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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 December 2007 (13.12.2007)

PCT

(10) International Publication Number
WO 2007/142367 A1

(51) International Patent Classification:
F02D 41/00 (2006.01) *F02D 41/40* (2006.01)

(21) International Application Number: PCT/JP2007/062185

(22) International Filing Date: 11 June 2007 (11.06.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2006-161498 9 June 2006 (09.06.2006) JP

(71) Applicant *(for all designated States except US)*: **TOYOTA JIDOSHA KABUSHIKI KAISHA** [JP/JP]; 1, Toyota-cho, Toyota-shi, Aichi, 4718571 (JP).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **OBA, Takahiro** [JP/JP]; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, 1, Toyota-cho, Toyota-shi, Aichi, 4718571 (JP).

(74) Agents: **KAWAGUCHI, Yoshiyuki** et al.; Acropolis 21 Building 6th floor, 4-10, Higashi Nihonbashi 3-chome, Chuo-ku, Tokyo 1030004 (JP).

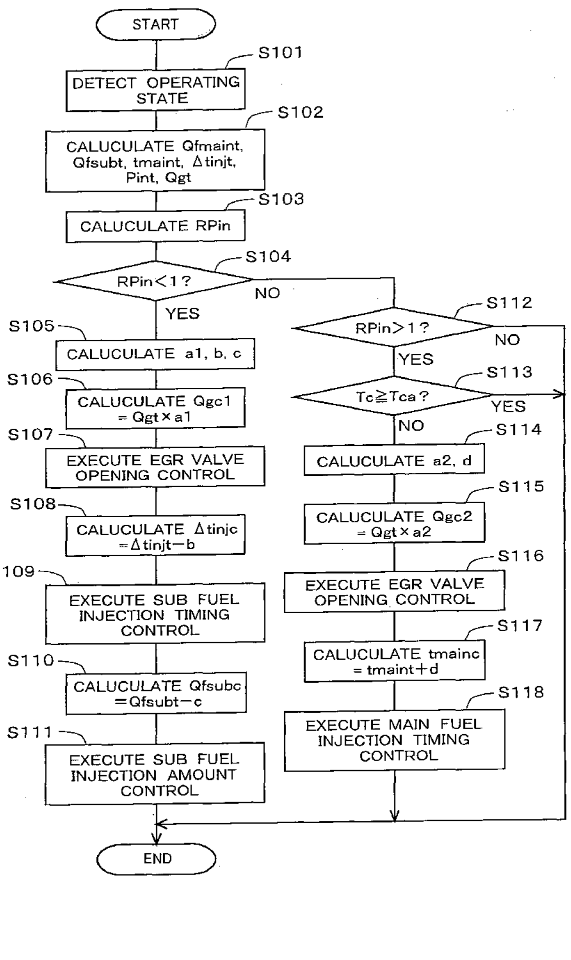
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: EXHAUST GAS PURIFICATION SYSTEM FOR INTERNAL COMBUSTION ENGINE



(57) Abstract: It is an object of the present invention to suppress NOx emissions while also suppressing an increase in unburned fuel emission and accidental fire in an exhaust gas purification system for an internal combustion engine that has a super charger and an EGR apparatus, when the internal combustion engine is in a transient operating state. In the present invention, a target charging pressure and a target EGR gas amount are calculated based on the operating state of the internal combustion engine. If the actual charging pressure has not reached the target charging pressure when the internal combustion is operating in a transient state, then the EGR gas amount is controlled to an amount smaller than the target EGR gas amount.

WO 2007/142367 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

EXHAUST GAS PURIFICATION SYSTEM FOR INTERNAL COMBUSTION ENGINE

TECHNICAL FIELD

The present invention relates to an exhaust gas purification system for an internal combustion engine that has a supercharger and an EGR apparatus.

PRIOR ART

In an exhaust gas purification system for an internal combustion engine, there is known one which has an EGR apparatus that introduces at least part of the exhaust gas of the internal combustion engine as EGR gas into an air intake system. It is possible to reduce the amount of NOx emissions by introducing the EGR gas into the air intake system .

Japanese Patent Application Laid-Open No. 5-263716 discloses techniques which, in exhaust gas purification system for an internal combustion engine, limit the amount of change when changing an EGR gas amount to be introduced to the air intake system .

In an exhaust gas purification system for an internal combustion engine that has a supercharger and an EGR apparatus, a charging pressure and an EGR gas amount are changed depending on the operating state of the internal combustion engine. However, the response when changing the charging pressure is low compared to the response when changing the EGR gas amount.

Therefore, when the charging pressure is raised and the EGR gas amount is increased at the time in which the operating state of the internal combustion engine becomes transient, the EGR gas amount is sometimes excessively large with respect to the actual charging pressure. In such cases, the EGR gas amount is excessively large with respect to an amount of intake air flowing into a cylinder. As a consequence, there is a risk of an increase in unburned fuel emissions and accidental fire.

DISCLOSURE OF THE INVENTION

The present invention has been made in view of the above described problem and has as an object to provide art for an exhaust gas purification system for an internal combustion engine that has a supercharger and an EGR apparatus, wherein such art is capable of suppressing NOx emissions while also suppressing an increase in unburned fuel emissions and accidental fire when the internal combustion engine is in a transient operating state.

In the present invention, the following means are employed to solve the above problems.

Namely, in the present invention, a target charging pressure and a target EGR gas amount are calculated based on the operating state of the internal combustion engine. If the actual charging pressure has not reached the target charging pressure when the internal combustion engine is operating in a transient operating state, the EGR gas amount is controlled to an amount smaller than the target EGR gas amount.

More specifically, an exhaust gas purification system for an internal combustion engine according to the present invention is characterized by including the following: an EGR apparatus for introducing at least part of the exhaust gas of the internal combustion engine as EGR gas into an air intake system of the internal combustion engine; a supercharger for supercharging intake air using energy from the exhaust gas of the internal combustion engine; EGR gas amount control means for controlling the EGR gas amount introduced into the air intake system of the internal combustion engine by the EGR apparatus; target EGR gas amount calculation means for calculating a target EGR gas amount that is a target value of the EGR gas amount, based on the operating state of the internal combustion engine; target charging pressure calculation means for calculating a target charging pressure that is a target value of the charging pressure, based on the operating state of the internal combustion engine; and charging pressure detection means for detecting the actual charging pressure, wherein if the actual charging pressure detected by the charging pressure detection means is lower than the target charging pressure when the internal combustion engine is in a transient operating state, the EGR gas amount control means controls the EGR gas amount to an amount smaller than the target EGR gas amount.

According to the present invention, it is possible to suppress the EGR gas amount introduced into the air intake system from becoming an excessively large amount with respect to the actual charging pressure (i.e., with respect to the intake air amount), when the internal combustion engine is in a transient operating state. Therefore, when the internal combustion engine is operating in a transient state, NOx emissions can be suppressed while also suppressing an increase in unburned fuel emissions and accidental fire.

In the present invention, if the actual charging pressure is lower than the target charging pressure when the internal combustion engine is operating in a transient state, the EGR gas amount may be controlled such that the lower the actual charging pressure, the smaller the EGR gas amount. Thus, it is possible to achieve an EGR gas amount more appropriate to the actual charging pressure.

The present invention may further include, in cases where a fuel injection valve in the internal combustion engine directly injects fuel into a cylinder: sub fuel injection execution means for performing a sub fuel injection at a timing ahead of a main fuel injection that is performed by the fuel injection valve at a timing near top dead center in a compression stroke; sub fuel injection timing control means for controlling an execution timing of the sub fuel injection is performed by the sub fuel injection execution means; and target sub fuel injection timing calculation means for calculating a target sub fuel injection timing that is a target value of the execution timing of the sub fuel injection, based on the operating state of the internal combustion engine.

In addition, if the actual charging pressure detected by the charging pressure detection means is lower than the target charging pressure when the internal combustion engine is in a transient operating state, the sub fuel injection timing control means may delay the execution timing of the sub fuel injection more than the target sub fuel injection timing.

Delaying the execution timing of the sub fuel injection shortens an interval between the execution timing of the sub fuel injection and the execution timing of the main fuel injection. Therefore, fuel injected by the sub fuel injection combusts more easily.

Therefore, according to the above, it is possible to suppress an increase in unburned fuel emissions and accidental fire in the case where the actual charging pressure is lower than the target charging pressure while the sub fuel injection is being performed.

Here, the intake air amount becomes smaller as the charging pressure becomes lower. Therefore, fuel injected by the sub fuel injection becomes more difficult to combust as the charging pressure becomes lower.

Hence, when the execution timing of the sub fuel injection is delayed more than the target sub fuel injection timing as in the above description, the execution timing of the sub fuel injection may be controlled such that the lower the actual charging pressure, the more delayed the execution timing of the sub fuel injection. Thus, fuel injected by the sub fuel injection can combust even more easily.

The present invention may further include: sub fuel injection amount control means for controlling a sub fuel injection amount; and target sub fuel injection amount calculation means for calculating a target sub fuel injection amount that is a target value of the sub fuel injection amount, based on the operating state of the internal combustion engine. Moreover, if the execution timing of the sub fuel injection is delayed more than the target sub fuel injection timing, the sub fuel injection amount control means may control the sub fuel injection amount to an amount smaller than the target sub fuel injection amount.

As described above, delaying the execution timing of the sub fuel injection shortens the interval between the execution timing of the sub fuel injection and the execution timing of the main fuel injection. Therefore, oxygen is consumed due to the combustion of fuel injected by the sub fuel injection, and it is highly possible that the main fuel injection is executed in such a state. As a consequence, there is a risk of an increase in particulate matter (hereinafter referred to as PM).

Hence, the oxygen amount consumed for the combustion of fuel injected by the sub fuel injection is decreased by decreasing the sub fuel injection amount. Thus, the generation of PM can be suppressed.

According to the above description, an increase in PM can therefore be suppressed in the case where the execution timing of the sub fuel injection is delayed more than the target sub fuel injection timing.

Here, the more delayed the execution timing of the sub fuel injection, i.e., the shorter the interval between the execution timing of the sub fuel injection and the execution timing of the main fuel injection, the more likely it is that oxygen will be lacking during the combustion of fuel injected by the main fuel injection. Therefore, the more delayed the execution timing of the sub fuel injection, the more likely it is that PM will increase.

Hence, when the sub fuel injection amount is controlled to an amount smaller than the target sub fuel injection amount as in the above description, the sub fuel injection amount may be controlled such that the more delayed the execution timing of the sub fuel injection, the smaller the sub fuel injection amount. Thus, the sub fuel injection amount can be set to an amount more appropriate to the interval between the execution timing of the sub fuel injection and the execution timing of the main fuel injection.

In cases where the charging pressure is raised to the target charging pressure as a result of a change in the operating state of the internal combustion engine, the actual charging pressure may temporarily exceed the target charging pressure. When the charging pressure increases, the intake air amount increases. Therefore, there is less possibility of an increase in unburned fuel emissions and accidental fire in the case where the EGR gas amount is increased.

Hence, in the present invention, if the actual charging pressure detected by the charging pressure detection means is higher than the target charging pressure when the internal combustion engine is in a transient operating state, the EGR gas amount control means may control the EGR gas amount to an amount larger than the target EGR gas amount.

According to this, in cases where the actual charging pressure is higher than the target charging pressure when the internal combustion engine is operating in a transient state, NOx emissions can be further suppressed while also suppressing an increase in unburned fuel emissions and accidental fire.

Also, in such case, when the actual charging pressure is higher than the target charging pressure when the internal combustion engine is operating in a transient state, the EGR gas amount may be controlled such that the higher the actual charging pressure, the larger the EGR gas amount. Thus, it is possible to achieve an EGR gas amount more appropriate to the actual charging pressure.

The present invention may further include, in cases where a fuel injection valve directly injects fuel into a cylinder of the internal combustion engine: fuel injection timing control means for controlling the fuel injection timing by the fuel injection valve; and target fuel injection timing calculation means for calculating a target fuel injection timing that is a target value of the fuel injection timing, based on the operating state of the internal combustion engine.

If the EGR gas amount is controlled to an amount larger than the target EGR gas amount, the fuel injection timing may be delayed more than the target fuel injection timing.

Delaying the fuel injection timing can raise the temperature of exhaust gas. Therefore, according to the above description, the oxidation of PM can be promoted in the case where the increase in PM caused by increasing the EGR gas amount.

Therefore, according to the above description, it is possible to suppress PM emissions from reaching the outside even when the EGR gas amount is controlled to an amount larger than the target EGR gas amount.

Here, the larger the EGR gas amount, the more likely it is that PM will increase. Also, delaying the fuel injection timing more means that the temperature of the exhaust gas can be made higher.

Hence, when the fuel injection timing is delayed more than the target fuel injection timing, the fuel injection timing control means may control the fuel injection timing such that the larger the EGR gas amount, the more delayed the fuel injection timing. According to this, the larger the EGR gas amount, the temperature of the exhaust gas can be made higher. Therefore, it is possible to further suppress PM emissions from reaching the outside.

The above and other objects, features and advantages of the present invention will become more readily apparent to those skilled in the art from the following detailed description of preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram schematically showing an internal combustion engine and an intake and exhaust system thereof according to an embodiment of the present invention; and

FIG. 2 is a flowchart showing a control routine for controlling the charging pressure, the EGR gas amount, the main fuel injection amount, the sub fuel injection amount, the main fuel injecting timing, and the sub fuel injection timing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Specific embodiments of an exhaust gas purification system for an internal combustion engine according to the present invention are described below based on the drawings.

FIG. 1 is a diagram schematically showing an internal combustion engine and an intake and exhaust system thereof according to the present embodiment. An internal combustion engine 1 is a diesel engine for driving a vehicle, and has four cylinders 2. The cylinders 2 are respectively provided with a fuel injection valve 3 that directly injects fuel into the cylinder 2.

The internal combustion engine 1 is connected with an intake manifold 5, and an exhaust manifold 7. An end of an intake passage 4 is in communication with the intake manifold 5, and an end of an exhaust passage 6 is in communication with the exhaust manifold 7.

A compressor 8a of a turbocharger (supercharger) 8 is installed in the intake passage 4. A turbine 8b of the turbocharger 8 is installed in the exhaust passage 6.

The intake manifold 5 is provided with a pressure sensor 14 that detects a charging pressure. In the present embodiment, the pressure sensor 14 corresponds to charging pressure detection means according to the present invention.

A particulate filter (hereinafter referred to as a filter) 9 that traps particulate matter (PM) in exhaust gas is provided downstream of the turbine 8b in the exhaust passage 6. The filter 9 supports a NOx storage-reduction catalyst (hereinafter referred to as a NOx catalyst). In addition, a temperature sensor 15 that detects an exhaust gas temperature is provided downstream of the filter 9 in the exhaust passage 6.

The internal combustion engine 1 according to the present embodiment has an EGR apparatus 11 that introduces at least part of the exhaust gas as EGR gas into an air intake system. The EGR apparatus 11 has an EGR passage 12 of which an end is in communication with the exhaust manifold 7 and another end is in communication with the intake manifold 5. EGR gas is introduced from the exhaust manifold 7 to the intake manifold 5 via the EGR passage 12. In addition, the EGR passage 12 is provided with an EGR valve 13 that controls an amount of EGR gas introduced to the intake manifold 5.

An electronic control unit (ECU) 10 is provided alongside the internal combustion engine 1. The ECU 10 is a unit that controls the operating state of the internal combustion engine 1 in accordance with requests from a driver and the operating conditions of the internal combustion engine 1. The ECU 10 is electrically connected with the pressure sensor 14, the temperature sensor 15, a crank position sensor 16, and an accelerator opening sensor 17. The crank position sensor 16 detects a crank angle of the internal combustion engine 1. The accelerator opening sensor 17 detects an accelerator opening of a vehicle mounted with the internal combustion engine 1. Output signals from the above sensors are input to the ECU 10.

The ECU 10 estimates a temperature of the filter 9 based on a detection value of the temperature sensor 15. Furthermore, the ECU 10 derives a rotational speed of the internal combustion engine 1 based on a detection value of the crank position sensor 16, and derives a load of the internal combustion engine 1 based on a detection value of the accelerator opening sensor 17.

The ECU 10 is also electrically connected with the fuel injection valve 3 and the EGR valve 13, and these are controlled by the ECU 10.

According to the present embodiment, a main fuel injection is performed by the fuel injection valve 3 at the timing near top dead center in the compression stroke, and a sub fuel injection is performed at the timing ahead of the main fuel injection during one combustion cycle. The main fuel injection amount, the sub fuel injection amount, the timing at which to perform the main fuel injection (hereinafter referred to as the main fuel injection timing), and the timing at which to perform the sub fuel injection (hereinafter referred to as the sub fuel injection timing) are controlled by the ECU 10.

According to the present embodiment, the ECU 10 controls the EGR gas amount by controlling the opening of the EGR valve 13. In the present embodiment, the EGR valve 13 corresponds to EGR gas amount control means according to the present invention.

Next, a control routine for controlling the charging pressure, the EGR gas amount, the main fuel injection amount, the sub fuel injection amount, the main fuel injection timing, and the sub fuel injection timing according to the present embodiment is described based on a flowchart shown in FIG. 2. The present routine is stored in advance in the ECU 10, and is repeatedly executed at a predetermined interval (for example, at every rotation of a crankshaft of the internal combustion engine1) during operation of the internal combustion engine 1.

In the present routine, first at S101, the ECU 10 detects the operating state (rotational speed, load, and the like) of the internal combustion engine 1.

Next, the ECU 10 proceeds to processing at S102, and calculates the target main fuel injection amount Qfmaint, the target sub fuel injection amount Qfsubt, the target main fuel injection timing tmaint, the target injection interval Δtinjt, the target charging pressure Pint, and the target EGR gas amount Qgt, based on the operating state of the internal combustion engine 1. Relationships between these values and the operating state of the internal combustion engine 1 are stored in advance in the ECU 10 as maps.

Note that the target injection interval Δtinjt is a target value for an injection interval that is the time between the main fuel injection timing and the sub fuel injection timing. In the present embodiment, the ECU 10 executing the processing at S102 corresponds to target EGR gas amount calculation means, target charging pressure calculation means, target sub fuel injection timing calculation means, target sub fuel injection amount calculation means, and target fuel injection timing calculation means.

Next the ECU 10 proceeds to processing at S103. If the internal combustion engine 1 is operating in a transient state, the above target values will change. However, the response delay for the charging pressure is larger than the response delay for the fuel injection amounts, the fuel injection timings, and the EGR gas amount. Thus in the present embodiment, as described later, the sub fuel injection amount, the main fuel injection timing, the sub fuel injection timing, and the EGR gas amount are corrected based on the charging pressure ratio RPin, which is a ratio (Pinm/Pint) of an actual charging pressure Pinm with respect to the target charging pressure Pint.

At S103, the ECU 10 calculates the charging pressure ratio RPin from the target charging pressure Pint and the actual charging pressure Pinm at that time as detected by the charging pressure sensor 14.

Next, the ECU 10 proceeds to processing at S104, and determines whether the charging pressure ratio RPin is smaller than one. If a positive determination is made at S104, then the ECU 10 proceeds to processing at S105; and if a negative determination is made, then the ECU 10 proceeds to processing at S112.

After proceeding to processing at S105, the ECU 10 calculates a correction coefficient a1 for correcting the EGR gas amount, a correction time b for correcting the injection interval, and a correction amount c for correcting the sub fuel injection amount, based on the charging pressure ratio RPin and a rotational speed Ne of the internal combustion engine 1.

Respective relationships of the correction coefficient a1, the correction time b, and the correction amount c with the charging pressure ratio RPin and the rotational speed Ne of the internal combustion engine 1 are stored in advance in the ECU 10 as first, second, and third maps. The ECU 10 respectively calculates the correction coefficient a1, the correction time b, and the correction amount c based on the maps.

In the first, second, and third maps, the charging pressure ratio RPin is a value equal to or smaller than one. In the first map, the correction coefficient a1 is one if the charging pressure ratio RPin is one, and the correction coefficient a1 is a positive value smaller than one if the charging pressure ratio RPin is smaller than one. And when the charging pressure ratio RPin is smaller than one, the correction coefficient a1 decreases as the charging pressure ratio RPin decreases, but increases as the rotational speed Ne of the internal combustion engine 1 increases.

In the second map, the correction time b is zero if the charging pressure ratio RPin is one, and the correction time b is a value larger than zero if the charging pressure ratio RPin is smaller than one. And when the charging pressure ratio RPin is smaller than one, the correction time b increases as the charging pressure ratio RPin decreases, but decreases as the rotational speed Ne of the internal combustion engine 1 increases.

In the third map, the correction amount c is zero if the charging pressure ratio RPin is one, and the correction amount c is a value larger than zero if the charging pressure ratio RPin is smaller than one. And when the charging pressure ratio RPin is smaller than one, the correction amount c increases as the charging pressure ratio RPin decreases, but decreases as the rotational speed Ne of the internal combustion engine 1 increases.

Next, the ECU 10 proceeds to processing at S106, and calculates a correction EGR gas amount Qgc1 by multiplying the correction coefficient a1 found at S105 and the target EGR gas amount Qgt. At this time, the correction EGR gas amount Qgc1 must be an amount smaller than the target EGR gas amount Qgt.

The ECU 10 then proceeds to processing at S107, and controls the opening of the EGR valve 13 so that the EGR gas amount introduced to the intake manifold 5 is equal to the correction EGR gas amount Qgc1. In other words, the opening of the EGR valve 13 is set to an opening that is smaller than when the EGR gas amount is controlled to the target EGR gas amount Qgt.

The ECU 10 then proceeds to processing at S108, and calculates a correction injection interval Δtinjc by subtracting the correction time b found at S105 from the target injection interval Δtinjc.

Next, the ECU 10 proceeds to processing at S109, and corrects the sub fuel injection timing so that the injection interval is equal to the correction injection interval Δtinjc. In other words, the sub fuel injection timing is delayed more than when the injection interval is controlled to the target injection interval Δtinjt (at which time the sub fuel injection timing corresponds to the target sub fuel injection timing according to the present invention).

The ECU 10 then proceeds to processing at S110, and calculates a correction sub fuel injection amount Qsubc by subtracting the correction amount c found at S105 from a target sub fuel injection amount Qfsubt.

The ECU 10 then proceeds to processing at S111, and controls the sub fuel injection amount to the correction sub fuel injection amount Qsubc. In other words, the sub fuel injection amount is controlled to an amount smaller than the target sub fuel injection amount Qsubt. The ECU 10 subsequently ends execution of the present routine.

Meanwhile, after proceeding to processing at S112, the ECU 10 determines whether the charging pressure ratio RPin is larger than one. If a positive determination is made at S112, then the ECU 10 proceeds to processing at S113. However, if a negative determination is made at S112, then the ECU 10 ends execution of the present routine. When execution of the present routine is ended at this time, the ECU 10 judges that there is no need to correct the main fuel injection amount, the sub fuel injection amount, the main fuel injection timing, the injection interval, and the EGR gas amount, and controls these to the target values calculated at S102.

At S113, the ECU 10 determines whether a temperature Tc of the filter 9 is equal to or higher than a predetermined temperature Tca. Here, the predetermined temperature Tca is a temperature equal to or higher than a lower limit value of an activation temperature of the NOx catalyst supported by the filter 9, and is a preset temperature. In other words, if the temperature of the filter 9 is equal to or higher than the predetermined temperature Tca, then the supported NOx catalyst can be judged as activated. If a negative determination is made at S113, then the ECU 10 proceeds to processing at S114. However, if a positive determination is made at S113, then the ECU 10 ends execution of the present routine. When execution of the present routine is ended at this time, similar to the case of a negative determination at S112, the ECU 10 judges that there is no need to correct the main fuel injection amount, the sub fuel injection amount, the main fuel injection timing, the injection interval, and the EGR gas amount, and controls these to the target values calculated at S102.

At S114, the ECU 10 calculates a correction coefficient a2 for correcting the EGR gas amount and a correction time d for correcting the main fuel injection timing, based on the charging pressure ratio RPin and the rotational speed of the internal combustion engine 1.

Respective relationships of the correction coefficient a2 and the correction time d with the charging pressure ratio RPin and the rotational speed of the internal combustion engine 1 are stored in advance in the ECU 10 as fourth and fifth maps. The ECU 10 respectively calculates the correction coefficient a2 and the correction time d based on the maps.

In the fourth and fifth maps, the charging pressure ratio RPin is a value equal to or larger than one. In the fourth map, the correction coefficient a2 is one if the charging pressure ratio RPin is one. When the charging pressure ratio RPin is larger than one, the correction coefficient a2 increases as the charging pressure ratio RPin increases, and also increases as the rotational speed Ne of the internal combustion engine 1 increases.

In the fifth map, the correction time d is zero if the charging pressure ratio RPin is one. When the charging pressure ratio RPin is larger than one, the correction time d increases as the charging pressure ratio RPin increases, and also increases as the rotational speed Ne of the internal combustion engine 1 increase.

Next, the ECU 10 proceeds to processing at S115, and calculates a correction EGR gas amount Qgc2 by multiplying the correction coefficient a2 found at S114 and the target EGR gas amount Qgt. At this time, the correction EGR gas amount Qgc2 must be an amount larger than the target EGR gas amount Qgt.

The ECU 10 then proceeds to processing at S116, and controls the opening of the EGR valve 13 so that the EGR gas amount introduced to the intake manifold 5 is equal to the correction EGR gas amount Qgc2. In other words, the opening of the EGR valve 13 is set to an opening that is larger than when the EGR gas amount is controlled to the target EGR gas amount Qgt.

The ECU 10 then proceeds to processing at S117, and calculates a correction main fuel injection timing tmainc by adding the correction time d found at S114 to the target main fuel injection timing tmaint.

Next, the ECU 10 proceeds to processing at S118, and controls the main fuel injection timing to the correction main fuel injection timing tmainc. In other words, the main fuel injection timing is delayed more than the target main fuel injection timing tmaint. Note that in such case, the sub fuel injection timing is controlled so that the injection interval equals the target injection interval Δtinjt. Thereafter, the ECU 10 ends execution of the present routine.

According to the routine described above, if the charging pressure ratio RPin becomes smaller than one due to the internal combustion engine 1 operating in a transient state, i.e., if the actual charging pressure Pinm is lower than the target charging pressure Pint, then the EGR gas amount is corrected to an amount smaller than the target EGR gas amount Qgt. Thus, when the internal combustion engine 1 is operating in a transient state, it is possible to suppress the EGR gas amount introduced to the intake manifold 5 becoming an excessively large amount with respect to the actual charging pressure Pinm. In other words, it is possible to suppress the EGR gas amount becoming excessively larger than the actual intake air amount.

Thus according to the present embodiment, when the internal combustion engine 1 is operating in a transient state, NOx emissions can be suppressed while also suppressing an increase in unburned fuel emissions and accidental fire.

According to the above routine, when the EGR gas amount is corrected to an amount smaller than the target EGR gas amount Qgt, the EGR gas amount is controlled such that the lower the actual charging pressure Pinm, the smaller the EGR gas amount. Thus, it is possible to achieve an EGR gas amount more appropriate to the actual charging pressure.

In addition, the intake air amount increases as the rotational speed of the internal combustion engine 1 increases. Therefore, according to the above routine, when the EGR gas amount is corrected to an amount smaller than the target EGR gas amount Qgt, the EGR gas amount is controlled such that the lower the rotational speed Ne of the internal combustion engine 1, the smaller the EGR gas amount.

According to the above routine, if the actual charging pressure Pinm is lower than the target charging pressure Pint, then the injection interval is corrected to a time shorter than the target injection interval Δtinjt by delaying the sub fuel injection timing. Thus, fuel injected by the sub fuel injection combusts more easily. Consequently, it is possible to suppress an increase in unburned fuel emissions and the occurrence of accidental fires caused as a result of it being harder to combust fuel injected by the sub fuel injection.

According to the above routine, when the injection interval is corrected to a time shorter than the target injection interval Δtinjt, the injection interval is controlled such that the lower the actual charging pressure Pinm, the shorter the injection interval. In other words, the smaller the intake air amount, the more delayed the sub fuel injection timing. Thus, fuel injected by the sub fuel injection can combust even more easily.

According to the above routine, in cases where the injection interval is corrected to a time shorter than the target injection interval Δtinjt, the intake air amount decreases as the rotational speed Ne of the internal combustion engine 1 decreases. Therefore, the injection interval is controlled to an even shorter time.

According to the above routine, if the actual charging pressure Pinm is smaller than the target charging pressure Pint, then the sub fuel injection amount is controlled to an amount smaller than the target sub fuel injection amount Qsubt. In other words, if the injection interval is corrected to a time shorter than the target injection interval Δtinjt, then the sub fuel injection amount is corrected to an amount smaller than the target sub fuel injection amount Qsubt.

With a shortened injection interval, oxygen is consumed due to the combustion of fuel injected by the sub fuel injection, and it is highly possible that the main fuel injection is executed in such a state. At this time, it is possible to decrease the oxygen amount consumed for the combustion of fuel injected by the sub fuel injection through decreasing the sub fuel injection amount. That is, the amount of oxygen usable for the combustion of fuel injected by the main fuel injection can be increased. As a consequence, by correcting the sub fuel injection amount to an amount smaller than the target sub fuel injection amount Qsubt, an increase in PM can be suppressed in the case where the injection interval is shorter than the target injection interval Δtinjt.

According to the above routine, when the sub fuel injection amount is corrected to an amount smaller than the target sub fuel injection amount Qsubt, the sub fuel injection amount is controlled such that the lower the actual charging pressure Pinm, the smaller the sub fuel injection amount. In other words, the sub fuel injection amount is controlled such that the shorter the injection interval, the smaller the sub fuel injection amount. Therefore, it is possible to suppress a lack of oxygen required for the combustion of fuel injected by the main fuel injection. As a consequence, by controlling the sub fuel injection amount as described above, the sub fuel injection amount can be set to an amount more appropriate to the injection interval, and thus, an increase in PM can be further suppressed.

As explained earlier, according to the above routine, when the injection interval is corrected to a time shorter than the target injection interval Δtinjt, the injection interval is controlled such that the lower the rotational speed Ne of the internal combustion engine 1, the shorter the injection interval. Therefore, when the sub fuel injection amount is corrected to an amount smaller than the target sub fuel injection amount Qsubt, the sub fuel injection amount is controlled such that the lower the rotational speed Ne of the internal combustion engine 1, i.e., the shorter the injection interval, the smaller the sub fuel injection amount.

According to the above routine, if the charging pressure ratio RPin is larger than one due to the internal combustion engine 1 operating in a transient state, i.e., if the actual charging pressure Pinm is higher than the target charging pressure Pint and the temperature Tc of the filter 9 is lower than the predetermined temperature Tca, then the EGR gas amount is corrected to an amount larger than the target EGR gas amount Qgt.

Due to an increase in the intake air amount resulting from a higher charging pressure, there is less likelihood of an increase in unburned fuel emissions and accidental fire, in the case where the EGR gas amount has been increased. Also, NOx emissions can be further decreased with further increases in the EGR gas amount. As a consequence, by correcting the EGR gas amount to an amount larger than the target EGR gas amount Qgt when the actual charging pressure Pinm is higher than the target charging pressure Pint, NOx emissions can be further decreased while also suppressing an increase in unburned fuel emissions and accidental fire.

According to the above routine, when the EGR gas amount is corrected to an amount larger than the target EGR gas amount Qgt, the EGR gas amount is controlled such that the higher the actual charging pressure Pinm, the larger the EGR gas amount. Thus, it is possible to achieve an EGR gas amount more appropriate to the actual charging pressure.

The higher the rotational speed of the internal combustion engine 1, the larger the intake air amount. Therefore, according to the above routine, when the EGR gas amount is corrected to an amount larger than the target EGR gas amount Qgt, the EGR gas amount is controlled such that the higher the rotational speed Ne of the internal combustion engine 1, the larger the EGR gas amount.

Furthermore, in the above routine, if the actual charging pressure Pinm is higher than the target charging pressure Pint and the temperature Tc of the filter 9 is lower than the predetermined temperature Tca, then the main fuel injection timing is delayed more than the target main fuel injection timing tmaint. In other words, when the EGR gas amount is corrected to an amount larger than the target EGR gas amount Qgt, the main fuel injection timing is delayed more than the target main fuel injection timing tmaint.

Delaying the main fuel injection timing makes it possible to raise the temperature of exhaust gas. Therefore, in the case where there is a likelihood of an increase in PM due to increasing the EGR gas amount over the target EGR gas amount Qgt, delaying the main fuel injection timing more than the target main fuel injection timing tmaint makes it possible to promote oxidation of the PM. As a consequence, it is possible to suppress PM emissions from reaching the outside.

According to the above routine, when the main fuel injection timing is delayed more than the target main fuel injection timing tmaint, the higher the actual charging pressure Pinm, the more the main fuel injection timing is delayed. In other words, the larger the EGR gas amount, the more delayed the main fuel injection timing. Thus, the temperature of exhaust gas can be increased as the EGR gas amount increases. Therefore, the temperature of exhaust gas can be made higher with further increases in the EGR gas amount. As a consequence, by controlling the main fuel injection timing as described above, it is possible to further suppress PM emissions from reaching the outside.

As explained earlier, according to the above routine, when the EGR gas amount is corrected to an amount larger than the target EGR gas amount Qgt, the EGR gas amount is controlled such that the higher the rotational speed Ne of the internal combustion engine 1, the larger the EGR gas amount. Therefore, when the main fuel injection timing is delayed more than the target main fuel injection timing tmaint, the higher the rotational speed Ne of the internal combustion engine 1, i.e., the larger the EGR gas amount, the more delayed the main fuel injection timing.

Note that if the temperature of the filter 9 is equal to or higher than the predetermined temperature Tca, the NOx catalyst supported by the filter 9 is activated. Therefore, it is possible to store NOx in exhaust gas in the NOx catalyst. Thus, in the present embodiment, in the case where the temperature of the filter 9 is equal to or higher than the predetermined temperature Tca, even when the actual charging pressure Pinm is higher than the target charging pressure Pint, there is no correction of the EGR gas amount to an amount larger than the target EGR gas amount Qgt. This consequently suppresses an increase in PM.

While the invention has been described in terms of preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modifications within the spirit and scope of the appended claims.

INDUSTRIAL APPLICABILITY

According to the present invention, an exhaust gas purification system for an internal combustion engine that has a supercharger and an EGR apparatus is capable of suppressing NOx emissions while also suppressing an increase in unburned fuel emissions and accidental fire when the internal combustion engine is in a transient operating state.

CLAIMS

1. An exhaust gas purification system for an internal combustion engine, characterized by comprising:

an EGR apparatus for introducing at least part of the exhaust gas of said internal combustion engine as EGR gas into an air intake system of said internal combustion engine;

a supercharger for supercharging intake air using energy from the exhaust gas of said internal combustion engine;

EGR gas amount control means for controlling the EGR gas amount introduced into said air intake system of said internal combustion engine by said EGR apparatus;

target EGR gas amount calculation means for calculating a target EGR gas amount that is a target value of the EGR gas amount, based on the operating state of said internal combustion engine;

target charging pressure calculation means for calculating a target charging pressure that is a target value of the charging pressure, based on the operating state of said internal combustion engine; and

charging pressure detection means for detecting the actual charging pressure, wherein

if the actual charging pressure detected by said charging pressure detection means is lower than the target charging pressure when said internal combustion engine is in a transient operating state, said EGR gas amount control means controls the EGR gas amount to an amount smaller than the target EGR gas amount.

2. The exhaust gas purification system for an internal combustion engine according to claim 1, when the EGR gas amount is controlled to an amount smaller than the target EGR gas amount, said EGR gas amount control means controls the EGR gas amount such that the lower the actual charging pressure, the smaller the EGR gas amount.

3. The exhaust gas purification system for an internal combustion engine according to claim 1 or 2, further comprising:

a fuel injection valve for directly injecting fuel into a cylinder of said internal combustion engine;

sub fuel injection execution means for performing a sub fuel injection at a timing ahead of a main fuel injection that is performed by said fuel injection valve at a timing near top dead center in a compression stroke;

sub fuel injection timing control means for controlling an execution timing of the sub fuel injection is performed by said sub fuel injection execution means; and

target sub fuel injection timing calculation means for calculating a target sub fuel injection timing that is a target value of the execution timing of the sub fuel injection, based on the operating state of said internal combustion engine, wherein

if the actual charging pressure detected by said charging pressure detection means is lower than the target charging pressure when said internal combustion engine is in a transient operating state, said sub fuel injection timing control means delays the execution timing of the sub fuel injection more than the target sub fuel injection timing.

4. The exhaust gas purification system for an internal combustion engine according to claim 3, wherein when the execution timing of the sub fuel injection is delayed more than the target sub fuel injection timing, said sub fuel injection timing control means controls the execution timing of the sub fuel injection such that the lower the actual charging pressure, the more delayed the execution timing of the sub fuel injection.

5. The exhaust gas purification system for an internal combustion engine according to claim 3 or 4, further comprising:

sub fuel injection amount control means for controlling the sub fuel injection amount; and

target sub fuel injection amount calculation means for calculating a target sub fuel injection amount that is a target value of the sub fuel injection amount, based on the operating state of said internal combustion engine, wherein

if the execution timing of the sub fuel injection is delayed more than the target sub fuel injection timing, said sub fuel injection amount control means controls the sub fuel injection amount to an amount smaller than the target sub fuel injection amount.

6. The exhaust gas purification system for an internal combustion engine according to claim 5, wherein when the sub fuel injection amount is controlled to an amount smaller than the target sub fuel injection amount, said sub fuel injection amount control means controls the sub fuel injection amount such that the more delayed the execution timing of the sub fuel injection, the smaller the sub fuel injection amount.

7. The exhaust gas purification system for an internal combustion engine according to claim 1, wherein if the actual charging pressure detected by said charging pressure detection means is higher than the target charging pressure when said internal combustion engine is in a transient operating state, said EGR gas amount control means controls the EGR gas amount to an amount larger than the target EGR gas amount.

8. The exhaust gas purification system for an internal combustion engine according to claim 7, wherein when the EGR gas amount is controlled to an amount larger than the target EGR gas amount, said EGR gas amount control means controls the EGR gas amount such that the higher the actual charging pressure, the larger the EGR gas amount.

9. The exhaust gas purification system for an internal combustion engine according to claim 7 or 8, further comprising:

a fuel injection valve for directly injecting fuel into a cylinder of said internal combustion engine;

fuel injection timing control means for controlling a fuel injection timing by said fuel injection valve; and

target fuel injection timing calculation means for calculating a target fuel injection timing that is a target value of the fuel injection timing, based on the operating state of said internal combustion engine, wherein

if the EGR gas amount is controlled to an amount larger than the target EGR gas amount, said fuel injection timing control means delays the fuel injection timing more than the target fuel injection timing.

10. The exhaust gas purification system for an internal combustion engine according to claim 9, wherein when the fuel

injection timing is delayed more than the target fuel injection timing, said fuel injection timing control means controls the fuel injection timing such that the larger the EGR gas amount, the more delayed the fuel injection timing.

1／2

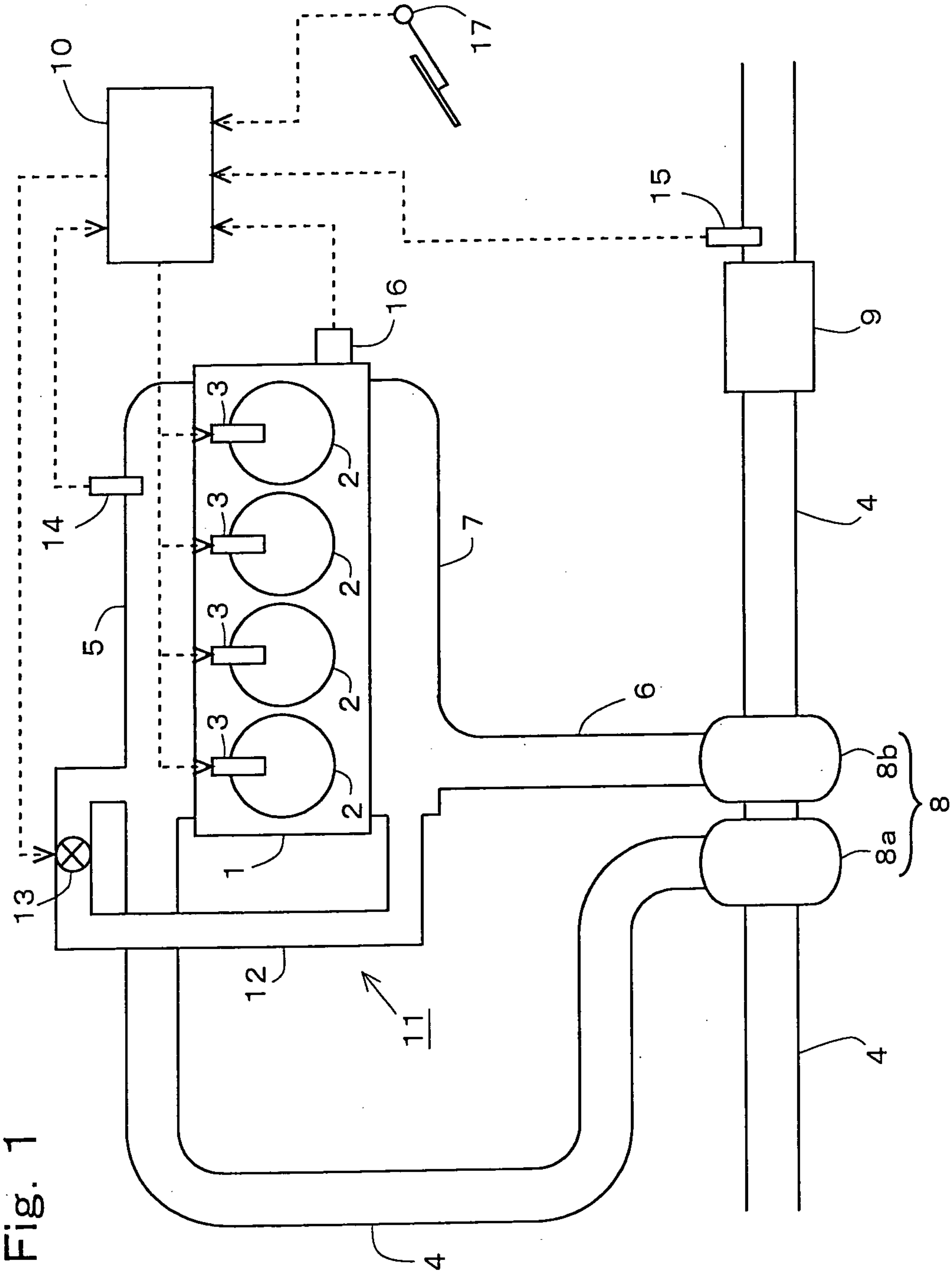


Fig. 1

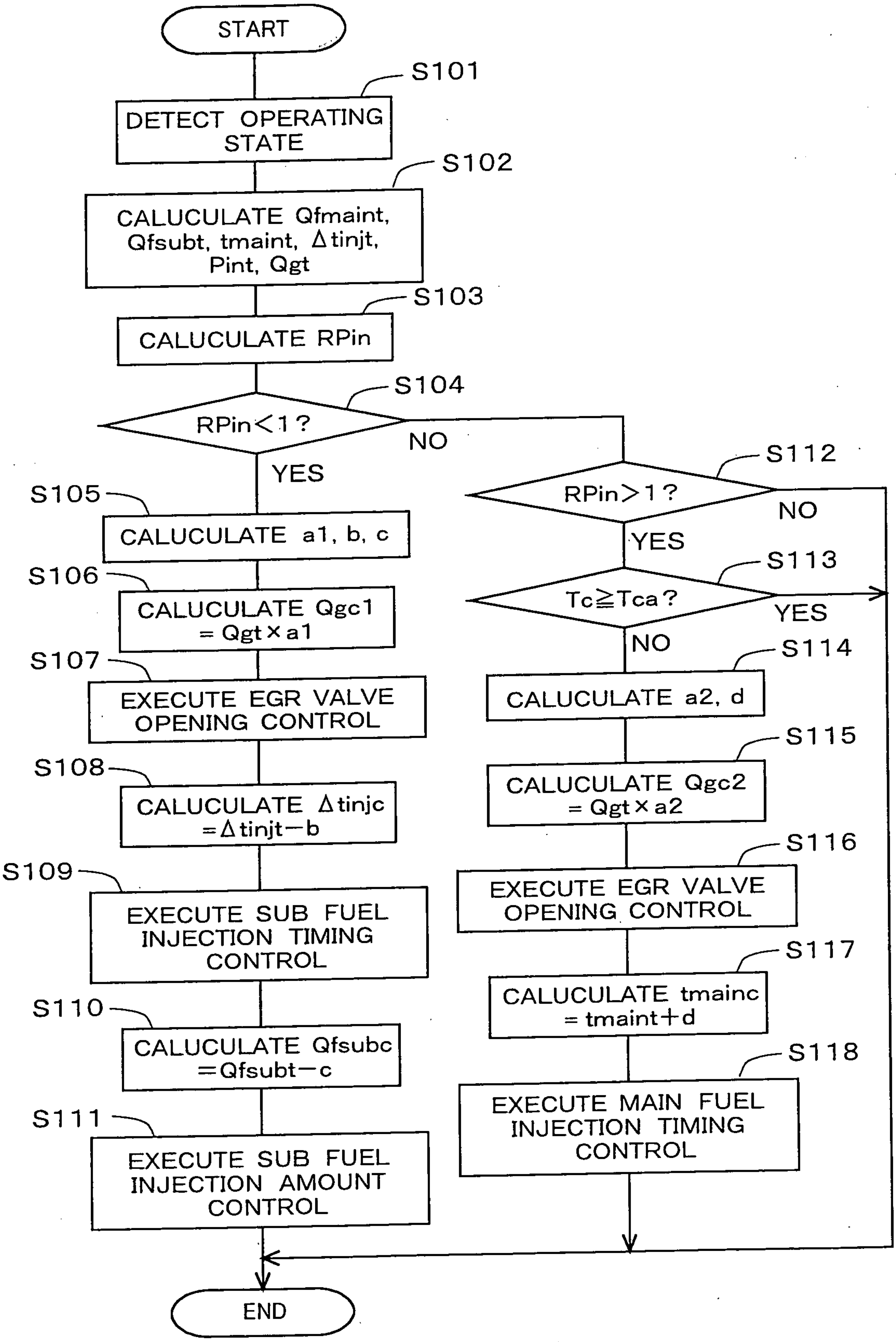

START
S101
DETECT OPERATING STATE
S102
CALUCULATE Qfmaint, Qfsubt, tmaint, Δtinjt, Pint, Qgt
S103
CALUCULATE RPin
S104
RPin<1?
NO
YES
S105
CALUCULATE a1, b, c
S106
CALUCULATE Qgc1 = Qgt×a1
S107
EXECUTE EGR VALVE OPENING CONTROL
S108
CALUCULATE Δtinjc =Δtinjt−b
S109
EXECUTE SUB FUEL INJECTION TIMING CONTROL
S110
CALUCULATE Qfsubc =Qfsubt−c
S111
EXECUTE SUB FUEL INJECTION AMOUNT CONTROL
S112
RPin>1?
NO
YES
S113
Tc≧Tca?
YES
NO
S114
CALUCULATE a2, d
S115
CALUCULATE Qgc2 = Qgt×a2
S116
EXECUTE EGR VALVE OPENING CONTROL
S117
CALUCULATE tmainc = tmaint+d
S118
EXECUTE MAIN FUEL INJECTION TIMING CONTROL
END

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2007/062185

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/00 F02D41/40

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 practical, 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	DE 196 28 235 A1 (NISSAN MOTOR [JP]) 16 January 1997 (1997-01-16) abstract; claims 13-15; figures 37-42,43A-F column 27, line 13 - column 29, line 31	1,2,7,8
X	DE 10 2005 014735 A1 (GEN MOTORS CORP [US]) 3 November 2005 (2005-11-03) abstract; claims 15-19; figure 2 paragraphs [0018] - [0027]	1,2,7,8
X	EP 1 077 319 A2 (MAZDA MOTOR [JP]) 21 February 2001 (2001-02-21) abstract; claims 1,2,7,8,12,13; figures 8,12 paragraphs [0032] - [0036]	1,7

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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
20 September 2007	27/09/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van der Staay, Frank

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2007/062185

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 980 973 A2 (TOYOTA MOTOR CO LTD [JP]) 23 February 2000 (2000-02-23) abstract; claims 1-3 paragraphs [0040] - [0060]	3-6
A	EP 1 221 544 A2 (NISSAN MOTOR [JP]) 10 July 2002 (2002-07-10) abstract; figures 55-77A,77B paragraphs [0277] - [0335]	3-6
A	EP 0 965 740 A2 (NISSAN MOTOR [JP]) 22 December 1999 (1999-12-22) abstract; claims 1,2; figure 8 paragraph [0022]	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2007/062185

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
DE 19628235	A1	16-01-1997	NONE			
DE 102005014735	A1	03-11-2005	US	2005228573	A1	13-10-2005
EP 1077319	A2	21-02-2001	DE	60019514	D1	25-05-2005
			DE	60019514	T2	18-08-2005
EP 0980973	A2	23-02-2000	DE	69925343	D1	23-06-2005
			DE	69925343	T2	19-01-2006
			JP	3292152	B2	17-06-2002
			JP	2000064891	A	29-02-2000
EP 1221544	A2	10-07-2002	DE	60117675	T2	07-09-2006
			US	2002124828	A1	12-09-2002
EP 0965740	A2	22-12-1999	DE	69921023	D1	18-11-2004
			DE	69921023	T2	24-02-2005
			JP	3430923	B2	28-07-2003
			JP	2000002122	A	07-01-2000
			US	6148616	A	21-11-2000