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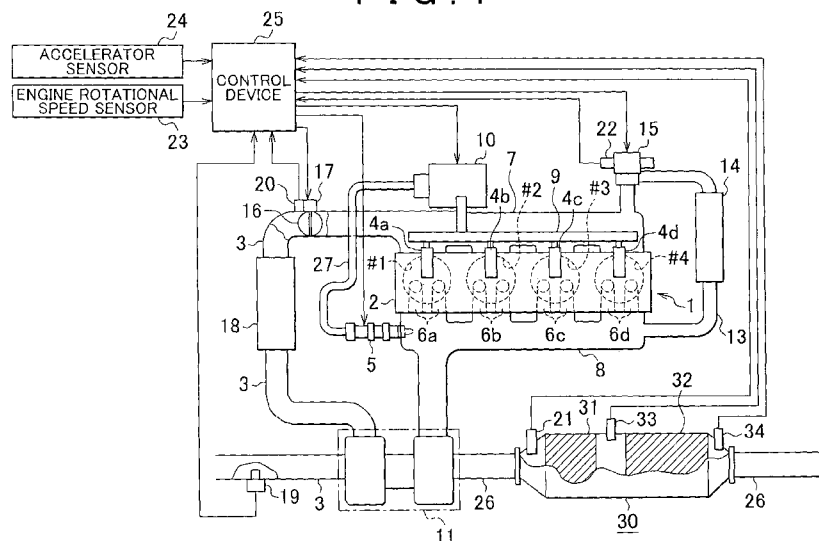
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(54) Title: EXHAUST GAS CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE

FIG. 1



(57) **Abstract:** An exhaust gas control apparatus for an internal combustion engine (1) is equipped with an exhaust gas control member (31) that is provided in an exhaust passage (26), an addition agent supply mechanism (5) that supplies an addition agent to the exhaust gas control member (31), an exhaust gas recirculation mechanism (13) that recirculates exhaust gas to an intake passage, and a control unit (25) that controls a recirculation amount of exhaust gas recirculated by the exhaust gas recirculation mechanism (13) on the basis of an engine operation state. When a clogging amount at a front end face of the exhaust gas control member (31) has exceeded a predetermined threshold (α), the control unit (25) reduces the recirculation amount to a value that is smaller than when the clogging amount has not exceeded the threshold(α).

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EXHAUST GAS CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to an exhaust gas control apparatus for an internal combustion engine.

2. Description of Related Art

10 [0002] In recent years, an exhaust system of some internal combustion engines is provided with an exhaust gas control member such as a filter, which collects particulate matter (PM) in exhaust gas. In some cases, this exhaust gas control member is supplied with an addition agent with a view to, for example, recovering the function of exhaust gas control. For example, in an apparatus described in Japanese Patent Application
15 Publication No. 2007-23792 (JP 2007-23792 A), when the collected PM is deposited in the filter, the pressure loss in the filter increases. Therefore, the collected PM is burned out by supplying the filter with fuel as an addition agent, so that the filter is recovered.

[0003] The addition agent supplied to the exhaust gas control member is basically gasified and burned out through combustion, an oxidation reaction or the like in
20 the exhaust gas control member. However, when part of the addition agent directly adheres to a front end face of the exhaust gas control member, which is at a relatively low temperature, instead of being burned out through combustion, an oxidation reaction or the like, the addition agent that has adhered to the front end face serves as a binder to adsorb the PM and the like. As a result, the front end face of the exhaust gas control member
25 may be clogged with the PM.

SUMMARY OF THE INVENTION

[0004] This invention provides an exhaust gas control apparatus for an internal

combustion engine that suitably reduces the clogging of a front end face of an exhaust gas control member with PM.

[0005] One aspect of the invention relates to an exhaust gas control apparatus for an internal combustion engine that includes an exhaust gas control member that is provided in an exhaust passage, an addition agent supply mechanism that supplies an addition agent to the exhaust gas control member, an exhaust gas recirculation mechanism that recirculates exhaust gas to an intake passage, and a control unit that controls a recirculation amount of exhaust gas recirculated by the exhaust gas recirculation mechanism on the basis of an engine operation state. When a clogging amount at a front end face of the exhaust gas control member has exceeded a predetermined threshold, the control unit reduces the recirculation amount to a value that is smaller than when the clogging amount has not exceeded the threshold.

[0006] According to this configuration, when the clogging amount at the front end face has become larger than the threshold, the recirculation amount of exhaust gas is reduced, so that the flow rate of exhaust gas flowing into the exhaust gas control member increases. When the flow rate of exhaust gas thus increases, the flow velocity of exhaust gas increases. Therefore, the PM with which the front end face of the exhaust gas control member is clogged is blown away by a dynamic pressure of exhaust gas. In consequence, according to this configuration, the clogging of the front end face of the exhaust gas control member with the PM can be suitably reduced.

[0007] The clogging of the front end face of the exhaust gas control member can also be reduced by raising the temperature of exhaust gas. However, the temperature of exhaust gas cannot always be thus raised. For example, when the load of the engine is low, namely, when the temperature of exhaust gas is relatively low, it is difficult to raise the temperature of exhaust gas. On the other hand, in the aforementioned configuration, the flow rate of exhaust gas is increased, and this processing can be performed even when, for example, the load of the engine is low. In consequence, according to this configuration, the number of opportunities to perform the processing of reducing the clogging can be increased.

[0008] Further, the amount of exhaust gas flowing into the exhaust gas control member is increased by reducing the recirculation amount of exhaust gas. Therefore, the clogging of the front end face can be reduced without separately providing a mechanism that serves solely to increase the flow rate of exhaust gas.

5 [0009] In the foregoing aspect of the invention, the control unit may calculate the clogging amount by obtaining a difference between an amount of increase in the clogging amount that is calculated on the basis of an engine rotational speed and a fuel injection amount, and an amount of decrease in the clogging amount that is calculated on the basis of an intake air amount.

10 [0010] The PM with which the front end face of the exhaust gas control member is clogged originates from fuel for the engine. Basically, the clogging amount at the front end face increases as the fuel injection amount increases. Further, as the engine rotational speed increases, the amount of exhaust gas discharged per unit time increases, and the discharge amount of PM increases. Therefore, basically, the clogging amount at
15 the front end face increases as the engine rotational speed increases. On the other hand, as the intake air amount increases, the flow rate of exhaust gas flowing through the exhaust passage increases, and hence, the likelihood of PM being blown away from the front end face increases. Accordingly, the clogging amount at the front end face decreases as the intake air amount increases. Thus, in this configuration, the amount of
20 increase in the clogging amount is calculated on the basis of the engine rotational speed and the fuel injection amount, the amount of decrease in the clogging amount is calculated on the basis of the intake air amount, and the amount of clogging of the front end face with the PM is calculated by obtaining a difference between this increase amount and this decrease amount. According to this configuration, the clogging amount
25 at the front end face can be suitably estimated.

[0011] In the foregoing aspect of the invention, the control unit may increase the amount of increase in the clogging amount as an atmospheric pressure decreases. The likelihood of soot, which is one component constituting the PM, being discharged from the engine increases as the atmospheric pressure decreases and as the oxygen density

decreases. Thus, in this configuration, the calculated amount of increase in the clogging amount is increased as the atmospheric pressure decreases. Thus, the influence of the atmospheric pressure on the amount of increase in the clogging amount can be suitably corrected.

5 **[0012]** In the foregoing aspect of the invention, the control unit may increase the amount of decrease in the clogging amount as the temperature of the front end face of the exhaust gas control member rises.

10 **[0013]** The PM that has adhered to the front end face is urged to be oxidized and burned out, and the amount of the PM decreases, as the temperature of the front end face of the exhaust gas control member rises. Thus, in this configuration, the calculated amount of decrease in the clogging amount is increased as the temperature of the front end face of the exhaust gas control member rises. Thus, the influence of the temperature of the front end face of the exhaust gas control member on the amount of decrease in the clogging amount can be suitably corrected.

15 **[0014]** In the foregoing aspect of the invention, the control unit may increase an amount of decrease in the recirculation amount as the engine rotational speed decreases.

20 **[0015]** The amount of exhaust gas discharged from the internal combustion engine decreases as the engine rotational speed decreases. Therefore, the effect of reducing the clogging of the front end face by exhaust gas weakens. In this respect, according to this configuration, as the engine rotational speed decreases, the amount of decrease in the exhaust gas recirculation amount is increased, so that the flow rate of exhaust gas flowing into the exhaust gas control member increases. Therefore, according to this configuration, the clogging of the front end face can be suitably reduced regardless of the engine rotational speed.

25 **[0016]** In the foregoing aspect of the invention, the control unit may increase an amount of decrease in the recirculation amount as the clogging amount increases.

[0017] According to this configuration, the flow rate of exhaust gas flowing into the exhaust gas control member is increased as the clogging amount increases and as the amount of the PM that needs to be blown away increases. Accordingly, the amount of

decrease in the recirculation amount can be appropriately set in accordance with the clogging amount.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0018]** Features, advantages, and technical and industrial significance of an exemplary embodiment of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic view showing an internal combustion engine to which an exhaust gas control apparatus for an internal combustion engine according to an
10 embodiment of the invention is applied, and a peripheral configuration of the internal combustion engine;

FIG. 2 is a flowchart showing a procedure of a processing of calculating a clogging amount;

FIG. 3 is a graph showing a relationship between an engine rotational speed and a
15 basic clogging amount, and a relationship between a fuel injection amount and the basic clogging amount;

FIG. 4 is a graph showing a relationship between an atmospheric pressure and the basic clogging amount;

FIG. 5 is a graph showing a relationship between an air amount ratio and an air
20 amount correction coefficient;

FIG. 6 is a graph showing a relationship between an intake air amount and a clogging decrease amount, and a relationship between a front end face temperature and the clogging decrease amount;

FIG. 7 is a flowchart showing a procedure of a processing of reducing the clogging
25 amount;

FIG. 8 is a graph showing a relationship between the engine rotational speed and an EGR decrease amount; and

FIG. 9 is a graph showing a relationship between the clogging amount and a clogging correction coefficient.

DETAILED DESCRIPTION OF EMBODIMENT

[0019] Hereinafter, one embodiment in which an exhaust gas control apparatus for an internal combustion engine according to this invention is embodied as an exhaust gas control apparatus for a diesel engine will be described with reference to FIGS. 1 to 9 all together. As shown in FIG. 1, an engine 1 is provided with a plurality of cylinders #1 to #4. A cylinder head 2 is provided with a plurality of fuel injection valves 4a to 4d. These fuel injection valves 4a to 4d inject fuel into combustion chambers of the cylinders #1 to #4 respectively. Further, in the cylinder head 2, intake ports for introducing outside air into the cylinders and exhaust ports 6a to 6d for discharging combustion gas to the outside of the cylinders are provided corresponding to the cylinders #1 to #4 respectively.

[0020] The fuel injection valves 4a to 4d are connected to a common rail 9 in which high-pressure fuel is accumulated. The common rail 9 is connected to a supply pump 10. The supply pump 10 sucks in fuel in a fuel tank, and supplies high-pressure fuel to the common rail 9. The high-pressure fuel supplied to the common rail 9 is injected from the fuel injection valves 4a to 4d into the cylinders respectively, when the fuel injection valves 4a to 4d are opened.

[0021] An intake manifold 7 is connected to the intake ports. The intake manifold 7 is connected to an intake passage 3. An intake throttle valve 16 for adjusting the amount of intake air is provided in this intake passage 3.

[0022] An exhaust manifold 8 is connected to the exhaust ports 6a to 6d. The exhaust manifold 8 is connected to an exhaust passage 26. A catalyst device 30 that purifies exhaust gas components is provided in the exhaust passage 26. An oxidation catalyst 31 and a filter 32 are disposed inside this catalyst device 30 in series with a direction in which exhaust gas flows.

[0023] A catalyst that subjects HC in exhaust gas to an oxidation treatment is supported on the oxidation catalyst 31. Further, the filter 32 is a member that collects a particulate matter (PM) in exhaust gas, and is constituted by a porous ceramic. The PM

in exhaust gas is collected when passing through a porous wall.

[0024] Further, the cylinder head 2 is provided with a fuel addition valve 5 to supply the oxidation catalyst 31 and the filter 32 with fuel as an addition agent. This fuel addition valve 5 is connected to the supply pump 10 via a fuel supply pipe 27, and 5. fuel is injected from the fuel addition valve 5 toward the interior of the exhaust port 6d of the fourth cylinder #4. This injected fuel reaches the oxidation catalyst 31 and the filter 32 together with exhaust gas. It should be noted that the position at which the fuel addition valve 5 is disposed can also be appropriately changed as long as the fuel addition valve 5 is located upstream of the catalyst device 30 in an exhaust system. Further, the 10 fuel addition valve 5, the fuel supply pipe 27, and the supply pump 10 constitute the aforementioned addition agent supply mechanism.

[0025] In addition, the engine 1 is equipped with an exhaust gas recirculation mechanism (hereinafter referred to as an EGR device). This EGR device is a device that introduces part of exhaust gas into intake air to lower the combustion temperature in the 15 cylinders and hence reduce the generation amount of NOx. This device includes an EGR passage 13 through which the intake passage 3 and the exhaust passage 26 communicate with each other, an EGR valve 15 that is provided in the EGR passage 13, an EGR cooler 14, and the like. By adjusting the opening degree of the EGR valve 15, the EGR valve 15 adjusts the recirculation amount of exhaust gas introduced from the 20 exhaust passage 26 into the intake passage 3, namely, an EGR amount EK. The EGR cooler 14 lowers the temperature of exhaust gas flowing in the EGR passage 13. Further, the EGR valve 15 is provided with an EGR valve opening degree sensor 22. An opening degree of the EGR valve 15, namely, an EGR valve opening degree EA is detected by this EGR valve opening degree sensor 22. The opening degree of the EGR 25 valve 15 is so controlled as to become equal to an opening degree corresponding to an EGR rate that is set on the basis of an engine operation state. It should be noted that as the EGR rate increases, the opening degree of the EGR valve 15 is increased, and hence the EGR amount EK is increased. The EGR rate is a value that is obtained according to an expression: "amount of recirculated exhaust gas flowing into cylinders / (amount of

fresh air flowing into cylinders + amount of recirculated exhaust gas flowing into cylinders)".

[0026] Further, the engine 1 is equipped with a turbocharger 11 that supercharges intake air introduced into the cylinders with the aid of an exhaust gas pressure. An intercooler 18 is provided in the intake passage 3 at a position between an intake-side turbine and the intake throttle valve 16, to lower the temperature of intake air whose temperature rises through the supercharging by this turbocharger 11.

[0027] The engine 1 is provided with various sensors for detecting an engine operation state. For example, an airflow meter 19 detects an intake air amount GA in the intake passage 3. A throttle valve sensor 20 detects a throttle valve opening degree TA as an opening degree of the intake throttle valve 16. A first temperature sensor 33, which is provided downstream of the oxidation catalyst 31 with respect to the flow of exhaust gas, measures a first exhaust gas temperature Th_1 as a temperature of exhaust gas that has just flowed through the oxidation catalyst 31. A second temperature sensor 34 is provided downstream of the filter 32 with respect to the flow of exhaust gas, and the filter 32 is provided downstream of the oxidation catalyst 31 with respect to the flow of exhaust gas. The second temperature sensor 34 detects a second exhaust gas temperature Th_2 as a temperature of exhaust gas that has just flowed through the filter 32. An engine rotational speed sensor 23 detects a rotational speed of a crankshaft, namely, an engine rotational speed NE. An accelerator sensor 24 detects a depression amount of an accelerator pedal, namely, an accelerator operation amount ACCP. An air-fuel ratio sensor 21 detects an air-fuel ratio λ of exhaust gas.

[0028] Outputs of these various sensors are input to a control device 25. This control device 25 is mainly constituted by a microcomputer that includes a central processing unit (a CPU), a read only memory (a ROM) in which various programs, maps and the like are stored in advance, a random access memory (a RAM) that temporarily stores a calculation result of the CPU or the like, a timer counter, an input interface, an output interface, and the like. Besides, this control device 25 performs various kinds of control of the engine 1, for example, fuel injection amount control and fuel injection

timing control for the fuel injection valves 4a to 4d, discharge pressure control for the supply pump 10, drive amount control for an actuator 17 that opens/closes the intake throttle valve 16, opening degree control for the EGR valve 15, injection control for the fuel addition valve 5, and the like. It should be noted that this control device 25 constitutes the aforementioned control unit that controls the recirculation amount of exhaust gas recirculated by the exhaust gas recirculation mechanism on the basis of the engine operation state. Further, various kinds of exhaust gas control, such as a recovery processing for a filter that causes the PM collected by the aforementioned filter 32 to burn, and the like, are also performed by the control device 25.

[0029] Because the recovery processing for the filter 32 is known, the outline thereof will be described hereinafter. In this recovery processing, a PM deposition amount of the filter 32 is estimated on the basis of an engine operation state or the like. Then, when the estimated PM deposition amount exceeds a predetermined value, fuel as an addition agent is injected from the fuel addition valve 5. This injected fuel is oxidized by the oxidation catalyst 31, and exhaust gas is heated up by this oxidation heat. When the exhaust gas heated up by the oxidation catalyst 31 flows into the filter 32, the temperature of the filter 32 is urged to rise and then reaches a temperature that allows the recovery relating to PM. Thus, the PM collected by the filter 32 is oxidized or burned, and the amount of the PM decreases. When the amount of the PM collected by the filter 32 decreases through this heat-up processing and the PM deposition amount decreases to a predetermined value, the addition of fuel from the fuel addition valve 5 is ended, and the recovery processing for the filter 32 ends.

[0030] The addition agent injected from the fuel addition valve 5 is oxidized while passing through the oxidation catalyst 31. Accordingly, the temperature of a front end face of the oxidation catalyst 31 is relatively low. Thus, part of the addition agent may directly adhere to the front end face of the oxidation catalyst 31, which is at a relatively low temperature, instead of being burnt out through combustion, an oxidation reaction or the like. When the addition agent thus adheres to the front end face, this addition agent serves as a binder to adsorb PM and the like, and the front end face of the

oxidation catalyst 31 may be clogged with PM.

[0031] When the front end face of the oxidation catalyst 31 is thus clogged, the area of the oxidation catalyst 31, through which the addition agent passes, decreases. Therefore, the amount of the addition agent oxidized by the oxidation catalyst 31 decreases. As a result, the amount of the addition agent, which directly passes through the oxidation catalyst 31 without being oxidized, increases. When the amount of the addition agent, which passes through the oxidation catalyst 31 instead of being oxidized, thus increases, the exhaust gas flowing into the filter 32 is insufficiently heated up, and the recovery processing for the filter 32 is suspended.

10 [0032] Further, when the front end face of the oxidation catalyst 31 is clogged, the flow of exhaust gas passing through the oxidation catalyst 31 tends to be drifted. As a result, exhaust gas may become unlikely to come into contact with the first temperature sensor 33, which is provided downstream of the oxidation catalyst 31 with respect to the flow of exhaust gas. When exhaust gas thus becomes unlikely to come into contact with the first temperature sensor 33, the temperature of exhaust gas that is detected by the first temperature sensor 33 becomes inaccurate. Therefore, for example, exhaust gas temperature control performed during the recovery processing may be adversely affected.

[0033] Thus, in this embodiment of the invention, the clogging of the front end face of the oxidation catalyst 31 with PM is reduced by performing a processing of calculating a clogging amount and a processing of reducing the clogging amount as will be described below. FIG. 2 shows a procedure of the processing of calculating a clogging amount M at the front end face of the oxidation catalyst 31. This processing is repeatedly performed by the control device 25 on a predetermined cycle.

25 [0034] When this processing is started, a basic clogging amount Mb as a basic value of the clogging amount M is first calculated on the basis of the engine rotational speed NE, a fuel injection amount Q, and an atmospheric pressure P (S100). In this case, as shown in FIG. 3, the basic clogging amount Mb is calculated to increase as the engine rotational speed NE increases or as the fuel injection amount Q increases. Further, as shown in FIG. 4, the basic clogging amount Mb is calculated to increase as the

atmospheric pressure P decreases even if the engine rotational speed NE and the fuel injection amount Q remain unchanged.

[0035] Subsequently, an air amount correction coefficient Ka is calculated on the basis of an air amount ratio GAH (S110). This air amount ratio GAH is a value that is obtained as "an intake air amount GA / a target air amount GAp ". That is, the air amount ratio GAH is a value indicating a ratio of the current intake air amount GA to the target air amount GAp that is set on the basis of an engine operation state. Accordingly, when the intake air amount GA and the target air amount GAp coincide with each other as during a steady state of the engine or the like, the air amount ratio GAH is "1". Further, when the intake air amount GA is smaller than the target air amount GAp as during a transient state of the engine or the like, the air amount ratio GAH is a value smaller than "1". Besides, as shown in FIG. 5, the air amount correction coefficient Ka is set to increase as the air amount ratio GAH decreases, namely, as the amount of the insufficiency of the intake air amount GA with respect to the target air amount GAp increases.

[0036] Subsequently, the basic clogging amount Mb is multiplied by the air amount correction coefficient Ka to calculate a clogging increase amount Mi (S120). This clogging increase amount Mi is calculated as an amount by which the clogging amount M has increased during a period between the last performance cycle of the processing and the current performance cycle of the processing.

[0037] Subsequently, a clogging decrease amount Md is calculated on the basis of the intake air amount GA and the front end face temperature Thm (S130). The front end face temperature Thm is a temperature of the front end face of the oxidation catalyst 31, and is estimated from the first exhaust gas temperature Thi detected by the first temperature sensor 33. It should be noted that a temperature sensor may be provided in the vicinity of the front end face of the oxidation catalyst 31 to directly measure the front end face temperature Thm . Further, the clogging decrease amount Md is calculated as an amount by which the clogging amount M has decreased during a period between the last performance cycle of the processing and the current performance cycle of the

processing. Besides, as shown in FIG. 6, the clogging decrease amount M_d is calculated to increase as the intake air amount GA increases or as the front end face temperature Th_m rises.

[0038] Subsequently, the clogging amount M in the current performance cycle of the processing is calculated (S140), and the processing is ended. In this step S140, the clogging amount M in the current performance cycle of the processing is calculated by adding the clogging increase amount M_i calculated in the aforementioned step S120 to the clogging amount M calculated in the last performance cycle of the processing and subtracting the clogging decrease amount M_d calculated in the aforementioned step S130 from the clogging amount M calculated in the last performance cycle of the processing.

[0039] Next, a procedure of a processing of reducing the clogging amount will be described with reference to FIG. 7. It should be noted that this reduction processing is also repeatedly performed on a predetermined cycle by the control device 25. When the processing is started, it is first determined whether or not the clogging amount M obtained in the foregoing calculation processing has exceeded a threshold α (S200). This threshold α is a value used for determining whether or not the current clogging amount M is such a value as to cause an inconvenience as described above. Then, when the clogging amount M is equal to or smaller than the threshold α (S200: NO), the processing is ended. When a negative determination is thus made in step S200, a basic EGR rate E_b is set on the basis of an engine operation state (e.g., an engine rotational speed and an engine load). A target EGR rate E_p is set on the basis of this basic EGR rate E_b , so that the opening degree of the EGR valve 15 is controlled. It should be noted that the basic EGR rate E_b is set to decrease as the engine operation state shifts toward a high-load high-rotational speed operation state.

[0040] On the other hand, when the clogging amount M has exceeded the threshold α (S200: YES), an inconvenience may be caused by the clogging of the front end face. Therefore, the processing starting from step S210 is performed to reduce such clogging.

[0041] In step S210, an EGR decrease value E_d is calculated on the basis of the

engine rotational speed NE . In this case, as shown in FIG. 8, the EGR decrease value Ed is set to reduce as the engine rotational speed NE increases.

[0042] Subsequently, a clogging correction coefficient Kc is calculated on the basis of the clogging amount M (S220). In this case, as shown in FIG. 9, the clogging
5 correction coefficient Kc is increased toward "1" as the clogging amount M increases, until the clogging amount M reaches a predetermined amount $M1$. Then, the clogging correction coefficient Kc is fixed to "1" after the clogging amount M has reached the predetermined amount $M1$.

[0043] Subsequently, an EGR correction value H is calculated (S230). In this
10 case, the EGR correction value H is calculated by multiplying the EGR decrease value Ed calculated in the aforementioned step S210 by the clogging correction coefficient Kc calculated in the aforementioned step S220. Accordingly, the EGR correction value H is set to reduce as the engine rotational speed NE increases. Further, the EGR correction value H is set to increase as the clogging amount M increases, until the clogging amount
15 M reaches the aforementioned predetermined amount $M1$. Then, the EGR decrease value Ed is directly set as the EGR correction value H after the clogging amount M has reached the aforementioned predetermined amount $M1$.

[0044] Subsequently, the target EGR rate Ep is calculated on the basis of the
aforementioned basic EGR rate Eb and the aforementioned EGR correction value H
20 (S240). In this step S240, a value obtained by subtracting the EGR correction value H from the basic EGR rate Eb is set as the target EGR rate Ep . Accordingly, as the EGR correction value H increases, the target EGR rate Ep decreases, and the EGR amount EK decreases. When the EGR amount EK thus decreases, the amount of exhaust gas returned to the intake passage decreases, and hence, the flow rate of exhaust gas flowing
25 into the oxidation catalyst 31 increases.

[0045] Next, the advantageous effects of this embodiment of the invention will be described. When it is determined in step S200 of FIG. 7 that the clogging amount M has not exceeded the threshold α , the target EGR rate Ep corresponding to the basic EGR rate Eb is set. On the other hand, when it is determined in step S200 that the clogging

amount M has become larger than the threshold α , a value obtained by subtracting the EGR correction value H from the basic EGR rate E_b is set as the target EGR rate E_p in step S240. Accordingly, when the clogging amount M has exceeded the threshold α , the target EGR rate E_p is reduced to a value that is smaller than when the clogging amount M has not exceeded the threshold α . When the target EGR rate E_p is thus reduced, the recirculation amount of exhaust gas decreases, and hence the flow rate of exhaust gas flowing into the oxidation catalyst 31 increases. When the flow rate of exhaust gas thus increases, the flow velocity of exhaust gas increases, so that the PM with which the front end face of the oxidation catalyst 31 is clogged is blown away by a dynamic pressure of exhaust gas. Accordingly, the clogging of the front end face of the oxidation catalyst 31 with PM is reduced.

[0046] It should be noted that the clogging of the front end face of the oxidation catalyst 31 can also be reduced by raising the temperature of exhaust gas. However, the temperature of exhaust gas cannot always be thus raised. For example, when the load of the engine is low, namely, when the temperature of exhaust gas is relatively low, it is difficult to raise the temperature of exhaust gas, and hence, the number of opportunities to perform the processing of reducing the clogging of the front end face is limited to a certain extent. On the other hand, in this embodiment of the invention, the flow rate of exhaust gas is increased, and the processing as described above can be performed even when, for example, the load of the engine is low. Accordingly, the number of opportunities to perform the processing of reducing the clogging of the front end face can be increased.

[0047] Further, the flow rate of exhaust gas flowing into the oxidation catalyst 31 is increased by reducing the EGR amount E_K . Thus, the clogging of the front end face can be reduced without separately providing a mechanism that serves solely to increase the flow rate of exhaust gas.

[0048] Further, the PM with which the front end face of the oxidation catalyst 31 is clogged originates from fuel for the engine. Basically, the clogging amount at the front end face (i.e., the amount of clogging of the front end face) increases as the fuel

injection amount Q increases. Further, as the engine rotational speed NE increases, the amount of exhaust gas discharged per unit time increases, and the discharge amount of PM increases as well. Therefore, basically, the clogging amount at the front end face increases as the engine rotational speed increases. Accordingly, in the embodiment of the invention, as the engine rotational speed NE increases or as the fuel injection amount Q increases, the basic clogging amount M_b is increased to increase the clogging increase amount M_i . On the other hand, as the intake air amount GA increases, the flow rate of exhaust gas flowing through the exhaust passage 26 increases, and hence, the likelihood of PM being blown away from the front end face increases. Accordingly, the clogging amount at the front end face decreases as the intake air amount GA increases. Thus, in this embodiment of the invention, the clogging increase amount M_i is calculated on the basis of the engine rotational speed NE and the fuel injection amount Q , the clogging decrease amount M_d is calculated on the basis of the intake air amount GA , and the amount M of clogging of the front end face with PM (i.e., the clogging amount M at the front end face) is calculated by obtaining a difference between this clogging increase amount M_i and this clogging decrease amount M_d . Accordingly, the clogging amount M at the front end face can be suitably estimated.

[0049] The likelihood of soot, which is one component constituting the PM, being discharged from the engine increases as the atmospheric pressure decreases and as the oxygen density decreases. Thus, as the atmospheric pressure P decreases, the basic clogging amount M_b is increased to increase the clogging increase amount M_i . Thus, the influence of the atmospheric pressure P on the clogging increase amount M_i can be appropriately corrected.

[0050] Further, the likelihood of soot being generated, and the likelihood of the clogging amount M increasing increase as the *aforementioned air amount ratio* GAH decreases, namely, as the amount of the insufficiency of the intake air amount GA with respect to the target air amount GAp increases. Thus, as the air amount ratio GAH (i.e., the ratio of the intake air amount GA to the target air amount GAp) decreases, the air amount correction coefficient Ka is increased to increase the clogging increase amount

Mi calculated in step S120. Accordingly, it is possible to enhance the accuracy in estimating the clogging increase amount Mi at the time when the engine is in a transient state in which the intake air amount GA is likely to be insufficient with respect to the target air amount GAp.

5 [0051] Further, as the temperature of the front end face of the oxidation catalyst 31 rises, the PM that has adhered to the front end face is urged to be oxidized and burned out, and the amount of the PM decreases. Thus, in this embodiment of the invention, the calculated clogging decrease amount Md is increased as the front end face temperature Thm of the oxidation catalyst 31 rises. Thus, the influence of the front end
10 face temperature Thm on the clogging decrease amount Md can be appropriately corrected.

 [0052] Further, as the engine rotational speed NE decreases, the amount of exhaust gas discharged from the engine 1 decreases, and hence, the effect of reducing the clogging of the front end face by exhaust gas weakens. In this respect, in this
15 embodiment of the invention, as the engine rotational speed NE decreases, the EGR decrease value Ed is increased to increase the amount of decrease in the exhaust gas recirculation amount, so that the flow rate of exhaust gas flowing into the oxidation catalyst 31 increases. Therefore, the clogging of the front end face can be appropriately reduced regardless of the engine rotational speed NE.

20 [0053] Further, as the clogging amount M increases, the clogging correction coefficient Kc is increased to make the EGR correction value H larger, so that the target EGR rate Ep decreases to make the EGR amount EK smaller. That is, the amount of decrease in the exhaust gas recirculation amount (the EGR amount EK) is increased as the clogging amount M increases. Accordingly, the flow rate of exhaust gas flowing
25 into the oxidation catalyst 31 is increased as the clogging amount M increases and as the amount of the PM that needs to be blown away increases. In this manner, the amount of decrease in the exhaust gas recirculation amount can be appropriately set in accordance with the clogging amount M.

 [0054] As described above, according to this embodiment of the invention, the

following effects can be obtained. (1) When the clogging amount M at the front end face of the oxidation catalyst 31 has exceeded the threshold α , the EGR amount EK is reduced.

[0055] Accordingly, the clogging of the front end face of the oxidation catalyst 31 with PM can be suitably reduced. Further, the number of opportunities to perform the processing of reducing the clogging can be increased as well. Besides, the clogging of the front end face of the oxidation catalyst 31 can be reduced without separately providing a mechanism that serves solely to increase the flow rate of exhaust gas.

[0056] (2) The clogging amount M is calculated by obtaining a difference between the clogging increase amount M_i that is calculated on the basis of the engine rotational speed NE and the fuel injection amount Q , and the clogging decrease amount M_d that is calculated on the basis of the intake air amount GA . Thus, the clogging amount M at the front end face can be suitably estimated.

[0057] (3) The clogging increase amount M_i is increased as the atmospheric pressure P decreases. Thus, the influence of the atmospheric pressure P on the amount of increase in the clogging amount M can be suitably corrected. (4) The clogging decrease amount M_d is increased as the front end face temperature Thm of the oxidation catalyst 31 rises. Thus, the influence of the front end face temperature Thm of the oxidation catalyst 31 on the amount of decrease in the clogging amount M can be suitably corrected.

[0058] (5) The EGR decrease value Ed is increased as the engine rotational speed NE decreases. Thus, the clogging of the front end face can be suitably reduced regardless of the engine rotational speed NE . (6) By increasing the clogging correction coefficient Kc as the clogging amount M increases, the amount of decrease in the EGR amount EK is increased as the clogging amount M increases. Accordingly, the amount of decrease in the EGR amount EK can be appropriately set in accordance with the clogging amount M .

[0059] It should be noted that the foregoing embodiment of the invention can also be implemented after being modified as follows. In the aforementioned step S210,

the EGR decrease value E_d is calculated on the basis of the engine rotational speed NE . It should be noted herein that, in general, the EGR amount E_K is often increased when the fuel injection amount is small, namely, when the engine load is low. Thus, the EGR decrease value E_d by which the EGR amount E_K is reduced can be increased as the engine load decreases. Thus, as a parameter used for setting the EGR decrease value E_d , the engine load may be used, in addition to the engine rotational speed NE . In this case, the EGR decrease value E_d is set to increase as the engine load decreases (e.g., as the fuel injection amount Q decreases). According to this modified example, a larger amount of exhaust gas can be introduced into the oxidation catalyst 31 than in the case where the EGR decrease value E_d is calculated on the basis of only the engine rotational speed NE .

[0060] The clogging amount M may be obtained in another manner. For example, a pressure difference between a region upstream of the oxidation catalyst 31 with respect to the flow of exhaust gas and a region downstream of the oxidation catalyst 31 with respect to the flow of exhaust gas may be measured, and the clogging amount may be estimated to increase as this pressure difference increases.

[0061] The clogging increase amount M_i is obtained from the engine rotational speed NE , the fuel injection amount Q , and the atmospheric pressure P . However, the atmospheric pressure P may be omitted, and the clogging increase amount M_i may be obtained from the engine rotational speed NE and the fuel injection amount Q .

[0062] The clogging decrease amount M_d is obtained on the basis of the intake air amount GA and the front end face temperature Th_m . However, the front end face temperature Th_m may be omitted, and the clogging decrease amount M_d may be obtained only from the intake air amount GA . The EGR decrease value E_d is variably set on the basis of the engine rotational speed NE . However, the EGR decrease value E_d may be appropriately set to a constant value.

[0063] The value of the clogging correction coefficient K_c is fixed after the clogging amount M has exceeded the predetermined amount M_1 . However, the clogging correction coefficient K_c may be increased as the clogging amount M increases.

[0064] The calculation of the clogging correction coefficient K_c may be omitted.

The calculation of the air amount correction coefficient K_a may be omitted. Fuel for heating up the filter 32 is supplied from the fuel addition valve 5. Alternatively, the filter 32 may be heated up by carrying out post injection (fuel injection that is carried out again at a timing later than a timing when main injection is carried out) by the fuel injection valves 4a to 4d. Further, the supply of fuel by the fuel addition valve 5 and the supply of fuel through post injection may be realized in a compatible manner.

[0065] The aforementioned addition agent is fuel for the engine 1. However, any addition agent may be used as long as a similar effect can be obtained. The number of catalysts or filters disposed in the catalyst device 30 can be arbitrarily set. For example, even in the case where only the filter 32 is provided, the front end face thereof may be clogged due to the addition of the addition agent. However, through the application of the invention, even in the case where only the filter 32 is provided, the clogging of the front end face thereof can be reduced.

[0066] An NO_x control catalyst may be provided instead of the oxidation catalyst 31. The aforementioned engine 1 is an inline four-cylinder internal combustion engine. However, the invention is also applicable in the same manner to an exhaust gas control apparatus for an internal combustion engine that includes one, two, three, five or more cylinders or includes cylinders arranged in a different manner.

CLAIMS:

1. An exhaust gas control apparatus for an internal combustion engine, comprising:
 - an exhaust gas control member that is provided in an exhaust passage;
 - an addition agent supply mechanism that supplies an addition agent to the exhaust gas control member;
 - an exhaust gas recirculation mechanism that recirculates exhaust gas to an intake passage; and
 - a control unit that controls a recirculation amount of exhaust gas recirculated by the exhaust gas recirculation mechanism on a basis of an engine operation state, wherein
 - when a clogging amount at a front end face of the exhaust gas control member has exceeded a predetermined threshold, the control unit reduces the recirculation amount to a value that is smaller than when the clogging amount has not exceeded the threshold.
2. The exhaust gas control apparatus according to claim 1, wherein the control unit calculates the clogging amount by obtaining a difference between an amount of increase in the clogging amount that is calculated on a basis of an engine rotational speed and a fuel injection amount, and an amount of decrease in the clogging amount that is calculated on a basis of an intake air amount.
3. The exhaust gas control apparatus according to claim 2, wherein the control unit increases the amount of increase in the clogging amount as the engine rotational speed increases or as the fuel injection amount increases.
4. The exhaust gas control apparatus according to claim 2 or 3, wherein the control unit increases the amount of decrease in the clogging amount as the intake air amount increases.

5. The exhaust gas control apparatus according to any one of claims 2 to 4, wherein the control unit increases the amount of increase in the clogging amount as an atmospheric pressure decreases.

6. The exhaust gas control apparatus according to any one of claims 2 to 5, wherein the control unit increases the amount of increase in the clogging amount as a ratio of the intake air amount to a target air amount decreases.

7. The exhaust gas control apparatus according to any one of claims 2 to 6, wherein the control unit increases the amount of decrease in the clogging amount as a temperature of the front end face of the exhaust gas control member rises.

8. The exhaust gas control apparatus according to any one of claims 1 to 7, wherein the control unit reduces an amount of decrease in the recirculation amount as an engine rotational speed increases.

9. The exhaust gas control apparatus according to any one of claims 1 to 8, wherein the control unit increases an amount of decrease in the recirculation amount as the clogging amount increases.

10. The exhaust gas control apparatus according to claim 8 or 9, wherein the control unit increases the amount of decrease in the recirculation amount as an engine load decreases.

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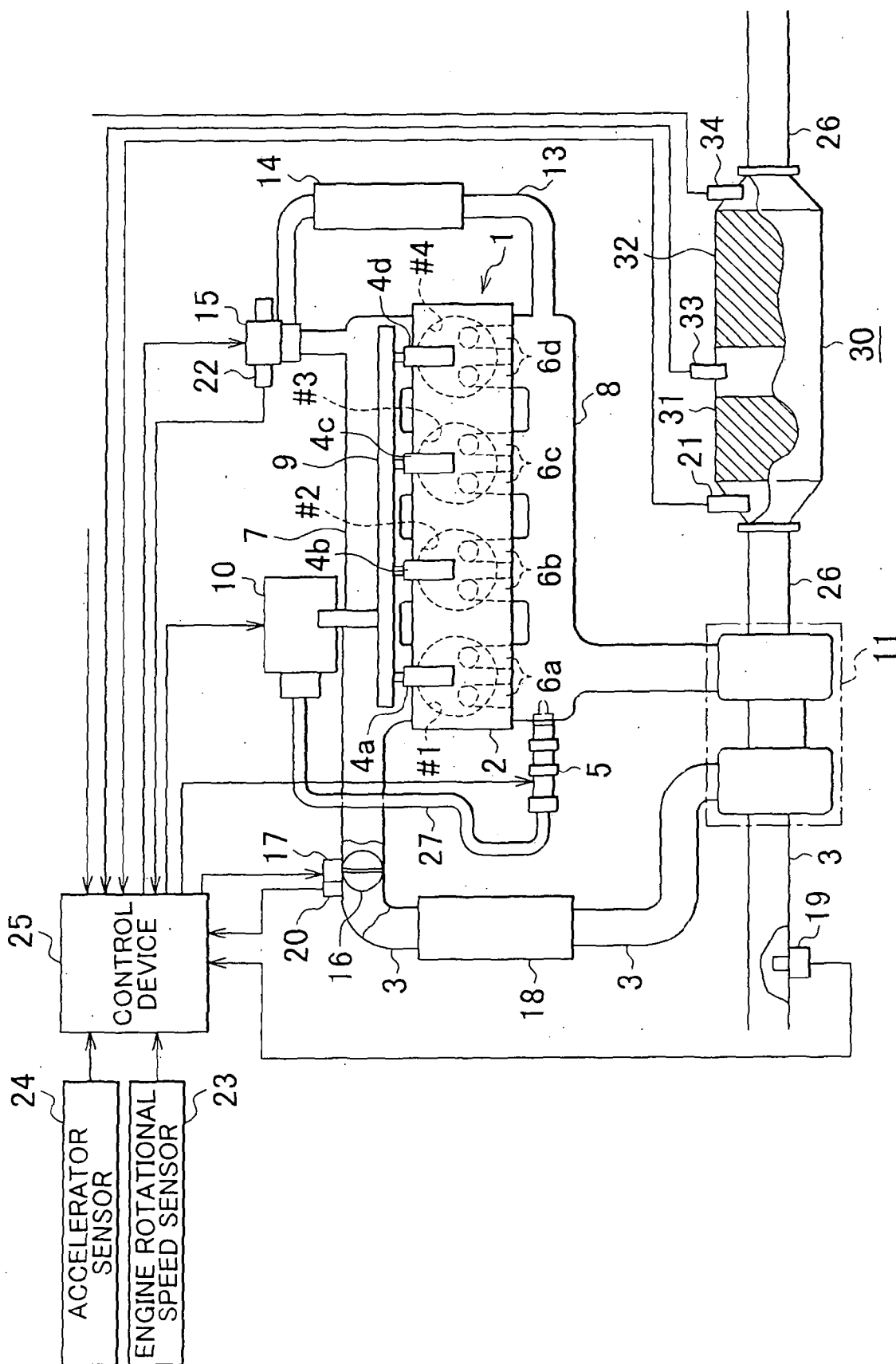


FIG. 2

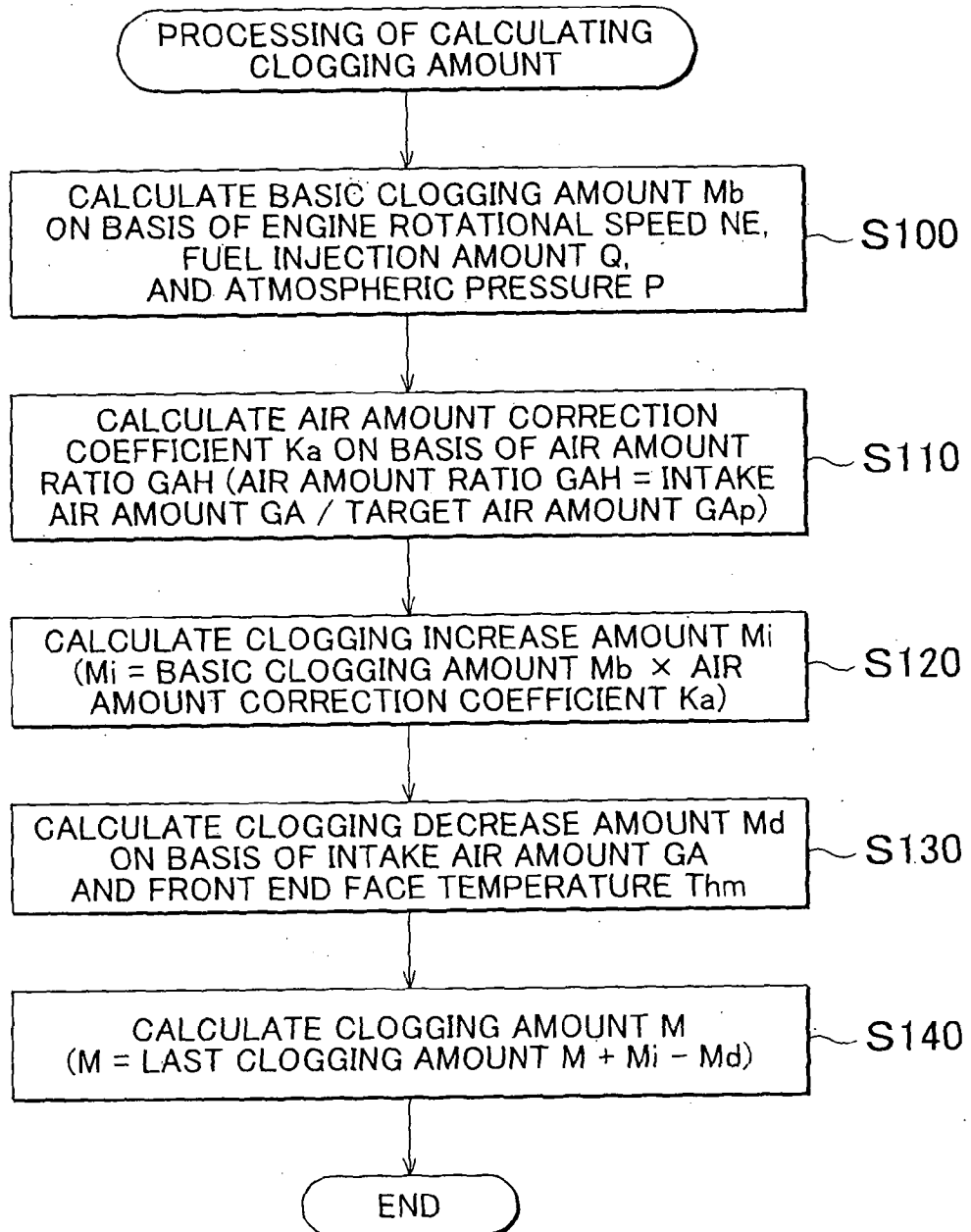


FIG. 3

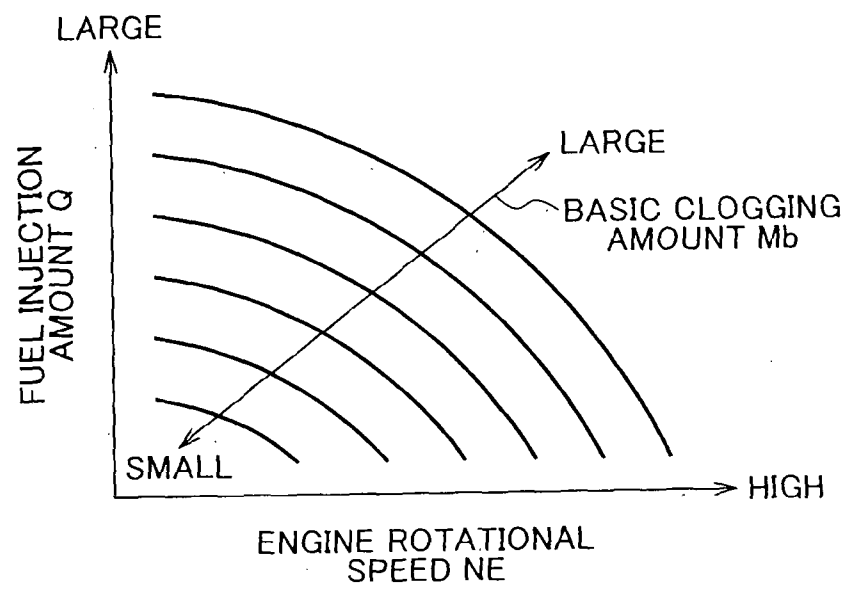


FIG. 4

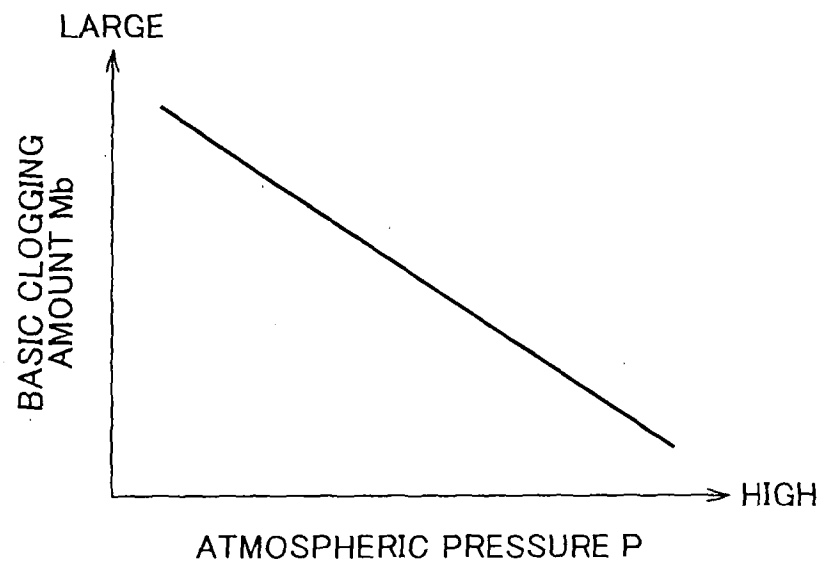


FIG. 5

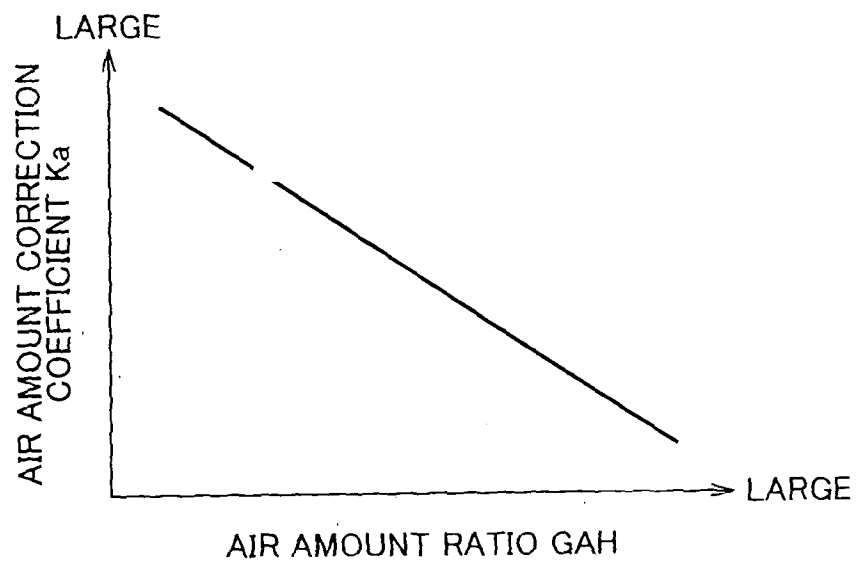


FIG. 6

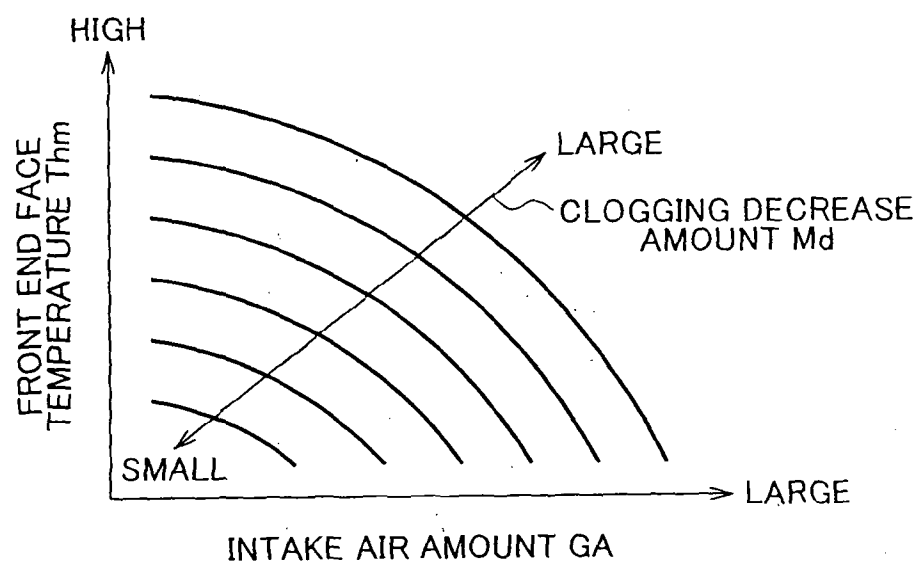


FIG. 7

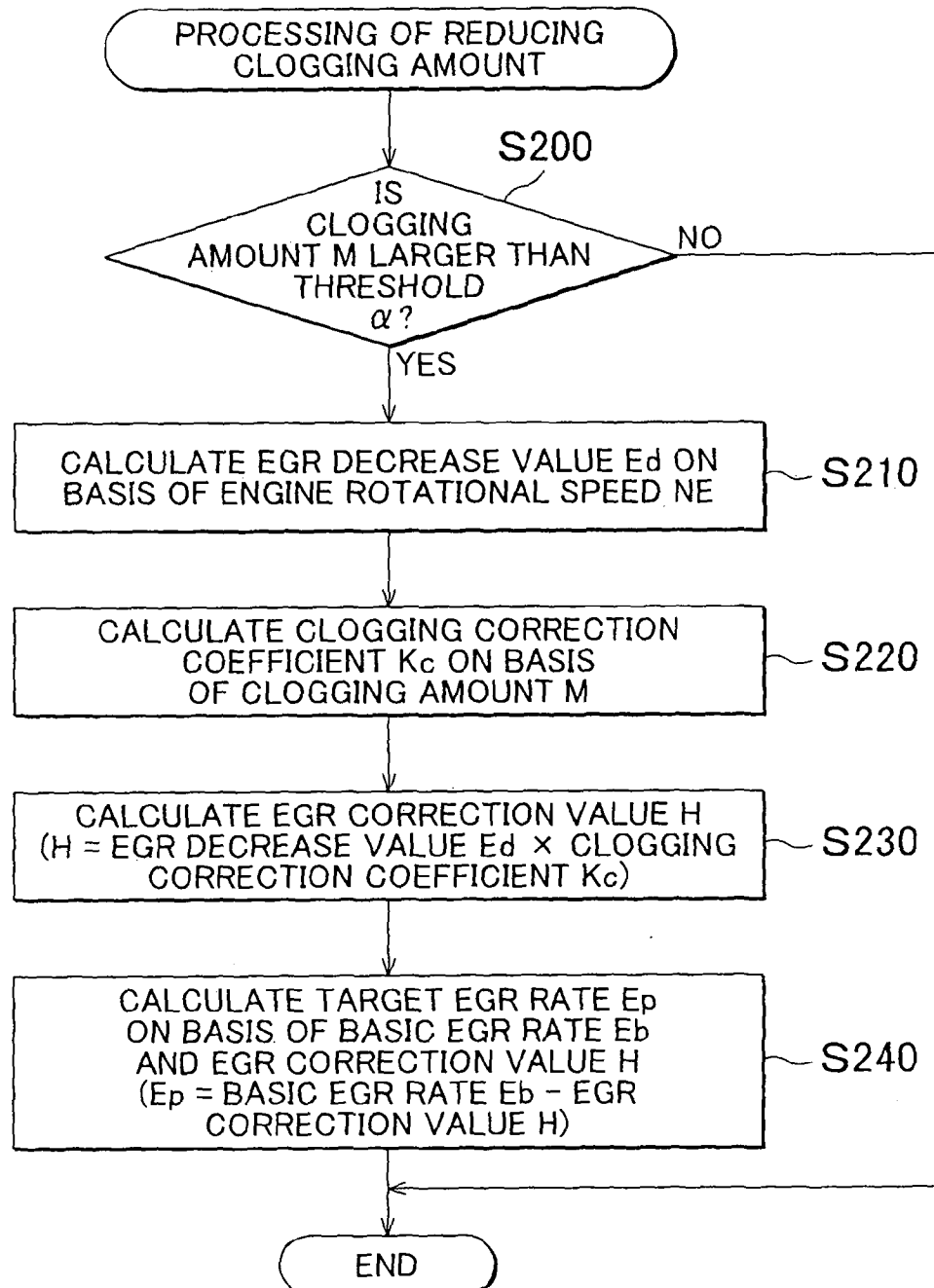


FIG. 8

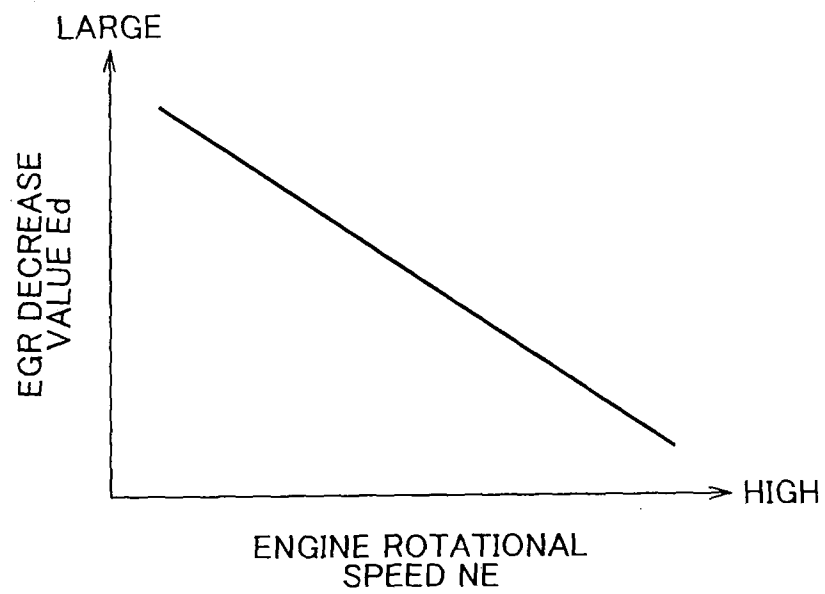
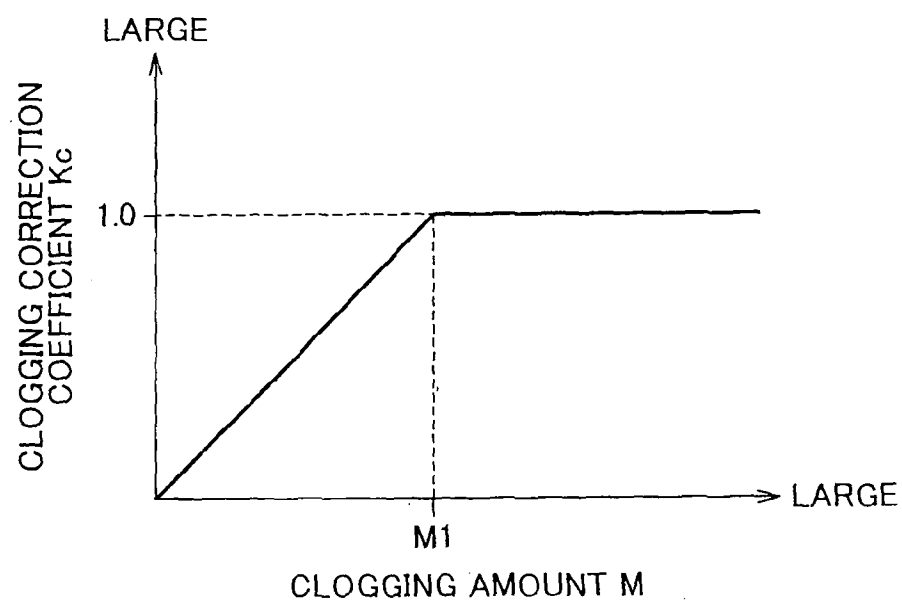


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/001285

A. CLASSIFICATION OF SUBJECT MATTER INV. F01N3/025 F01N3/035 F01N3/20 F01N3/10 F02M25/07 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F01N F02M		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 669 565 A1 (TOYOTA MOTOR CO LTD [JP]) 14 June 2006 (2006-06-14) column 10, line 41 - column 13, line 2; figures 1,4 -----	1-10
A	JP 2009 013809 A (HINO MOTORS LTD) 22 January 2009 (2009-01-22) abstract; figure 3 -----	1
☐ Further documents are listed in the continuation of Box C. ☒ 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 application or patent 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 17 September 2012	Date of mailing of the international search report 28/09/2012	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Zebst, Marc	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2012/001285

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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