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(54) **Fuel injection control apparatus**

(57) Fuel injection control apparatus for a diesel engine having a plurality of cylinders, the fuel injection control apparatus comprising a calculation unit that calculates a fuel injection amount for each cylinder, and a storage unit (16) that has a storage area corresponding to each cylinder and stores in a corresponding storage area a calculation result generated by the calculation unit.

When a low rotation speed switches to a high rotation speed, a calculation result $Q\#_2$, which was used to inject fuel into a cylinder #2 prior to the switch, is used to inject fuel into a cylinder #3, which is subjected to fuel injection following the cylinder #2. A calculation result $Q\#_1$ can be used by an ECU (8) to inject fuel into the cylinder #2 immediately after the aforesaid switch.

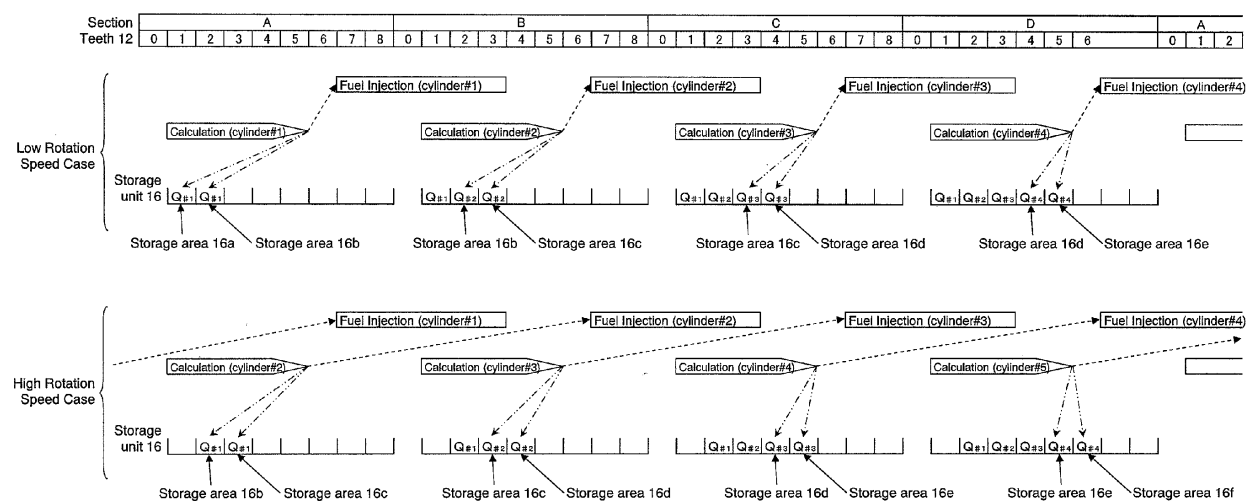


Fig. 3

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a fuel injection control apparatus for a diesel engine.

2. Description of the Related Art

[0002] In recent years, common rail type diesel engines have gained prominence among diesel engines. In a common rail type diesel engine, split injection and so on can be performed easily by having a fuel injection control apparatus control energization time (valve opening time) of a fuel injection valve (injector), and therefore injection can be performed with a high degree of freedom. Incidentally, the fuel injection control apparatus typically starts to calculate fuel injection amounts for respective cylinders on the basis of a predetermined crank angle. To ensure that fuel is injected into the respective cylinders reliably, calculation of the fuel injection amounts must be completed at a timing before the start of fuel injection when injection is not impaired, or in other words before a calculation completion limit angle.

[0003] Typically, an interval between the calculation start timing of the fuel injection amount and an injection energization start timing of the fuel injection valve is preferably as short as possible. The reason for this is that as time elapses, variations occur in information relating to operating conditions (engine rotation speed, load, pressure in a common rail, and so on) used in the calculation, and therefore control can be executed with a higher degree of precision as the aforementioned interval decreases. Meanwhile, the engine rotation speed of an automobile in particular varies within a wide range from a low rotation speed to a high rotation speed. Therefore, when the calculation start timing of the fuel injection amount is aligned with a high rotation speed side, the actual time from the start of calculation to the start of injection energization increases on a low rotation speed side, leading to a reduction in precision. When the calculation start timing of the fuel injection amount is aligned with the low rotation speed side, on the other hand, the calculation is not completed in time on the high rotation speed side.

[0004] As a countermeasure to this problem, Japanese Patent Application Publication No. 2004-150321 proposes a technique of setting two predetermined crank angles corresponding to the calculation start timing following the start of injection into a certain cylinder and before the start of injection into the next cylinder to be subjected to fuel injection, and modifying the calculation start timing on the basis of the rotation speed.

[0005] A diesel engine described in Japanese Patent Application Publication No. 2004-150321 is a four-cylinder engine, but as the number of cylinders in a diesel engine increases, the crank angle that can be used to

calculate the fuel injection amount narrows, leading to a reduction in the actual amount of time that can be used for the calculation. For example, when the crank angle of a single cycle is divided by the number of cylinders, 180° is obtained in a four-cylinder diesel engine but only 90° is obtained in an eight-cylinder diesel engine. Therefore, when an attempt is made to perform similar control in a diesel engine having a large number of cylinders, i.e. eight or more cylinders, calculation of the fuel injection amount is not completed by the calculation completion limit angle on the high rotation speed side of the engine, even if the calculation start timing is advanced as far as possible. When calculation of the fuel injection amount is not completed in time, fuel injection may be missed or performed without making use of the calculation result.

[0006] Measures may easily be taken to simplify the content of the calculation processing or to employ a high-performance ECU in the fuel injection amount control apparatus. In this case, however, new problems such as deterioration of the precision of the fuel injection amount control and cost increases arise.

SUMMARY OF THE INVENTION

[0007] The present invention has been designed to solve these problems, and an object thereof is to provide a fuel injection control apparatus that can inject fuel into respective cylinders without missing any of the cylinders and without causing the problems described above.

[0008] The present invention provides a fuel injection control apparatus for a diesel engine having a plurality of cylinders, the fuel injection control apparatus comprising: a calculation unit that calculates a fuel injection amount for each cylinder; and a storage unit that has a storage area corresponding to each cylinder and stores in a corresponding storage area a calculation result generated by the calculation unit, the fuel injection control apparatus being characterized in that, when the rotation speed of the diesel engine is equal to or lower than a preset reference rotation speed, the calculation result is stored in a corresponding storage area as a fuel injection amount for each of two cylinders, namely a first cylinder, which is a cylinder first subjected to fuel injection following the start of the calculation, and a following cylinder, which is a cylinder subjected to fuel injection following the first cylinder, and when the rotation speed of the diesel engine is higher than the reference rotation speed, the calculation result is stored in the corresponding storage area as at least the fuel injection amount of the following cylinder.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the accompanying drawings:

Fig. 1 is a schematic constitutional diagram of a diesel engine including a fuel injection control apparatus according to an embodiment of the present invention;

Fig. 2 is a view illustrating the constitution of an engine rotation sensor provided in the fuel injection control apparatus according to this embodiment; and Fig. 3 is a view illustrating an operation of the fuel injection control apparatus according to this embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] An embodiment of the present invention will be described below on the basis of the attached drawings.

[0011] Fig. 1 shows the constitution of a diesel engine including a fuel injection control apparatus according to an embodiment of the present invention. A diesel engine 1 is a V type eight-cylinder common rail diesel engine. Each cylinder 2 (only one cylinder is shown in Fig. 1) is provided with an injector 3 for injecting fuel into the cylinder. Each injector 3 is provided with a solenoid valve 4 for ON/OFF control of the fuel injection.

[0012] The injector 3 is connected to a common rail 5 by a high pressure fuel pipe 14. Fuel is accumulated in the common rail 5 in a high pressure state such that when the solenoid valve 4 is opened, the fuel is fed through the fuel pipe 14 by an internal pressure of the common rail 5 and injected from the injector 3. The fuel is supplied to the common rail 5 from a fuel tank 7 by a pump 6 such that the internal pressure of the common rail 5 is maintained at a predetermined pressure.

[0013] The diesel engine 1 is further provided with an ECU 8 for controlling an operation of the diesel engine 1. The ECU 8 is provided with a calculation unit 15 for calculating a fuel injection amount on the basis of operating conditions of the diesel engine 1, and a storage unit 16 for storing information relating to fuel injection into the respective cylinders 2. The storage unit 16 includes eight storage areas 16a to 16h corresponding to the respective cylinders 2, and the storage areas 16a to 16h respectively store calculation results generated by the calculation unit 15 in relation to the fuel injection amounts for the respective cylinders 2. Further, correction information corresponding to a corresponding cylinder 2 is stored separately in each storage area 16a to 16h. The correction information is based on temporal deterioration of the injector 3, a degree of blockage of an injection hole, and so on, and is used for correction when a command value of open/close control of the respective solenoid valves 4 is calculated on the basis of the fuel injection amount. Conventional means, such as a method of calculating a correction value in relation to temporal deterioration disclosed in Japanese Patent Application Publication No. 2002-89333, for example, is used as the means for calculating the correction information, and therefore description thereof has been omitted. An engine rotation sensor 9 for detecting a crank angle and a rotation speed of the diesel engine 1 and a drive circuit 10 are electrically connected to the ECU 8. The solenoid valve 4 is electrically connected to the drive circuit 10.

[0014] As shown in Fig. 2, the engine rotation sensor 9 includes a pulser 9a and a pickup 9b. The pulser 9a is disc-shaped, and a central portion thereof is coupled to a crankshaft 11 such that the pulser 9a rotates in conjunction with rotation of the crankshaft 11. Thirty-four teeth 12 are formed on an outer peripheral edge of the pulser 9a. The teeth 12 are provided in positions obtained by dividing the entire outer peripheral edge of the pulser 9a by thirty-six, and therefore tooth missing portions 13 exist in two tooth positions indicated by dotted lines. In other words, two teeth are missing. The teeth 12 are divided into four sections A to D at intervals of 90°, and numbers 0 to 8 are allocated respectively to the teeth 12 in the sections A to C. Only seven teeth exist in the section D including the tooth missing portions 13, and therefore numbers 0 to 6 are allocated respectively to the teeth 12 in the section D. The pickup 9b is a magnetic sensor disposed in a position facing the teeth 12 in order to output a pulse signal to the ECU 8 electrically connected thereto every time a tooth 12 approaches during rotation of the pulser 9a. The ECU 8 to which the pulse signals are transmitted calculates the rotation speed on the basis of an interval between the pulse signals. Further, the ECU 8 calculates the crank angle on the basis of the tooth missing portions 13, at which pulse signals are not detected, and the number of pulse signals detected after the tooth missing portions 13.

[0015] Next, operation of the fuel injection control apparatus according to this embodiment will be described.

[0016] In this embodiment, a low rotation speed case corresponds to a case in which the rotation speed of the diesel engine 1 is comparatively low, calculation of the fuel injection amount is started at a predetermined crank angle following the start of fuel injection into a certain cylinder, and calculation of the fuel injection amount of the cylinder (to be referred to hereafter as the first cylinder) that is first subjected to fuel injection after the start of the calculation is completed before a calculation completion limit angle. Further, a high rotation speed case corresponds to a case in which the rotation speed of the diesel engine 1 increases such that when a crank angle range that can be used for the calculation, or in other words a calculation angle, remains constant, the actual time that can be used for the calculation decreases, and therefore, if calculation of the fuel injection amount is started at the same predetermined crank angle as the low rotation speed case, calculation of the fuel injection amount of the first cylinder cannot be completed before the calculation completion limit angle of the first cylinder. Note that the rotation speed of the diesel engine 1 forming a boundary between the low rotation speed case and the high rotation speed case is set as a reference rotation speed and held in advance in the ECU 8. When the predetermined crank angle is reached, the ECU 8 first compares the rotation speed of the diesel engine 1 with the reference rotation speed in order to select control corresponding to the low rotation speed case or control corresponding to the high rotation speed case, to be de-

scribed below. The content of the control corresponding to the low rotation speed case and the control corresponding to the high rotation speed case will be described specifically below.

[0017] Note that the fuel injection amount denotes not only a total amount of fuel injected into each cylinder. Depending on the operating conditions of the diesel engine 1, the fuel may be divided into a plurality of injections, such as a main injection and a post-injection, before being injected into the respective cylinders, and therefore the fuel injection amount also includes a number of divided injections, as well as timings and amounts of the divided injections.

[0018] The low rotation speed case will now be described in detail. Reference symbols #1 to #8 are allocated respectively to the eight cylinders 2 of the diesel engine 1 in the order of fuel injection. As shown in Fig. 3, calculation of the fuel injection amount for the cylinder #1 begins when the pickup 9b (see Fig. 2) detects the tooth 12 allocated the number 1 in the section A of the pulser 9a, or in other words at a crank angle of 10°.

[0019] When the crank angle reaches 10°, the ECU 8 (see Fig. 1) first determines whether the low rotation speed case or the high rotation speed case is established. After determining that the low rotation speed case is established, the calculation unit 15 starts to calculate the fuel injection amount. The actual calculation of the fuel injection amount is a well known calculation based on the rotation speed of the diesel engine 1, accelerator opening, and so on, and therefore description thereof has been omitted. The calculation of the fuel injection amount is completed when the pickup 9b detects the tooth 12 allocated the number 6, for example, or in other words at a crank angle of 60°. When the calculation of the fuel injection amount is complete, the ECU 8 stores a calculation result $Q_{\#1}$ in the storage area 16a corresponding to cylinder #1 (corresponding to the first cylinder). Simultaneously, the ECU 8 stores the calculation result $Q_{\#1}$ in the storage area 16b corresponding to cylinder #2 to be subjected to fuel injection following cylinder #1 (hereafter, the cylinder that is subjected to fuel injection following the first cylinder will be referred to as the following cylinder, and in this case, cylinder #2 corresponds to the following cylinder).

[0020] At a predetermined timing following completion of the calculation of the fuel injection amount, for example when the pickup 9b detects the tooth 12 allocated the number 7, or in other words at a crank angle of 70°, the ECU 8 issues a request command relating to fuel injection into cylinder #1 and based on the calculation result $Q_{\#1}$ stored in the storage area 16a to the drive circuit 10, or in other words makes a reservation (omitted from Fig. 3). As a result of this reservation processing, the drive circuit 10 executes fuel injection by opening or closing the solenoid valve 4 (see Fig. 1) of the injector 3 disposed in cylinder #1 following the elapse of a predetermined time. The request command issued to cylinder #1 at this time is calculated by performing separate correction process-

ing on the calculation result $Q_{\#1}$, i.e. the fuel injection amount stored in the storage area 16a, using the correction information corresponding to the cylinder, which is held in the storage area 16a.

[0021] Calculation of the fuel injection amount for cylinder #2 is started using a similar method when the pickup 9b detects the tooth 12 allocated the number 1 in section B of the pulser 9a (see Fig. 2), or in other words at a crank angle of 100°. In this case, the calculation unit 15 stores a calculation result $Q_{\#2}$ in the storage area 16b corresponding to cylinder #2. The calculation result $Q_{\#1}$ is already stored in the storage area 16b, and therefore the calculation result $Q_{\#2}$ is overwritten. Simultaneously, the calculation unit 15 stores the calculation result $Q_{\#2}$ in the storage area 16c corresponding to cylinder #3 to be subjected to fuel injection following cylinder #2. Thereafter, fuel is injected into cylinder #2 using a method similar to that described above. Fuel injection into cylinder #3 thru cylinder #8 is performed in a similar manner, and when fuel injection into cylinder #8 is complete, fuel is injected into cylinder #1 again using a similar method.

[0022] Processing performed when the ECU 8 determines that a high rotation speed case is established will now be described in detail. The ECU 8 performs a switch such that the calculation performed by the calculation unit 15 is advanced by one cylinder. More specifically, the calculation result $Q_{\#1}$ of the calculation that starts when the pickup 9b detects the tooth 12 allocated the number 1 in the section A of the pulser 9a is stored in the storage area 16b in order to be used for cylinder #2 (corresponding to the following cylinder). Similarly, the ECU 8 also stores the calculation result $Q_{\#1}$ in the storage area 16c corresponding to cylinder #3 to be subjected to fuel injection following cylinder #2. The ECU 8 then performs the reservation processing in relation to cylinder #2 when the pickup 9b detects the tooth 12 allocated the number 7 in the section B. As a result, fuel is injected into cylinder #2 on the basis of the calculation result $Q_{\#1}$ stored in the storage area 16b and the correction information held in the storage area 16b.

[0023] If the calculation result is stored in only one storage area when the rotation speed of the diesel engine 1 switches from a low rotation speed to a high rotation speed such that the switch described above is performed, the calculation unit 15 starts to perform the calculation for the following cylinder rather than the first cylinder, and since a calculation result does not exist in relation to the first cylinder, the reservation processing performed on the drive circuit 10 in relation to the first cylinder is skipped, leading to a situation in which fuel injection into the first cylinder is missed or performed without making use of the calculation result. For example, if the switch described above is performed before performing the calculation in the period of the numbers 1 to 6 in section B of the pulser 9a, the calculation result $Q_{\#2}$, which was used to inject fuel into the first cylinder, or in other words cylinder #2, prior to the switch is used to inject fuel into the following cylinder, which is subjected to fuel injection

following cylinder #2, or in other words cylinder #3 (i.e. stored in the storage areas 16c and 16d), and as a result, the calculation result for injecting fuel into cylinder #2 disappears. However, the calculation result ($Q_{\#1}$ calculated in the period of numbers 1 to 6 in section A of the pulser 9a is stored in the storage areas 16a and 16b, and therefore the ECU 8 can perform fuel injection immediately after the switch by performing the reservation processing on the drive circuit 10 on the basis of the calculation result $Q_{\#1}$ stored in the storage area 16b. As a result, a situation in which fuel injection into cylinder #2 is skipped can be prevented. In this example, a situation in which fuel injection into cylinder #2 is skipped can be prevented, but regardless of the timing of the switch, situations in which calculation results are skipped for the cylinders corresponding to the calculations performed by the calculation unit 15 can similarly be prevented from occurring.

[0024] Conversely, when the high rotation speed case switches to the low rotation speed case, a modification should be made so that the calculation result being calculated at the time of the switch is used as the fuel injection amount for the original cylinder. For example, when the high rotation speed case switches to the low rotation speed case during the calculation performed in the period of the numbers 1 to 6 in the section B of the pulser 9a, the calculation result $Q_{\#2}$ should be used to inject fuel into cylinder #2 rather than cylinder #3.

[0025] By switching from control in which the calculation result of the fuel injection amount is used to inject fuel into the cylinder that is first subjected to fuel injection following the start of the calculation to control in which the calculation result is used to inject fuel into the cylinder that is next subjected to fuel injection on the basis of the rotation speed of the diesel engine 1 in this manner, fuel injection can be performed without missing any of the cylinders.

[0026] In this embodiment, the calculation result generated by the calculation unit 15 is stored in two storage areas even in the high rotation speed case, but the present invention is not limited thereto. The calculation result is stored in two storage areas to prevent a situation in which a fuel injection calculation result is not performed in relation to the cylinder that is subjected to fuel injection immediately after a switch from the low rotation speed case to the high rotation speed case, and therefore, following a switch to the high rotation speed case, the calculation result may be stored only in the storage area corresponding to the cylinder on which the calculation result is to be used.

[0027] In this embodiment, the respective storage areas 16a to 16h hold the calculation results of the fuel injection amount and store the correction information corresponding to the respective cylinders. However, the present invention is not limited thereto, and instead, for example, the respective storage areas 16a to 16h may hold only the calculation results of the fuel injection amount. In this case, a different storage area may be

provided and the correction information corresponding to the respective cylinders may be stored therein.

[0028] In this embodiment, calculation of the fuel injection amount for each cylinder is started when the pickup 9b detects the tooth 12 allocated the number 1 in the respective sections A to D. However, the present invention is not limited thereto, and by performing setting in advance, the calculation may be started when the pickup 9b detects a tooth 12 allocated an arbitrary number. In other words, the calculation may be started at an arbitrary preset crank angle.

[0029] In this embodiment, the diesel engine 1 is a V type eight cylinder diesel engine, but the present invention is not limited thereto, and any diesel engine having a plurality of cylinders, for example a line type engine or a horizontally opposed engine, may be used instead. Note that the number of cylinders is not limited to eight, and the present invention may be used with more than eight cylinders and is particularly effective when the number of cylinders is large. Also note that the number of storage areas must be identical to the number of cylinders.

[0030] When a low rotation speed switches to a high rotation speed before a calculation is performed in a period of numbers 1 to 6 in a section B of a pulser 9a, a calculation result $Q_{\#2}$, which was used to inject fuel into a cylinder #2 prior to the switch, is used to inject fuel into a cylinder #3, which is subjected to fuel injection following the cylinder #2, and as a result, the calculation result for injecting fuel into the cylinder #2 disappears. However, a calculation result $Q_{\#1}$ calculated in the period of the numbers 1 to 6 in a section A of the pulser 9a is stored in a storage area 16b, and therefore an ECU 8 can inject fuel into the cylinder #2 immediately after the aforesaid switch by performing reservation processing on a drive circuit 10 on the basis of the calculation result $Q_{\#1}$ stored in the storage area 16b.

Claims

1. A fuel injection control apparatus for a diesel engine having a plurality of cylinders, said fuel injection control apparatus comprising:

a calculation unit that calculates a fuel injection amount for each cylinder; and

a storage unit that has a storage area corresponding to each cylinder and stores in a corresponding storage area a calculation result generated by said calculation unit, said fuel injection control apparatus being **characterized in that**,

when the rotation speed of said diesel engine is equal to or lower than a preset reference rotation speed, said calculation result is stored in a corresponding storage area as a fuel injection amount for each of two cylinders, namely a first

cylinder, which is a cylinder first subjected to fuel injection following the start of said calculation, and a following cylinder, which is a cylinder subjected to fuel injection following said first cylinder, and

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when said rotation speed of said diesel engine is higher than said reference rotation speed, said calculation result is stored in said corresponding storage area as at least said fuel injection amount of said following cylinder.

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2. The fuel injection control apparatus according to claim 1, **characterized in that** a calculation result, generated in a fuel injection amount calculation started first after said rotation speed of said diesel engine rises above said reference rotation speed, is stored in said corresponding storage area as at least said fuel injection amount of said following cylinder, and a calculation result, generated in a fuel injection amount calculation performed immediately before said fuel injection amount calculation started first after said rotation speed of said diesel engine rises above said reference rotation speed, is used as said fuel injection amount of said first cylinder.

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3. The fuel injection control apparatus according to claim 1 or 2, **characterized in that** each of said cylinders is provided with an injector for injecting a fuel, and said calculation results relating to said respective cylinders are overwritten to and saved in said respective storage areas together with correction information relating to said injector of said corresponding cylinder.

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4. The fuel injection control apparatus according to any one of claims 1 to 3, comprising:

an ECU including said calculation unit and said storage unit; and

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a drive circuit that drive-controls said injectors on the basis of a signal from said ECU, said fuel injection control apparatus being **characterized in that** said drive circuit ON/OFF controls said corresponding injector on the basis of said calculation result and said correction information stored in said respective storage areas.

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5. The fuel injection control apparatus according to any one of claims 1 to 4, **characterized in that** said calculation of said fuel injection amount for each of said cylinders is started at a preset crank angle.

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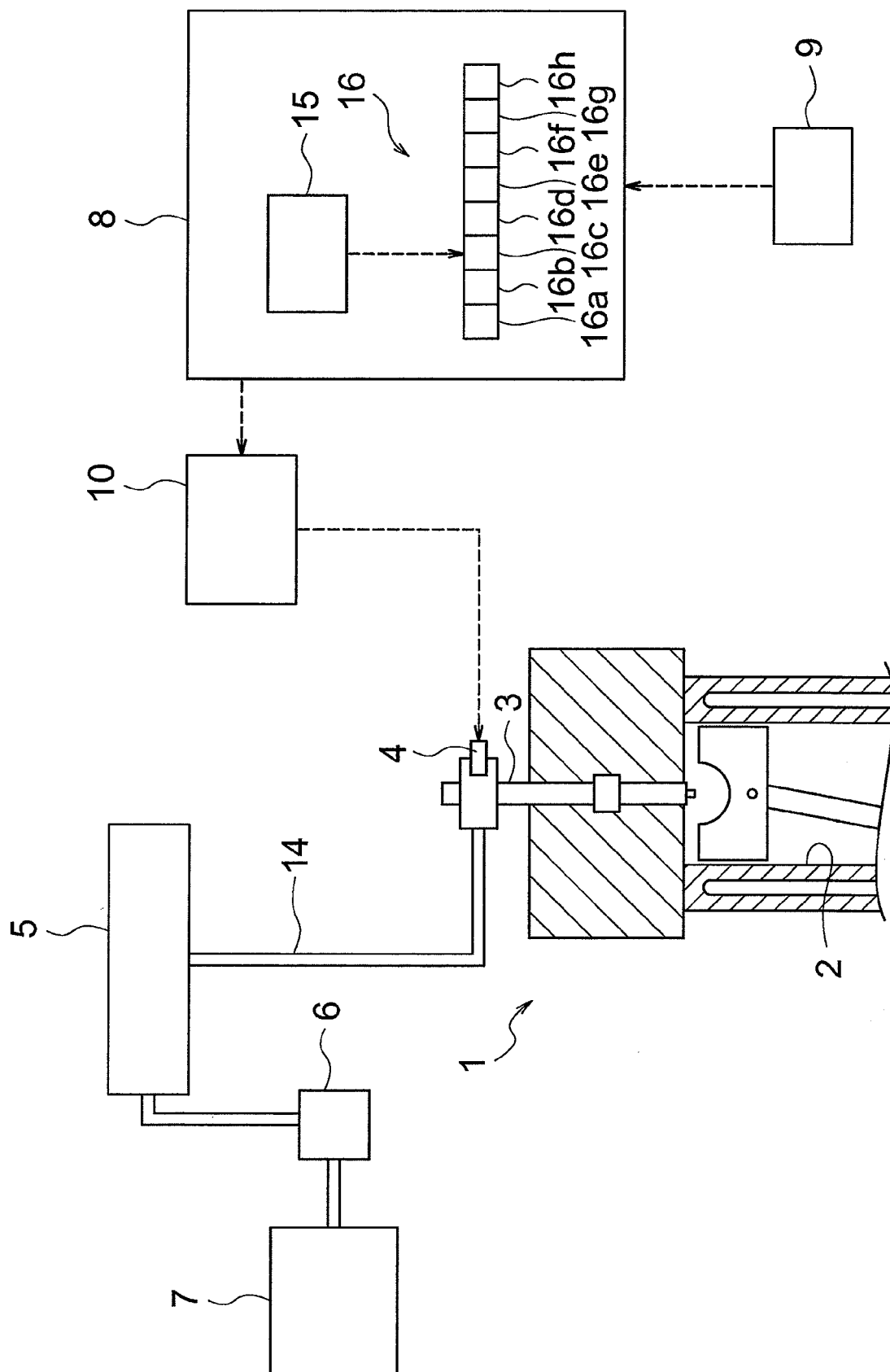


Fig. 1

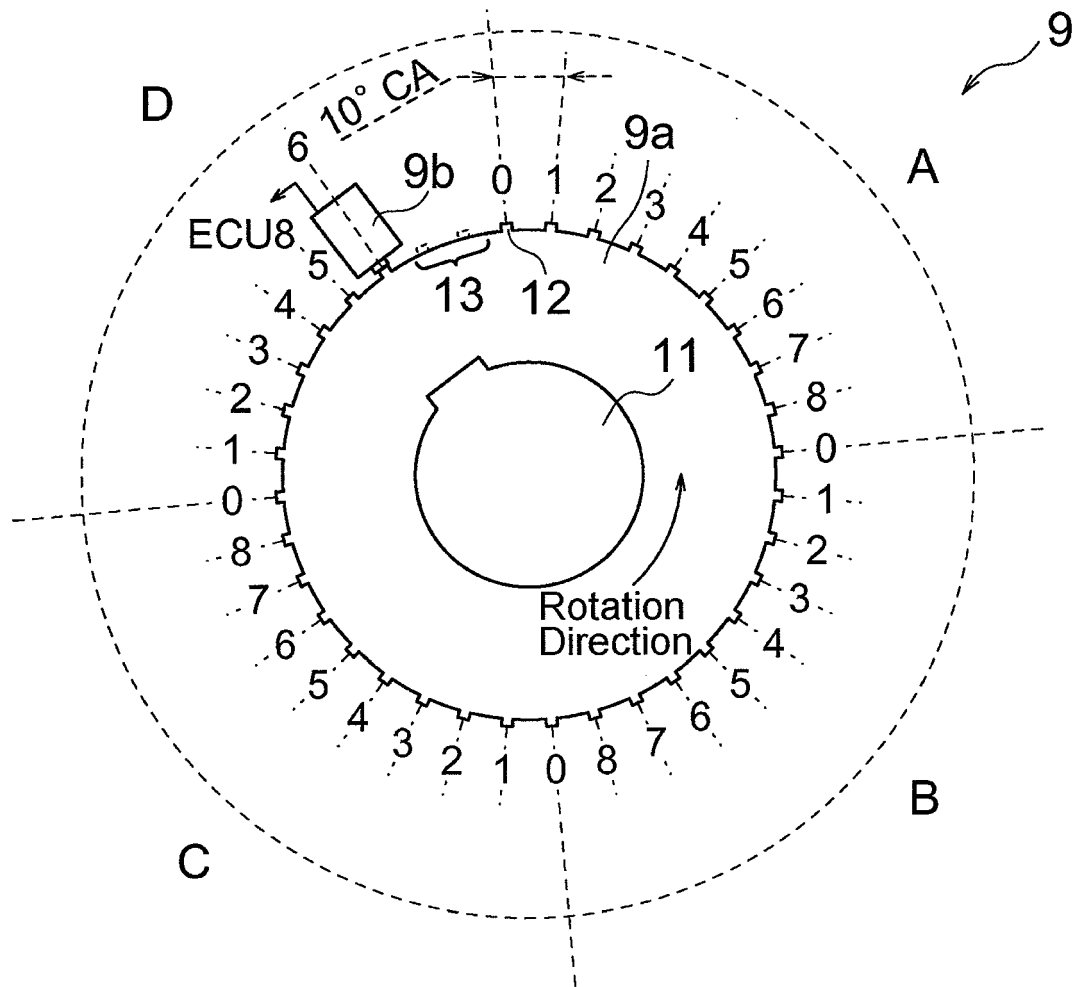


Fig. 2

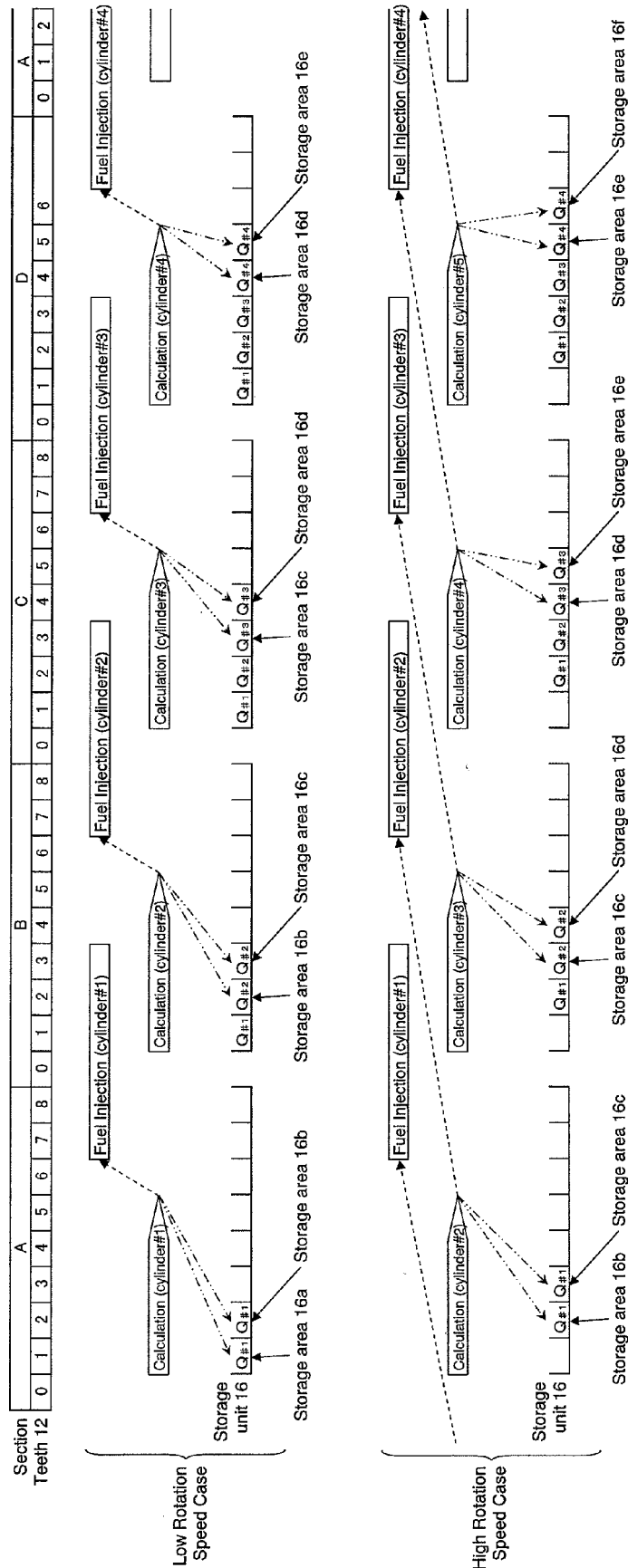


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004150321 A [0004] [0005]
- JP 2002089333 A [0013]