure chamber 24 increases. Therefore, by controlling the lowering timing of the fuel control valve 27, the amount of fuel pumped from the fuel pump 5 toward the common rail 3 is controlled, In this embodiment, the amount of fuel pumped out of the fuel pump 5 is controlled so that the fuel injection pressure becomes equal to a target fuel pressure.

[0019] A pair of cams for driving the first and second plungers are formed on a common cam shaft 23a. The cam shaft 23a is rotated at half the engine revolution speed. Each cam 23 has only one cam nose. The cam noses of the cams 2 are shifted in phase from each other by 360° in crank angle, hereinafter referred to as "CA". Therefore, for every two rotations of the crankshaft (not shown), each plunger pumps out fuel once. The two fuel pumping operations are shifted from each other by 360° CA.

[0020] Referring back to Fig. 1, the electronic control unit 40 is formed by a digital computer having a read-only memory (ROM) 42, a random access memory (RAM) 43, a micro-processor or central processing unit (CPU) 44, a backup RAM (B-RAM) 45 always connected to a power source, an input port 46, and an output port 47. The common rail 3 is provided with a pressure sensor 48 that generates an output voltage proportional to the fuel pressure in the common rail 3. An accelerator pedal (not shown) is provided with a depression amount sensor 49 that generates an output voltage proportional to the amount of depression of the accelerator pedal. The output voltages from the sensors 48, 49 are inputted to the input port 46 via respectively corresponding A/D converters 50. An engine revolution speed sensor 51 that generates pulses indicating the engine revolution speed is also connected to the input port 46. The output port 47 is connected to the fuel injection valve 2 and the solenoid coil 28 of the fuel pump 5 via corresponding drive circuits (drivers) 52.

[0021] It is undesirable to perform the fuel pumping from the fuel pump 5 once for every fuel injecting operation, as stated above. Therefore, in this embodiment, the fuel pumping is performed once for two fuel injecting operations. That is, since four fuel injecting operations are performed for every 720°CA in the internal combustion engine shown in Fig. 1, the fuel pumping timing is set so that the fuel pumping is performed once for every 360°CA. By setting the fuel pumping timing in this manner, the fuel pumping is performed once for two fuel injecting operations. As a result, it becomes possible to ensure a minimum size of the fuel pump 5 and a minimum cost of the apparatus while securing good durability of the fuel pump 5. In this embodiment, it is also possible to consider that the fuel pumping timing is set so that the time interval of fuel pumping becomes longer than the time interval of fuel injection.

[0022] However, if the number of fuel pumping operations relative to the number of fuel injecting operations is simply reduced, the variations in the fuel injection pressure increase so that the amount of fuel supplied to the individual cylinders will vary to a considerable extent. This will be explained with reference to Fig. 3.

[0023] The time chart of Fig. 3 illustrates an example in which the fuel pumping timing is unsuitably set. The chart indicates execution (ON) and discontinuation (OFF) of fuel injection, the fuel pressure FP in the common rail 3, execution (ON) and discontinuation (OFF) of fuel pumping, and the plunger lift PL. With regard to the plunger lift PL, a solid line indicates the lift of the first plunger, and a broken line indicates the lift of the second plunger.

[0024] In the example illustrated in Fig. 3, the fuel pressure FP decreases at the time of a fuel injecting operation I1' for the cylinder C1. The fuel pressure FP further decreases at the time of a fuel injecting operation I3' for the cylinder C3. Subsequently, a fuel pumping operation P1' is performed to increase the fuel pressure. After that, a fuel injecting operation I4' for the cylinder C4 is performed, followed by a fuel injecting operation I2' for the cylinder C2. Then, a fuel pumping operation P2' is performed. Subsequently, the fuel injecting operation I1' for the cylinder C1 is performed again. After the fuel injecting operation I3', the fuel pumping operation P1' is performed.

[0025] In this example, large differences in fuel injection pressure occur as indicated in Fig. 3. For example, a large pressure difference PD' occurs between the fuel injection pressure for the cylinder C1 and the fuel injection pressure for the cylinder C3. Such pressure differences indicate or represent the fuel injection pressures for the individual cylinders. Thus, in the example illustrated in Fig. 3, the fuel injection pressure for the individual cylinders varies to a great extent.

[0026] The variation in the fuel injection pressure for the individual cylinders can be reduced by suitably adjusting the fuel pumping timing relative to the fuel injecting timing. In this embodiment, therefore, the fuel pumping timing relative to the fuel injecting timing is set so as to reduce the variation in the fuel injection pressure for the individual cylinders, The embodiment of the invention will be described in detail below with reference to Fig. 4.

[0027] Fig. 4 is a time chart illustrating the fuel pumping timing of the preferred embodiment of the invention, As indicated in Fig. 4, the fuel pressure decreases at the time of a fuel injecting operation I1 for the cylinder C1. Subsequently, a fuel pumping operation P1 is started. Although the fuel pressure FP decreases, during the next fuel injecting operation, that is, a fuel injecting operation I3 for the cylinder C3, the fuel pressure FP starts increasing again after the end of the fuel injecting operation I3 for the cylinder C3 since the fuel pumping operation P1 is continuing. After the fuel pumping operation P1 ends, the fuel pressure FP is kept at a constant level until the fuel injecting operation I4 for the cylinder C4 starts. After the fuel injecting operation I4 for the cylinder C4 ends, a fuel pumping operation P2 is started. Subsequently, the fuel injecting operation I2 for the cylinder C2 is started. After the fuel injecting operation I2 for the cylinder C2 ends, the fuel pumping operation P2 ends.

[0028] In this embodiment, a fuel pumping operation is started before a fuel injecting operation starts. For example, the fuel pumping operation P1 is started before the fuel injecting operation I3 for the cylinder C3 starts. Therefore, the fuel injection pressure for the cylinder C3 can be sufficiently increased. After the fuel injecting operation I3 for the cylinder C3, the fuel pumping operation P1 is continued until the fuel pressure FP reaches a sufficiently high level. Therefore, the subsequent fuel injection pressure for the cylinder C4 can be sufficiently increased. As a result, the pressure difference PD between the fuel injection pressure for the cylinder C1 and the fuel injection pressure for the cylinder C3 can be maintained at a small value. That is, the variation in the fuel injection pressure for the individual cylinders can be reduced. Therefore, the variation in the amount of fuel supplied to the individual cylinders C1-C4 can be reduced. Furthermore, the deviation of the supply of fuel to the individual cylinders C1-C4 from a prescribed amount can be reduced.

[0029] In this embodiment, the fuel pumping timing relative to the fuel injecting timing is set so that the pressure difference PD, representing the variation in the fuel injection pressure for the individual cylinders C1-C4, becomes smaller than a predetermined set value, The set value is, for example, about 2 to 3 Mpa.

[0030] In this embodiment, it may be considered that the fuel pumping timing is set so that each fuel pumping operation overlaps every other fuel injecting operation in such a manner that the fuel pumping operation starts before the start of the fuel injecting operation, and ends after the end of the fuel injecting operation, whereby the fuel pressure FP at the time of the start of the fuel injecting operation and the fuel pressure FP at the end of the fuel pumping operation is made smaller than a set value. However, it is possible to set the fuel pumping timing so that a fuel pumping operation starts before a fuel injecting operation starts, and the fuel pumping operation ends before a next fuel injecting operation ends, whereby the fuel pressure FP at the time of the start of the fuel injecting operation and the fuel pressure FP at the end of the fuel injecting operation is made smaller than a set value. Furthermore, it is also possible to set the fuel pumping timing so that a fuel pumping operation starts after a fuel injecting operation starts, and the fuel pumping operation ends after a next fuel injecting operation ends, whereby the fuel pressure FP at the time of the start of the fuel injecting operation and the fuel pressure FP at the end of the fuel pumping operation is made smaller than a set value.

[0031] Although in the foregoing embodiment, the fuel pump 5 is formed by an inline pump equipped with a pair of plungers, the fuel pump 5 may also be formed by any known or subsequently developed pump, such as, for example, a pump equipped with a single plunger, a distribution-type pump, and the like.

[0032] While the present invention has been described with reference to a preferred embodiment thereof, it is evident that many alternatives, modifications and variations may be apparent to those skilled in the art. Accordingly, the preferred embodiment of the invention as set forth herein is intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

[0033] An accumulator-type fuel injection apparatus has a plurality of fuel injection valves for corresponding individual cylinders of an engine. The fuel injection valves (2) are connected to a common pressure-accumulator chamber (3) that is connected to an ejection side of a fuel pump (5). Fuel is pumped from the fuel pump (5) into the pressure-accumulator chamber (3) and then supplied into the cylinders via the corresponding fuel injection valves (2). The fuel pumping timing of the fuel pump is set relative to the fuel injection timing so that a variation in fuel pressure in the pressure-accumulating chamber (3) at the time of start of a fuel injecting operation is smaller than a predetermined set value.

Claims

1. An accumulator-type fuel injection apparatus including a pressure-accumulating chamber (3) connected to a plurality of fuel injection valves (2) corresponding to a plurality of cylinders of an engine, wherein fuel is supplied from the pressure-accumulating chamber (3) into the cylinders via the fuel injection valves (2), comprising:

    a fuel pump (5) that pumps fuel firm a fuel tank (7) into the pressure-accumulating chamber (3); and

    fuel pump controlling means (40) for controlling the fuel pump (5) so that fuel is pumped to the pressure-accumulating chamber (3) during an earlier fuel injecting operation of at least two consecutive fuel injecting operations.

2. An accumulator-type fuel injection apparatus according to claim 1,wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) before starting the earlier fuel injecting operation and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after end of the earliest fuel injecting operation.

3. An accumulator-type fuel injection apparatus according to claim 1, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) before starting the earlier fuel injecting operation and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

4. An accumulator-type fuel injection apparatus according to claim 1, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) after starting the earlier fuel injecting operation and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

5. An accumulator-type fuel injection apparatus according to claim 1, wherein the fuel pump controlling means (40) causes the fuel pump (5) to pump fuel to the pressure-accumulating chamber (3) during one of alternate fuel injecting operations of the at least two consecutive fuel injecting operations.

6. An accumulator-type fuel injection apparatus according to claim 4, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start

pumping fuel to the pressure-accumulating chamber (3) before starting the earlier fuel injecting operation and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) before ending the earlier fuel injecting.

7. An accumulator-type fuel injection apparatus according to claim 5, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) before starting the earlier fuel injecting operation and causes the fuel pump to stop pumping fuel to the pressure accumulating chamber (3) after ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

8. An accumulator-type fuel injection apparatus according to claim 5, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) after starting the earlier fuel injecting operation and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

9. A method for supplying fuel to an accumulator-type fuel injection apparatus having a pressure-accumulating chamber (3) connected to a plurality of fuel injection valves (2) corresponding to a plurality of cylinders of an engine, wherein fuel is supplied from the pressure-accumulating chamber (3) into the cylinders via the corresponding fuel injection valves (2), comprising the following step:

   pumping fuel from the fuel pump (5) to the pressure-accumulating chamber (3) during an earlier fuel injecting operation of at least two consecutive fuel injecting operations.

10. A method for supplying fuel to an accumulator-type fuel injection apparatus according to claim 9, wherein fuel pumping is started before starting the earlier fuel injecting operation and the fuel pumping is stopped after ending the earlier fuel injecting operation.

11. A method for supplying fuel to an accumulator-type fuel injection apparatus according to claim 9, wherein fuel pumping is started before starting the earlier fuel injecting operation and the fuel pumping is stopped after ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

12. A method for supplying fuel to an accumulator-type fuel injection apparatus according to claim 9, wherein the fuel pumping is started before starting the earlier fuel injecting operation and the fuel pumping is stopped before ending a later fuel injecting operation of the at least two consecutive fuel injecting operations.

13. An accumulator-type fuel injection apparatus including a pressure-accumulating chamber (3) connected to a plurality of fuel injection valves (2) corresponding to the plurality of cylinders, wherein fuel is supplied from the pressure-accumulating chamber (3) into the cylinders via the fuel injection valves (2), comprising:

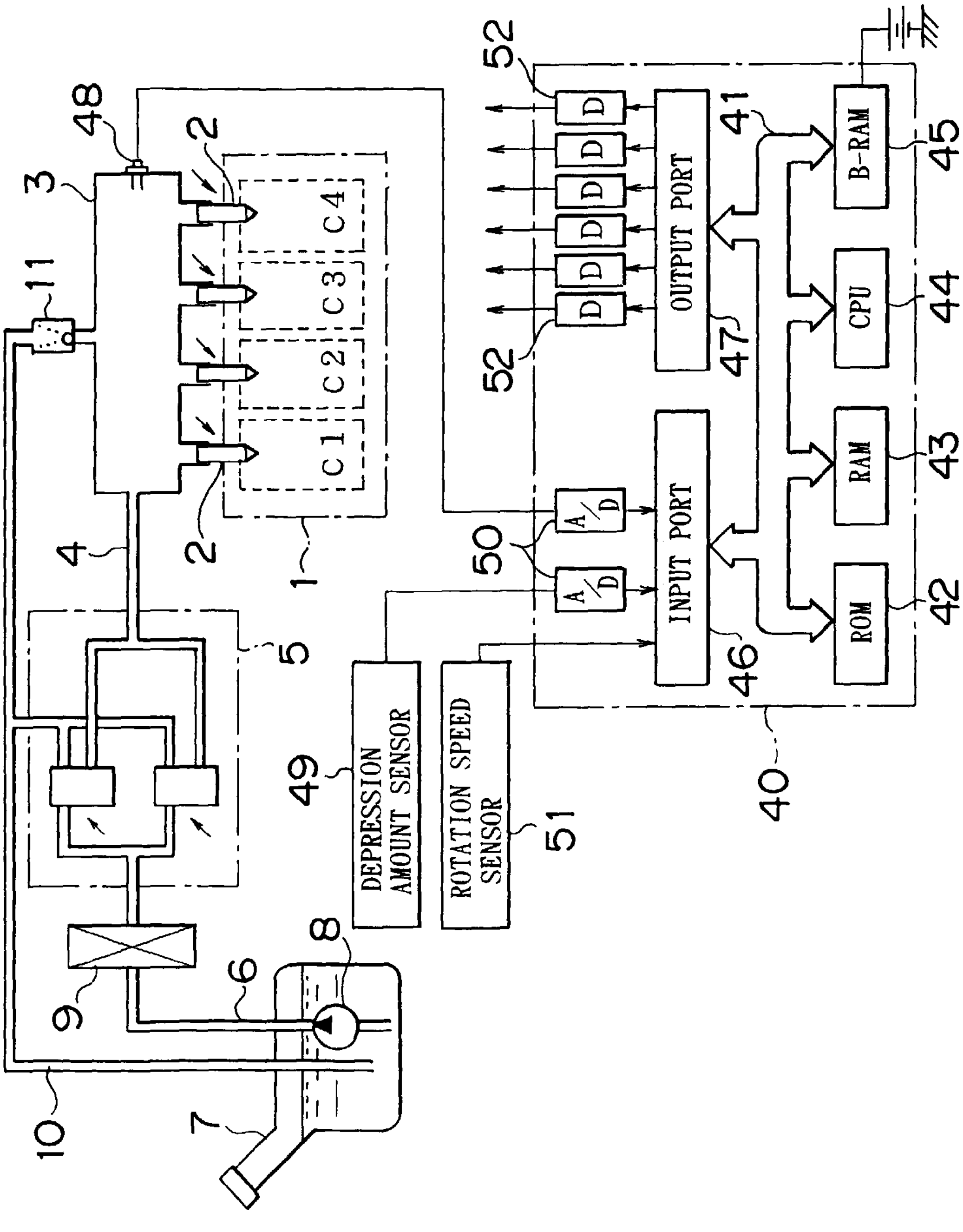
   a fuel pump (5) that pumps fuel from a fuel tank (7) into the pressure-accumulating chamber (3); and
   fuel pump controlling means (40) for controlling the fuel pump (5) so that fuel pumping by the fuel pump (5) is performed once for a plurality of fuel injecting operations, wherein a pumping timing of the fuel pump is set relative to a fuel injecting timing so that a variation in fuel pressure in the pressure-accumulating chamber (3) at the start time of a fuel injecting operation becomes smaller than a predetermined set value.

14. An accumulator-type fuel injection apparatus according to claim 13, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) before starting an earlier fuel injecting operation of the plurality of fuel injecting operations and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after ending the earlier fuel injecting operation.

15. An accumulator-type fuel injection apparatus according to claim 13, wherein the fuel pump controlling means (40) causes the fuel pump (5) to start pumping fuel to the pressure-accumulating chamber (3) before starting an earlier fuel injecting operation of the plurality of fuel injecting operations and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) after ending a later fuel injecting operation of the plurality of fuel injecting operations.

16. An accumulator-type fuel injection apparatus according to claim 13, wherein the fuel pump controlling means (40) causes the fuel pump (5) to pump fuel to the pressure-accumulating chamber (3) before starting an earlier fuel injecting operation of the plurality of fuel injecting operations and causes the fuel pump (5) to stop pumping fuel to the pressure-accumulating chamber (3) before ending a later fuel injecting operation of the plurality of fuel injecting operations.

FIG. 1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ROTATION SPEED SENSOR
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CPU
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C3
C4
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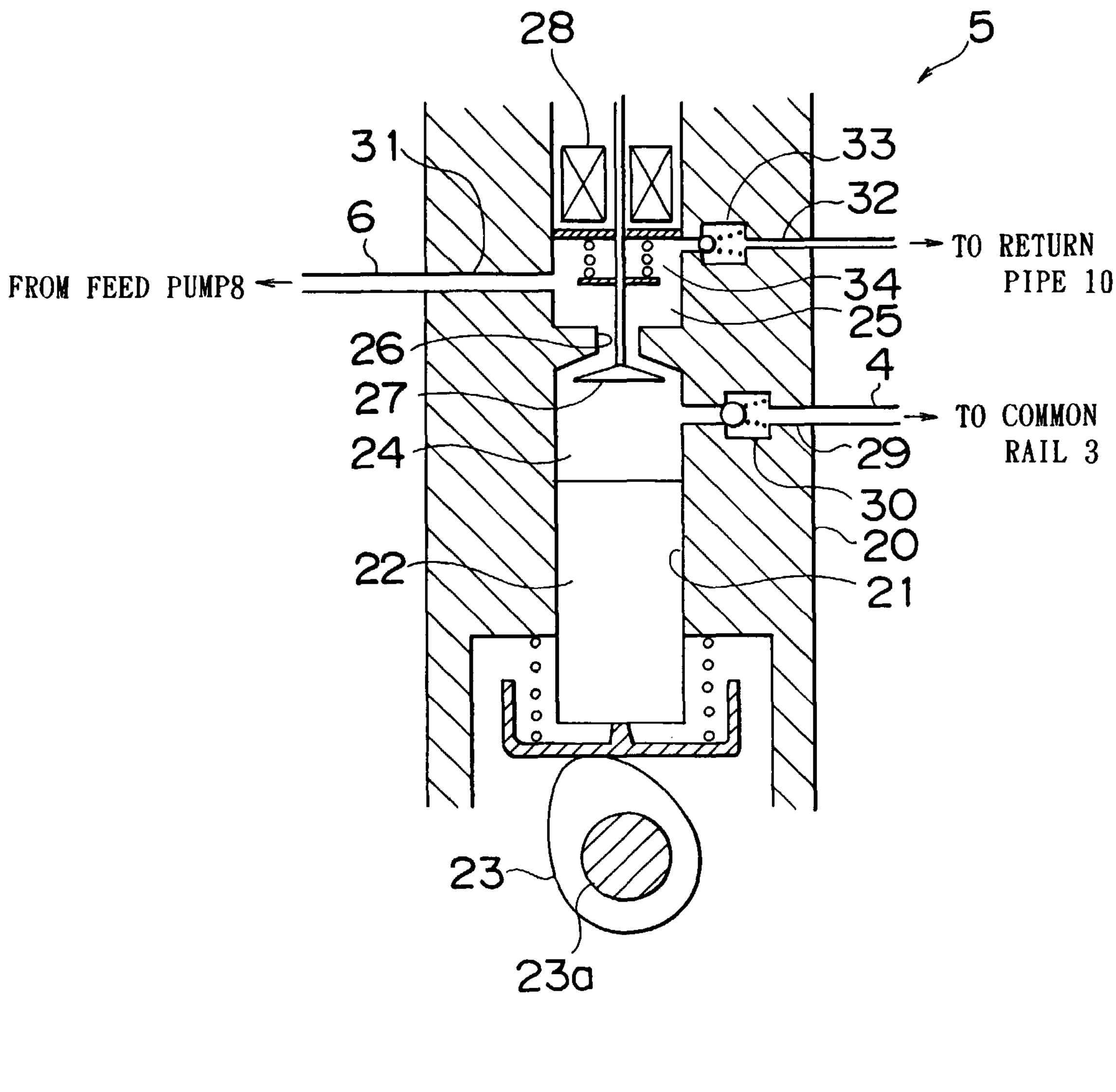
FIG. 2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23a

FIG. 3

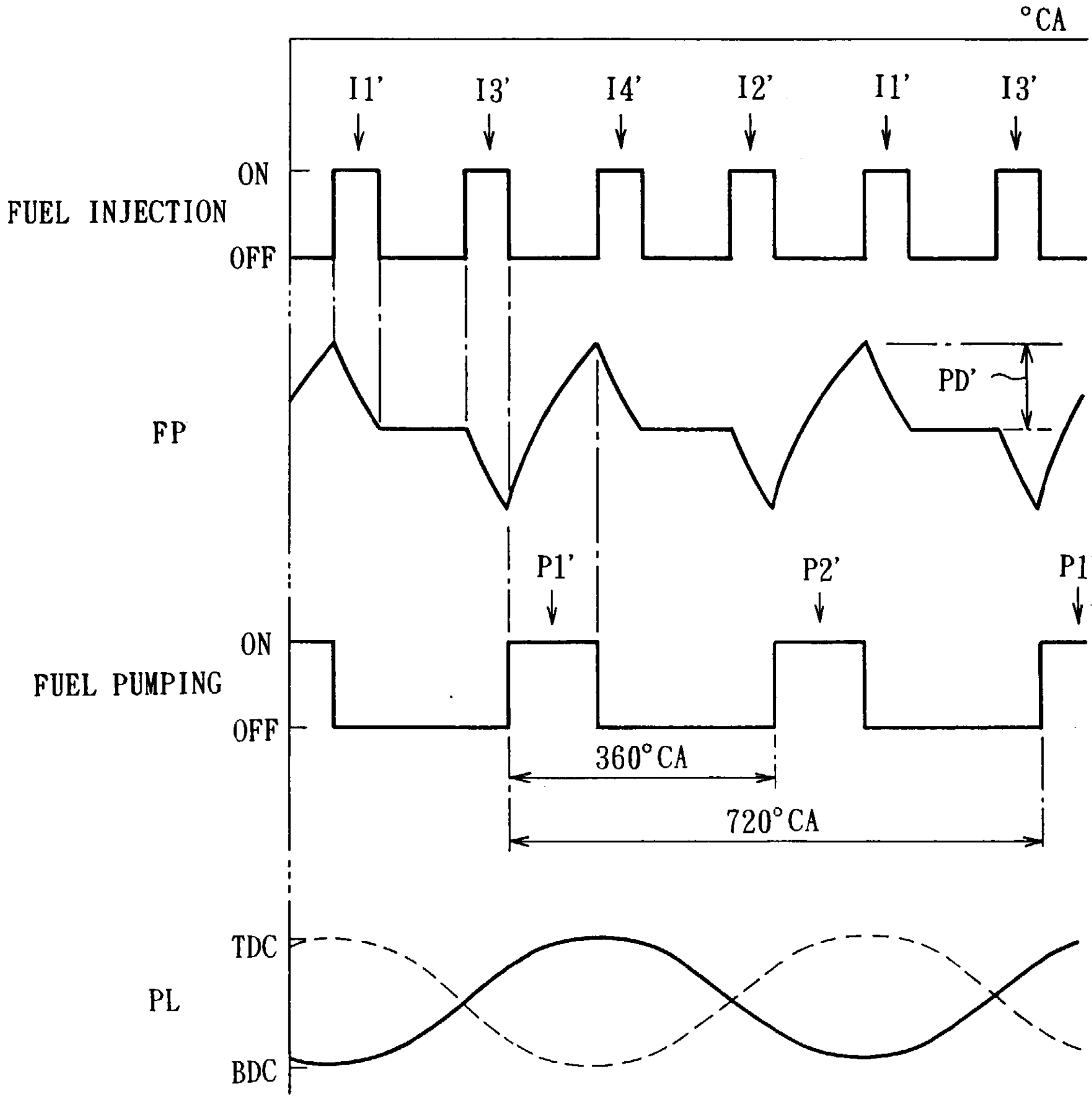
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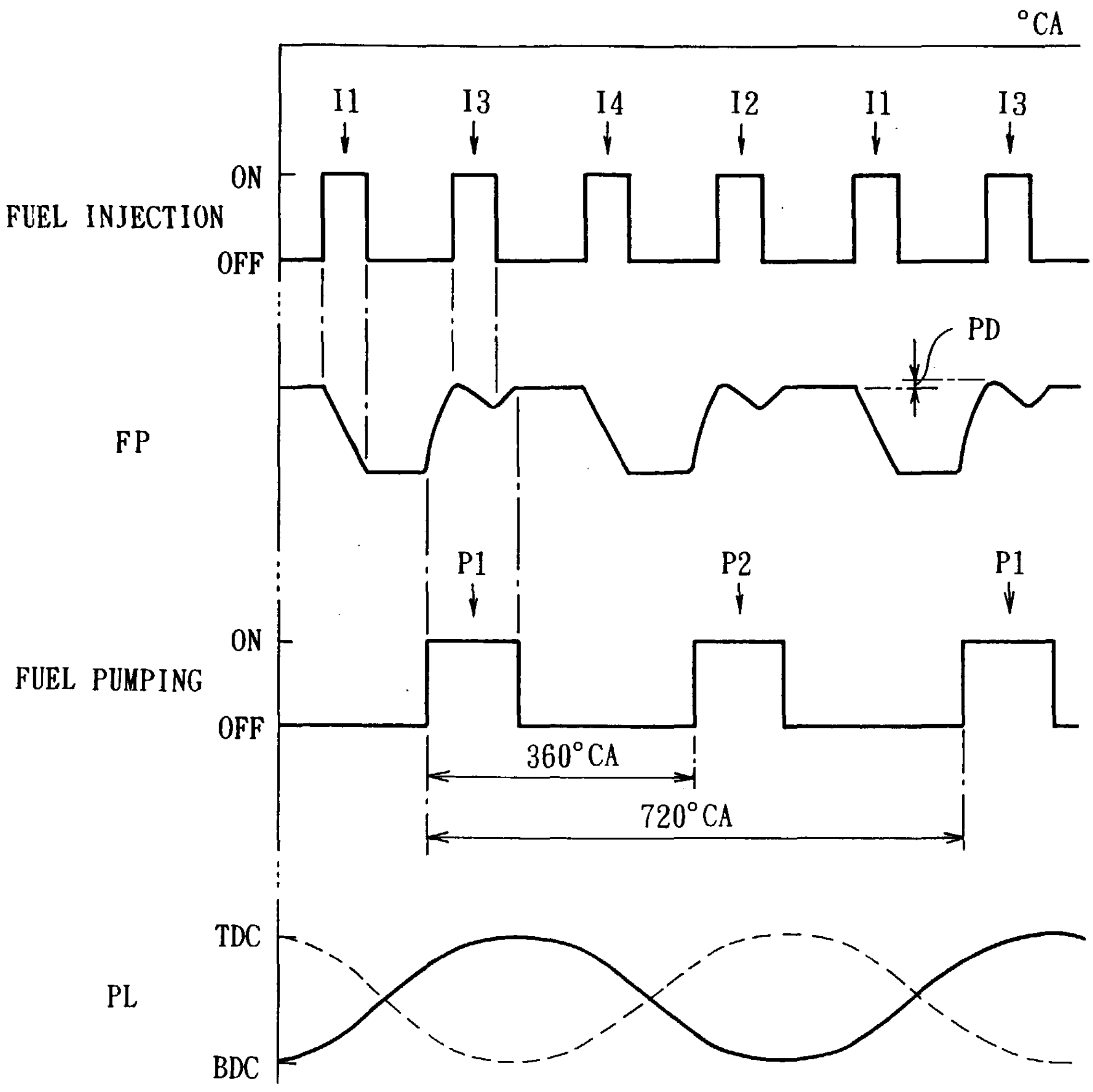
FIG. 4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