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(54) **EXHAUST GAS PURIFICATION SYSTEM FOR INTERNAL COMBUSTION ENGINE**

(57) The present invention provides a technology which is capable of specifying a deviation in a PM trapped quantity between the central portion and the peripheral portion in the radial direction of a particulate filter. In order to achieve this object, the invention is to measure a PM quantity contained in an exhaust gas flowing out from the

central portion in the radial direction of the particulate filter, and a PM quantity contained in the exhaust gas flowing out from the peripheral portion in the radial direction of the particulate filter, and, from these results, obtains the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion.

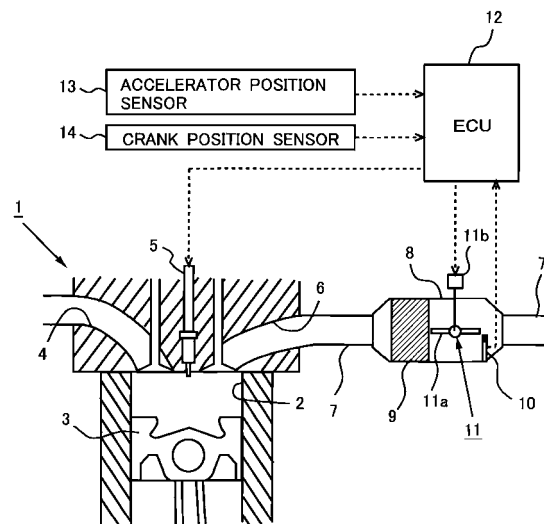


FIG.1

Description

TECHNICAL FIELD

[0001] The present invention relates to a technology for determining a quantity of particulate matter (PM) trapped in a particulate filter arranged in an exhaust system of an internal combustion engine.

BACKGROUND ART

[0002] In the structure, in which the particulate filter is arranged in the exhaust system of the internal combustion engine, the technology is known such that when the quantity of the particulate matter (PM) trapped in the particulate filter exceeds a certain quantity, the particulate filter is heated, thereby the PM trapped in the particulate filter is oxidized and removed (PM regeneration process).

[0003] For the method of determining whether or not the quantity of PM trapped in the particulate filter exceeds a certain quantity, there has been proposed a method which determines that the PM trapped quantity has exceeded a certain quantity when a differential pressure between the upstream and the downstream of the particulate filter (hereinafter will be referred to as the "fore-and-aft differential pressure") has exceeded a predetermined value (see, for example, the Patent Document 1).

PRIOR ART DOCUMENTS

Patent Documents

[0004]

Patent Document 1: Japanese Patent Application Laid-Open Publication No. 2008-106698

Patent Document 2: Japanese Patent Application Laid-Open Publication No. 2008-190470

Patent Document 3: Japanese Patent Application Laid-Open Publication No. 2008-082199

Patent Document 4: Japanese Patent Application Laid-Open Publication No. 08(1996)-028248

Patent Document 5: Japanese Patent Application Laid-Open Publication No. 05(1993)-026029

Patent Document 6: Japanese Patent Application Laid-Open Publication No. 2009-512814

Patent Document 7: Japanese Patent Application Laid-Open Publication No. 2009-513870

Patent Document 8: Japanese Patent Application Laid-Open Publication No. 2009-197718

DISCLOSURE OF THE INVENTION

Problem To Be Solved By The Invention

[0005] It should be noted that the above-mentioned fore-and-aft pressure varies according to a temperature and a flow rate of the exhaust gas. To deal with this, a

method of correcting a detected value of the fore-and-aft differential pressure by using the exhaust gas temperature and the exhaust gas flow rate as parameters, can be considered. However, there may be a possibility that the correlation between the corrected fore-and-aft differential pressure and the actual PM trapped quantity becomes low.

[0006] Further, the Patent Document 2 proposes a method in which a PM sensor which detects a PM quantity flowing into the particulate filter is mounted on the exhaust system, and the PM trapped quantity of the particulate filter is obtained from a detected value of the PM sensor. However, there is a possibility that the PM trapped quantity differs between the central portion and the peripheral portion of the particulate filter in a radial direction thereof. Because of this, when the timing of the PM regeneration process is determined based on the detected value of the PM sensor, there may possibly occur such situation where the PM has not been removed but remains in the central portion or the peripheral portion of the particulate filter, or the situation where the PM regeneration process would be continued even after removing the PM.

[0007] The present invention has been made in view of the above-described various circumstances, and its object is to provide a technology that can specify the deviation in the PM trapped quantity between the central portion and the peripheral portion of the particulate filter in the radial direction thereof.

Means For Solving The Problem

[0008] In order to solve the above-described problems, the present invention is to measure a quantity of particulate matter (PM) contained in the exhaust gas flowing out from the central portion of the particular filter in the radial direction thereof and a quantity of PM contained in the exhaust gas flowing out from the peripheral portion of the particulate filter in the radial direction thereof, by a PM sensor, and the PM trapped quantity of the central portion and the PM tapped quantity of the peripheral portion are obtained from the results of these measurements.

[0009] In detail, the exhaust gas purification system for an internal combustion engine of the present invention comprises:

a particulate filter which is arranged in an exhaust passage of the internal combustion engine and traps particulate matter in an exhaust gas;

a PM sensor which is arranged in the exhaust passage at the downstream of the particulate filter and measures a quantity of particulate matter contained in the exhaust gas;

a switching mechanism for switching between a first mode in which the quantity of particulate matter contained in the exhaust gas flowing out from the central portion of the particulate filter in the radial direction

thereof is measured by the PM sensor, and a second mode in which the quantity of particulate matter contained in the exhaust gas flowing out from the peripheral portion of the particulate filter in the radial direction thereof is measured by the PM sensor; and a calculation unit for calculating a first trapped quantity which is the PM trapped quantity of the central portion from the value measured by the PM sensor when the switching mechanism is in the first mode, and also calculating a second trapped quantity which is the PM trapped quantity of the peripheral portion from the value measured by the PM sensor when the switching mechanism is in the second mode.

[0010] When the quantity of PM trapped in the particulate filter is large, the PM trapping ability of the particulate filter becomes high, as compared to when the quantity of PM trapped in the particulate filter is small. This is due to the fact that when the quantity of PM trapped in the particulate filter is large, a cross-sectional area of a flow passage in the particulate filter becomes small as compared to when the quantity of PM trapped in the particulate filter is small.

[0011] According to the above-described characteristics, when the PM trapped quantity of the particulate filter is large, the quantity of PM flowing out from the particulate filter (namely, the quantity of PM that passes through the filter) is small as compared to when the PM trapped quantity is small. Consequently, when the PM quantity detected by the PM sensor is small, it means that the PM trapped quantity of the particulate filter is large, as compared to when the PM quantity detected by the PM sensor is large. Thereby, the PM trapped quantity of the particulate filter can be calculated from the value detected by the PM sensor.

[0012] Further, according to the present invention, the quantity of PM flowing out from the central portion of the particulate filter in the radial direction thereof, and the quantity of PM flowing out from the peripheral portion of the particulate filter in the radial direction thereof, can be detected individually. As a result, the PM trapped quantity of the central portion (first trapped quantity) and the PM trapped quantity of the peripheral portion (second trapped quantity) can be specified, respectively.

[0013] When the first trapped quantity and the second trapped quantity are specified respectively, the PM trapped in the central portion and the PM trapped in the peripheral portion can be oxidized and removed properly, that is, neither too much nor too little. For example, the exhaust gas purification system for the internal combustion engine of the present invention may further comprises a regeneration processing unit for performing a PM regeneration process which is the process of raising the temperature of the particulate filter for oxidizing and removing the PM trapped in the particulate filter. And, the regeneration processing unit may finish the PM regeneration process when the first trapped quantity and the second trapped quantity becomes equal to or less than

a target quantity. The target quantity is a quantity determined by the specifications of the internal combustion engine and the specifications of the particulate filter. Such the target quantity may be zero or a value which is larger than zero.

[0014] When the PM regeneration process is executed by such method, it is possible to avoid a situation where the quantity of PM un-oxidized at the central portion or the peripheral portion of the particulate filter becomes large, and a situation where the PM regeneration process will be continued even after the first trapped quantity and the second trapped quantity become equal to or less than the target quantity. As a result, the PM trapped at the central portion and the peripheral portion can be oxidized and removed properly.

[0015] Further, the exhaust gas purification system for the internal combustion engine of the present invention may further comprises a regeneration processing unit for performing the PM regeneration process which is the process of raising the temperature of the particulate filter in order to oxidize and remove the PM trapped in the particulate filter, and a heater for heating the peripheral portion locally. And, if a decreasing rate of the second trapped quantity is low as compared to a decreasing rate of the first trapped quantity during execution of the PM regeneration process, the heater may be operated.

[0016] When the heater is controlled in this manner, an oxidation rate of the PM at the central portion and an oxidation rate of the PM at the peripheral portion become substantially uniform. Thus, a period of time of execution of the PM regeneration process can be shortened. Further, it is possible to avoid a situation where the heater is operated unnecessarily when the PM oxidation rate at the peripheral portion is equal to or greater than the PM oxidation rate at the central portion.

[0017] Even when the decreasing rate of the second trapped quantity is low with respect to the decreasing rate of the first trapped quantity, the heater may be adapted to be not operated if the second trapped quantity is less than the first trapped quantity. Preferably, the heater may be adapted to be not operated even when the decreasing rate of the second trapped quantity is low with respect to the decreasing rate of the first trapped quantity, if the regeneration at the periphery portion is predicted to be finished by the time of finishing the regeneration at the central portion. When the heater is controlled in this manner, the PM trapped at the central portion and the peripheral portion can be oxidized and removed, without operating the heater unnecessarily.

[0018] Here, as a method for predicting whether or not the regeneration of the peripheral portion will finish by the time of finishing the regeneration of the central portion, the regeneration finishing time (or a period of time required for regeneration) at the central portion is calculated from the PM oxidation rate at the central portion and the first trapped quantity, and also the regeneration finishing time (or a period of time required for regeneration) at the peripheral portion is calculated from the PM

oxidation rate at the peripheral portion and the second trapped quantity, and to compare these calculations.

[0019] In the present invention, for the switching mechanism, a mechanism, which switches between a mode wherein the flow of the exhaust gas flowing out from the central portion is directed to the PM sensor, and a mode wherein the flow of the exhaust gas flowing out from the peripheral portion is directed to the PM sensor, may be used. For such a switching mechanism, a valve mechanism having a butterfly type valve body, may be used. In that case, when the state of the valve body is in parallel to a virtual straight line connecting the central portion of the particulate filter and the PM sensor, the exhaust gas flowing out from the central portion is led to the PM sensor by the valve body. Further, when the state of the valve body is in parallel to a virtual straight line connecting the peripheral portion of the particulate filter and the PM sensor, the exhaust gas flowing out from the peripheral portion is lead to the PM sensor by the valve body. By switching the state of the valve body in this manner, the first trapped quantity and the second trapped quantity can be obtained by a single PM sensor.

[0020] When the valve body is parallel to the virtual line connecting the central portion of the particulate filter with the PM sensor or when the valve body is parallel to the virtual line connecting the peripheral portion of the particulate filter with the PM sensor, the PM sensor may be arranged so that the degree of opening of the valve body is fully open. In this case, the valve body is fully open either in the first mode or in the second mode, increase of a pressure loss caused by providing the valve body can be kept to a minimum.

[0021] Further, for the switching mechanism of the present invention, a mechanism which changes the position of the PM sensor may be used. In more detail, the switching mechanism may be a mechanism which switches between a mode wherein the PM sensor is moved onto the path of the exhaust gas flowing out from the central portion, and a mode wherein the PM sensor is moved onto the path of the exhaust gas flowing out from the peripheral portion.

Effects Of The Invention

[0022] According to the present invention, it is possible to accurately obtain the PM trapped quantity of the particulate filter arranged in the exhaust system of the internal combustion engine

Brief Description Of The Drawings

[0023]

Fig. 1 is a diagram showing a schematic structure of an internal combustion engine to which the present invention is applied and an exhaust system thereof. Fig. 2 is a diagram showing the relationship between the PM trapped quantity of the particulate filter and

the PM outflow quantity.

Fig. 3 is a diagram showing a state of a valve body when detecting the quantity of PM flowing out from the central portion of the particulate filter.

Fig. 4 is a diagram showing a state of the valve body when detecting the quantity of PM flowing out from the peripheral portion of the particulate filter.

Fig. 5 is a flowchart showing a PM trapped quantity calculation process routine in a first embodiment.

Fig. 6 is a flowchart showing a PM regeneration process routine in the first embodiment.

Fig. 7 is a diagram showing a structure of an exhaust gas purification apparatus in a second embodiment.

Fig. 8 is a flowchart showing the PM regeneration process routine in the second embodiment.

Fig. 9 is a diagram showing another structural example of the switching mechanism according to the present invention.

Fig. 10 is a diagram showing still another structural example of the switching mechanism according to the present invention.

The Best Mode For Carrying Out The Invention

[0024] Hereinafter, a description will be made of specific embodiments of the present invention with reference to the accompanying drawings. Regarding the dimensions, materials, shapes and relative arrangements, etc. of the components to be described in the embodiments are not intended to limit the technical scope of the present invention unless specifically described.

<Embodiment 1>

[0025] First, a description will be made of a first embodiment of the present invention based on Fig. 1 to Fig. 6. Fig. 1 is a diagram showing a schematic structure of an internal combustion engine to which the present invention is applied and an exhaust system thereof. An internal combustion engine 1 shown in Fig. 1 is a compression ignition internal combustion engine (diesel engine).

[0026] The internal combustion engine 1 includes cylinders 2. A piston 3 is slidably mounted in the cylinder. The internal combustion engine 1 comprises an intake port 4 for guiding new air (air) into the cylinder 2, a fuel injection valve 5 for injecting fuel into the cylinder 2, and an exhaust port 6 for discharging gas (burnt gas) from the cylinder 2. The exhaust port 6 is connected to an exhaust pipe 7.

[0027] A casing 8 of the exhaust gas purification apparatus is provided at the middle of the exhaust pipe 7. A particulate filter 9, which traps particulate matter (PM) in the exhaust gas, is provided inside the casing 8. Inside the casing 8, a PM sensor 10 is provided at the downstream of the particulate filter 9. The PM sensor 10 is a sensor which outputs an electric signal corresponding to a quantity of PM contained in the exhaust gas.

[0028] A valve mechanism 11 is provided between the particulate filter 9 and the PM sensor 10 in the casing 8. The valve mechanism 11 includes a butterfly valve body 11 a and an actuator 11 b for changing an opening degree of the valve body 11 a.

[0029] Further, an ECU 12 is provided as an annex to the internal combustion engine 1. The ECU 12 is an electronic control unit comprising CPU, ROM, RAM, back-up RAM, etc. In addition to the above-mentioned PM sensor 10, output signals from an accelerator position sensor 13 and a crank position sensor 14 are inputted into the ECU 12. The ECU 12 controls the fuel injection valve 5 and the actuator 11 b based on output signals from the above-mentioned various sensors.

[0030] For example, the ECU 12 performs controlling (fuel injection control) of a valve opening timing (fuel injection timing) of the fuel injection valve 5 and a period of time of valve opening (fuel injection quantity) of the fuel injection valve 5 by using output signals from the accelerator position sensor 13 and the crank position sensor 14, as parameters. Moreover, the ECU 12 executes the PM trapped quantity calculation process and the PM regeneration process which are the gist of the present invention, by using the output signal of the PM sensor 10 as the parameter.

[0031] Hereinafter, a description will be made of the PM trapped quantity calculation process and the PM regeneration process in the present embodiment. First, in the PM trapped quantity calculation process, the ECU 12 calculates the quantity of PM trapped in the particulate filter 9 (PM trapped quantity) from the output signal of the PM sensor 10.

[0032] Here, the particulate filter 9 has the property that its PM trapping ability is increased when the PM trapped quantity is large, rather than when the PM trapped quantity is small. As a result, when the PM trapped quantity of the particulate filter 9 is large, the quantity of PM flowing out from the particulate filter 9 (hereinafter referred to as "the PM outflow quantity") decreases in comparison to when the PM trapped quantity of the particulate filter 9 is small.

[0033] Accordingly, the output signal (the PM outflow quantity) of the PM sensor 10 becomes a smaller value as shown in Fig. 2, when the PM trapped quantity of the particulate filter 9 is large, rather than when it is small. Hence, by obtaining the correlation as shown in Fig. 2 experimentally in advance, it is possible to convert the output signal value of the PM sensor 10 into the PM trapped quantity. According to this method, the PM trapped quantity of the particulate filter 9 can be obtained more accurately.

[0034] When the PM trapped quantity of the particulate filter 9 is specified, the starting time and the finishing time of the PM regeneration process can be determined based on the specified PM trapped quantity. For example, the ECU 12 can start the PM regeneration process when the PM trapped quantity becomes equal to or exceeding the upper limit quantity. Further, the ECU 12 can finish the

PM regeneration process when the PM trapped quantity, which is sought during the execution of the PM regeneration process, becomes equal to or less than the lower limit quantity.

[0035] Note that the above-mentioned upper limit quantity corresponds to the PM trapped quantity, for which it is thought that the magnitude of a back pressure caused by increase of the pressure loss of the particulate filter 9 exceeds the acceptable value. Further, the above-mentioned lower limit quantity is the PM trapped quantity, for which it is thought that an interval between the PM regeneration process finishing time and the starting time of the next PM regeneration process does not become excessively short. Preferably, the lower limit quantity is zero.

[0036] Note that there may be a case where the degree of increase of the PM trapped quantity while the PM regeneration process is not executed, or the degree of decrease of the PM trapped quantity while the PM regeneration process is executed, may differ depending on the part of the particulate filter 9. For example, in the radial direction of the particulate filter 9, the degree of change in the PM trapped quantity of the central portion and the degree of change in the PM trapped quantity of the peripheral portion may differ from one another.

[0037] In the above-mentioned case, if the PM regeneration process is carried out based on the PM trapped quantity of either at the central portion or the peripheral portion of the particulate filter 9, there may occur a situation where the PM quantity remaining in the particulate filter 9 at the time of finishing the PM regeneration process becomes excessive, or a situation where the PM regeneration process is continued even after the PM quantity remaining in the particulate filter has been decreased to less than the lower limit quantity.

[0038] Thus, in the PM trapped quantity calculation process of the present embodiment, the ECU 12 calculates the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion of the particulate filter 9 respectively, thereby to determine the starting timing and the finishing timing of the PM regeneration process based on these calculation results.

[0039] Here, a method of obtaining the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion of the particulate filter 9 will be described, based on Figs. 3 and 4. A measuring part 10a of the PM sensor 10 is disposed on the path of the exhaust gas flowing out from the central portion of the particulate filter 9. That is, the measuring part 10a of the PM sensor 10 is located on a line extending from the central portion in the direction of the flow of the exhaust gas.

[0040] According to this arrangement, when the valve body 11 a of the valve mechanism 11 is fully opened (when the valve body 11 a is parallel to the direction of the flow of the exhaust gas flowing out from the particulate filter 9), the exhaust gas flowing out from the central portion of the particulate filter 9 is to flow via the measuring

part 10a of the PM sensor 10, as shown in Fig. 3. Hence, the ECU 12 can calculate the quantity of PM trapped at the central portion of the particulate filter 9 (first trapped quantity), using a measured value of the PM sensor 10 at the time of fully open of the valve body 11 a, as the parameter.

[0041] Further, in the case where the quantity of PM trapped at the peripheral portion of the particulate filter 9 (second trapped quantity) is obtained, the ECU 12 controls the valve mechanism 11 so that the valve body 11 a is caused to rotate counter-clockwise in Fig. 3. At that time, the valve body 11 a is to rotate until the opening degree of the valve body 11 a becomes substantially parallel to the virtual straight line connecting the peripheral portion of the particulate filter 9 and the measuring part 10a (hereinafter will be called "the reference opening degree"). When the valve mechanism 11 is controlled in this manner, the exhaust gas flowing out from the peripheral portion of the particulate filter 9 is to flow via the measuring part 10a of the PM sensor 10. Hence, the ECU 12 can calculate the second trapped quantity by using the measured value of the PM sensor 10 at the time when the opening degree of the valve body 11 a is made the reference opening degree, as the parameter.

[0042] Note that the second trapped quantity obtained by the above-mentioned method is the PM trapped quantity of a specified area (the area located in the lower part of Figs. 3 and 4) of the peripheral portion. Consequently, in the case where the PM trapped quantity of the entire area of the peripheral portion is specified, the second trapped quantity may be corrected based on a ratio (proportion) of the specified area to the entire area of the peripheral portion. However, with the present embodiment, it is sufficient that a relative relation (ratio or deviation) between the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion is specified. Hence, there is no need to obtain the PM trapped quantity of the entire area of the peripheral portion.

[0043] Here, procedures for obtaining the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion of the particulate filter 9 will be described with reference to Fig. 5. Fig. 5 is a flowchart showing a PM trapped quantity calculation process routine. This routine is a routine is stored in the ROM of the ECU 12 in advance, and executed at intervals by the ECU 12.

[0044] Firstly, in the PM trapped quantity calculation process routine, the ECU 12 controls, in S101, the valve mechanism 11 so that the opening degree of the valve body 11a is fully opened. Note that the opening degree of the valve body 11 a is preferably maintained fully opened, except the case where the second trapped quantity is obtained. However, this is not a limitation to the case where the valve mechanism 11 also has the function as the known exhaust gas throttle valve.

[0045] In S102, the ECU 12 reads the measured value of the PM sensor 10. Subsequently the ECU 12 proceeds

to S103 where the ECU 12 calculates the first trapped quantity $\Sigma PM1$ from the measured value read in the S102 and the map as shown in Fig. 2.

[0046] In S104, the ECU 12 controls the valve mechanism 11 so that the opening degree of the valve body 11 a becomes the reference opening degree. Subsequently, the ECU proceeds to S105 where the ECU 12 reads the measured value of the PM sensor. In S106, the ECU 12 calculates the second trapped quantity $\Sigma PM2$ from the measured value read in the S105 and the above-mentioned map shown in Fig. 2.

[0047] In S107, the ECU 12 stores the first trapped quantity $\Sigma PM1$ and the second trapped quantity $\Sigma PM2$ calculated in the S103 and the S105 in the backup RAM. In S108, the ECU 12 controls the valve mechanism 11 so as to return the opening degree of the valve body 11 a to fully open.

[0048] As described above, the calculation unit according to the present invention is implemented by the execution of the PM trapped quantity calculation process routine by the ECU12. As result, the distribution of the PM trapped quantity in the radial direction of the particulate filter 9, in other words, the deviation between the PM trapped quantity at the central portion and the PM trapped quantity at the peripheral portion can be specified.

[0049] Also, the process of the S102 and the process of the S105 are preferably performed under the same engine operation state as much as possible. This is because the PM quantity discharged from the internal combustion engine 1 varies according to the engine operation state. Further, when the process of the S104 is executed, the back pressure acting on the internal combustion engine 1 rises. Because of this, it is preferable that the process of the S104 is performed at the time of low load operation state. Hence, the PM trapped quantity calculation process routine is executed when the internal combustion engine 1 is in the stationary operation state, preferably in the idling operation state.

[0050] Next, procedures for execution of the PM regeneration process will be described with reference to Fig. 6. Fig. 6 is a flowchart showing the PM regeneration process routine in the present embodiment. This routine is stored in the ROM of the ECU 12 in advance, and executed at intervals by the ECU12.

[0051] Firstly, in the PM regeneration process routine, the ECU 12 determines, in S201, whether or not the conditions for execution of the PM regeneration process have been established. As the conditions for execution of the PM regeneration process, the fact that the PM trapped quantity of the entire particulate filter 9 is equal to or more than the upper limit quantity may be exemplified. However, with the present embodiment, the PM regeneration process is executed under the condition that the above-stated first trapped quantity $\Sigma PM1$ is equal to or more than the upper limit quantity. This is due to the fact that the magnitude of the pressure loss of the particulate filter 9 mainly depends on the PM trapped quan-

tity of the central portion. Hence, the ECU 12 reads the first trapped quantity $\Sigma PM1$ obtained by the above-mentioned PM trapped quantity calculation process routine, and determines whether the read out first trapped quantity $\Sigma PM1$ is equal to or more than the upper limit quantity.

[0052] When the negative determination is made in the S201, the ECU 12 terminates temporarily the execution of this routine. On the other hand, when the affirmative determination is made in the S201, the ECU 12 proceeds to S202.

[0053] In S202, the ECU 12 executes the PM regeneration process. In detail, the ECU 12 raises the temperature of the particulate filter 9 up to the temperature region where the PM is oxidized. For the method of raising the temperature of the particulate filter 9, a method of raising the temperature of the exhaust gas flowing into the particulate filter 9, or a method of generating heat of oxidation reaction in the particulate filter 9, may be used.

[0054] For the method of raising the temperature of the exhaust gas, a method which oxidizes the fuel in the exhaust gas, by injecting the fuel (secondary injection) from the fuel injection valve 5 during a period from the latter half of the expansion stroke to the first half of the exhaust stroke, may be used. For the other method of raising the temperature of the exhaust gas, a method wherein an oxidization catalyst is disposed at the upstream of the particulate filter 9 thereby the fuel injected from the fuel injection valve 5 during the exhaust stroke is oxidized by the oxidization catalyst, may be used. Note that, in the case where the reducing agent adding valve is disposed at the upstream of the oxidization catalyst, it is possible to use a method in which the reducing agent added into the exhaust gas from the reducing agent adding valve is oxidized in the oxidization catalyst.

[0055] For the method of generating heat of oxidation reaction in the particulate filter 9, a method in which the particulate filter 9 carries thereon the oxidization catalyst, and the fuel or the reducing agent supplied to the exhaust gas from the fuel injection valve 5 or the reducing agent adding valve is oxidized in the particulate filter 9, may be used.

[0056] When the process of S202 is executed using the above-mentioned various methods, the ECU 12 proceeds to S203. In S203, the ECU 12 reads out from the backup RAM the latest first trapped quantity $\Sigma PM1$ and the second trapped quantity $\Sigma PM2$ which were calculated by the PM trapped quantity calculation process routine.

[0057] In S204, the ECU 12 determines whether or not the first trapped quantity $\Sigma PM1$ and the second trapped quantity $\Sigma PM2$ which were read out in the S203 are equal to or less than the lower limit quantity. When the negative determination is made in S204, the ECU 12 returns to S203. On the other hand, when the affirmative determination is made in S204, the ECU 12 proceeds to S205 where the ECU 12 terminates the PM regeneration process.

[0058] When the PM regeneration process of the particulate filter 9 is executed according to the PM regener-

ation process routine in such manner as described above, occurrence of the situation in which the PM quantity remaining at the central portion or at the peripheral portion is excessive at the time of termination of the PM regeneration process, and occurrence of the situation in which the PM regeneration process is continued even after the PM quantity remaining in the particulate filter 9 has been decreased to equal to or less than the lower limit quantity, can be avoided.

<Embodiment 2>

[0059] Next, a second embodiment of the present invention will be described based on Fig. 7 and Fig. 8.

Here, a description will be made of the structures which are different from that of the above-described first embodiment, and regarding the same structures, the description will be omitted.

[0060] The point of difference between the present embodiment and the above-described first embodiment is that the PM oxidization rate at the central portion and the PM oxidization rate at the peripheral portion of the particulate filter 9 are made uniform during the execution of the PM regeneration process in the present embodiment.

[0061] Fig. 7 is a cross-sectional diagram showing a structure of an exhaust gas purification apparatus in a second embodiment. In Fig. 7, a cylindrical shape heater 90 is provided between the inner wall of the casing 8 and the outer wall of the particulate filter 9. The heater 90 heats the peripheral portion of the particulate filter 9 by, for example, converting the electric energy supplied from a battery (not shown) into the heat energy. The switching between an operation state and a non-operation state of the heater 90 is controlled by the ECU 12.

[0062] Fig. 8 is a flowchart showing the PM regeneration process routine in the second embodiment. The same reference numerals are used for denoting the same processes as the PM regeneration process routine of the above-described first embodiment.

[0063] In the PM regeneration process routine of Fig. 8, the ECU 12 proceeds to S301 after having executed the process of S202. In S301, the ECU 12 calculates the decreasing rate $v1$ of the first trapped quantity $\Sigma PM1$ and the decreasing rate $v2$ of the second trapped quantity $\Sigma PM2$.

[0064] For example, the ECU 12 obtains the decreasing rate $v1$ of the first trapped quantity $\Sigma PM1$ by dividing the difference $\Delta \Sigma PM1 (= \Sigma PM1_{old} - \Sigma PM1)$ between the latest first trapped quantity $\Sigma PM1$ obtained in the PM trapped quantity calculation process routine and the previously obtained first trapped quantity $\Sigma PM1_{old}$ by the execution interval t of the PM trapped quantity calculation process routine, that is, $v1 (= \Delta \Sigma PM1/t)$.

[0065] Similarly, the ECU 12 obtains the decreasing rate $v2$ of the second trapped quantity $\Sigma PM2$ by dividing the difference $\Delta \Sigma PM2 (= \Sigma PM2_{old} - \Sigma PM2)$ between the latest second trapped quantity $\Sigma PM2_{old}$ obtained in the PM trapped quantity calculation process routine and the

previously obtained second trapped quantity $\Sigma PM2old$ by the execution interval t , that is, $v2 (= \Delta \Sigma PM2/t)$.

[0066] Note that the ECU 12 may use the above-mentioned difference $\Delta \Sigma PM1$ as a substitute value of the decreasing rate $v1$ of the first trapped quantity $\Sigma PM1$, and the ECU 12 may also use the above-mentioned difference $\Delta \Sigma PM2$ as a substitute value of the decreasing rate $v2$ of the second trapped quantity $\Sigma PM2$.

[0067] In S302, the ECU 12 compares the decreasing rates $v1$ and $v2$ obtained in the S301. Specifically, the ECU 12 determines whether or not the decreasing rate $v2$ of the second trapped quantity $\Sigma PM2$ is lower than the decreasing rate $v1$ of the first trapped quantity $\Sigma PM1$.

[0068] When the affirmative determination ($v2 < v1$) is made in the S302, the ECU 12 proceeds to S303 to operate the heater 90. In that case, the temperature of the peripheral portion of the particulate filter 9 rises, thereby the PM oxidation rate at the peripheral portion is increased. As a result, the PM oxidation rate at the peripheral portion and the PM oxidation rate at the central portion become uniform. On the other hand, when the negative determination ($v2 \geq v1$) is made in the S303, the ECU 12 proceeds to S304 to stop operation of the heater 90. Then, execution of the process of the S303 or the S304 has been finished, the ECU 12 executes the process of S203 and the subsequent processes.

[0069] When the PM regeneration process is executed according to the PM oxidation process routine in such manner as described above, the PM oxidation rate at the central portion and the PM oxidation rate at the peripheral portion of the particulate filter 9 become substantially uniform. Consequently, the period of time of execution of the PM regeneration process can be shortened. Further, it is possible to avoid occurrence of the situation where the heater 90 is operated unnecessarily when the PM oxidation rate at the peripheral portion is equal to or greater than the PM oxidation rate at the central portion.

[0070] With the above-described first and the second embodiments, the valve mechanism 11 including the butterfly valve body 11 a was exemplified as the switching mechanism according to the present invention. However, any mechanism, so long as it enables to perform measurement individually of the quantity of PM flowing out from the central portion and the quantity of PM flowing out from the peripheral portion of the particulate filter 9.

[0071] For example, as shown in Fig. 9, a flap 110 which is rotatably supported on the inner wall surface of the casing 8, may be used. Further, as shown in Fig. 10, a driving mechanism 100 which displaces the measurement part 10a of the PM sensor 10 to be in parallel to the radial direction of the particulate filter 9, may be used. Still further, PM sensors may be disposed respectively on the path of the exhaust gas flowing out from the central portion and on the path of the exhaust gas flowing out from the peripheral portion of the particulate filter 9.

[0072] Moreover, with the above-described first and the second embodiments, the internal combustion engine of the compression ignition engine was exemplified

as the internal combustion engine to which the present invention is applied, but the present invention can be applied also to the internal combustion engine of the spark ignition type (gasoline engine).

Description Of The Reference Numerals And Symbols

[0073]

1. internal combustion engine
2. cylinder
3. piston
4. intake port
5. fuel injection valve
6. exhaust port
7. exhaust pipe
8. casing
9. particulate filter
10. PM sensor
- 10a measurement part
11. valve mechanism
- 11a valve body
- 11b actuator
13. accelerator position sensor
14. crank position sensor
90. heater
100. driving mechanism
110. flap

Claims

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

a particulate filter which is arranged in an exhaust passage of the internal combustion engine and traps particulate matter in an exhaust gas;

a PM sensor which is arranged in the exhaust passage at the downstream of the particulate filter and measures a quantity of particulate matter contained in the exhaust gas;

switching mechanism for switching between a first mode in which the quantity of particulate matter contained in the exhaust gas flowing out from the central portion of the particulate filter in the radial direction thereof is measured by the PM sensor and a second mode in which the quantity of particulate matter contained in the exhaust gas flowing out from the peripheral portion of the particulate filter in the radial direction thereof is measured by the PM sensor; and

a calculation unit for calculating a first trapped quantity which is the PM trapped quantity of the central portion from the value measured by the PM sensor when the switching mechanism is in

the first mode, and also calculating a second trapped quantity which is the PM trapped quantity of the peripheral portion from the value measured by the PM sensor when the switching mechanism is in the second mode.

2. The exhaust gas purification system according to claim 1,
wherein the switching mechanism is arranged in the exhaust passage at the downstream of the particulate filter and at the upstream of the PM sensor, and switches between a first mode where the flow of the exhaust gas flowing out from the central portion is directed to the PM sensor and a second mode where the flow of the exhaust gas flowing out from the peripheral portion is directed to the PM sensor. 10
3. The exhaust gas purification system according to claim 2,
wherein the switching mechanism is equipped with a butterfly valve body, and adjust an opening degree of the valve body so that in the first mode the valve body is in parallel to a virtual straight line connecting the central portion and the PM sensor, and adjust the opening degree of the valve body so that in the second mode the valve body is in parallel to a virtual straight line connecting the peripheral portion and the PM sensor. 15 20 25
4. The exhaust gas purification system according to claim 3,
wherein the PM sensor is arranged so that the valve body is fully open when the valve body is parallel to the virtual straight line connecting the central portion and the PM sensor, or when the said valve body is parallel to the virtual straight line connecting the peripheral portion and the PM sensor. 30 35
5. The exhaust gas purification system according to claim 1,
wherein the switching mechanism is a mechanism that switches between a first mode where the PM sensor is moved onto a path of the exhaust gas flowing out from the central portion, and a second mode where the PM sensor is moved onto a path of the exhaust gas flowing out from the peripheral portion. 40 45
6. The exhaust gas purification system according to any one of claims 1 to 5, further comprising:
a regeneration processing unit for performing a PM regeneration process which is a process of raising a temperature of the particulate filter for oxidizing and removing the particulate matter trapped in the particulate filter; 50 55
wherein the regeneration processing unit finishes the PM regeneration process when the first trapped quantity and the second trapped quan-

tity become equal to or less than a predetermined target quantity.

7. The exhaust gas purification system according to claim 4, further comprising:

a heater which heats the peripheral portion locally;
wherein the regeneration processing unit operates the heater when a decreasing rate of the second trapped quantity is small with respect to a decreasing rate of the first trapped quantity, during the execution of the PM regeneration process.

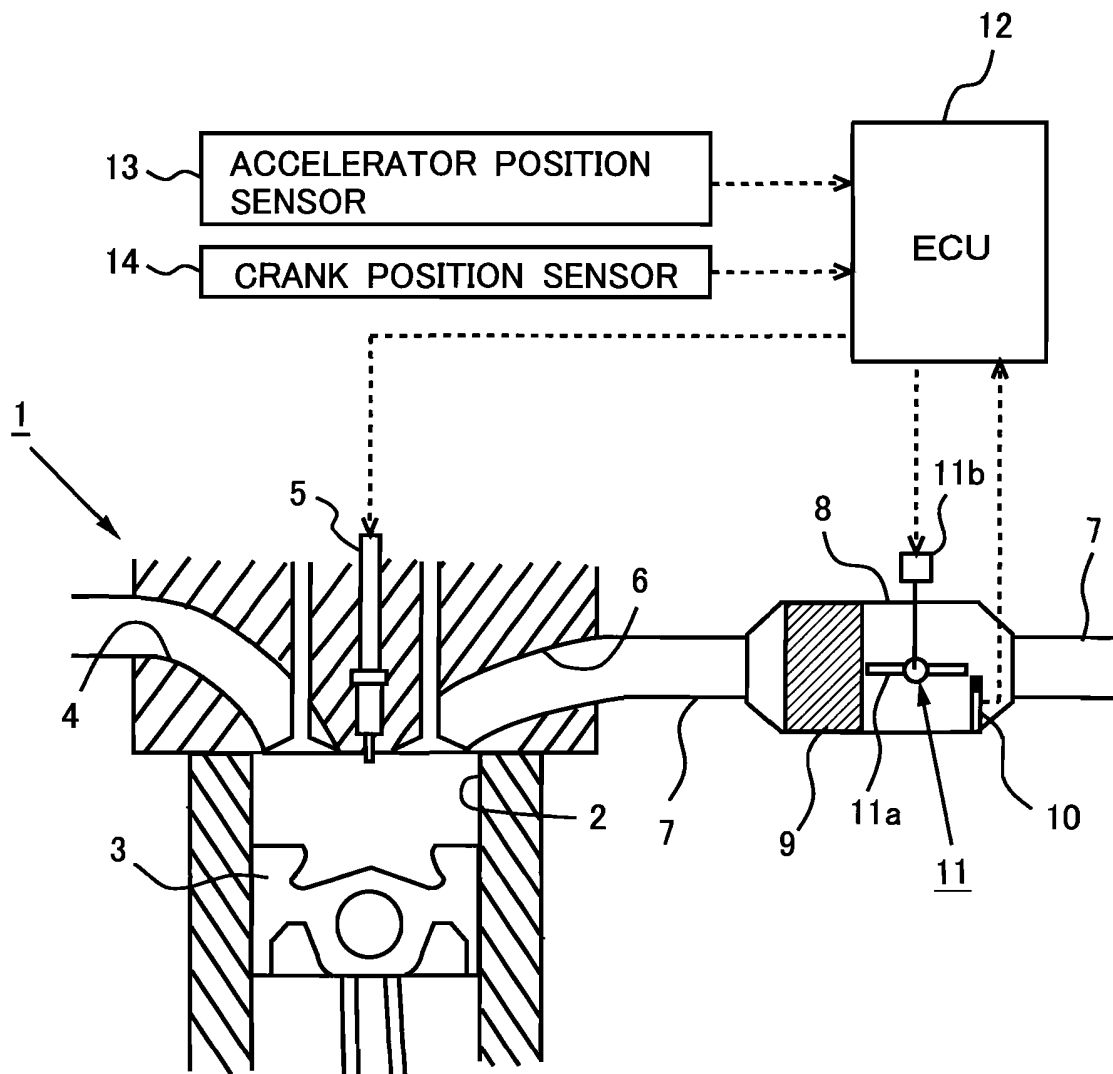


FIG.1

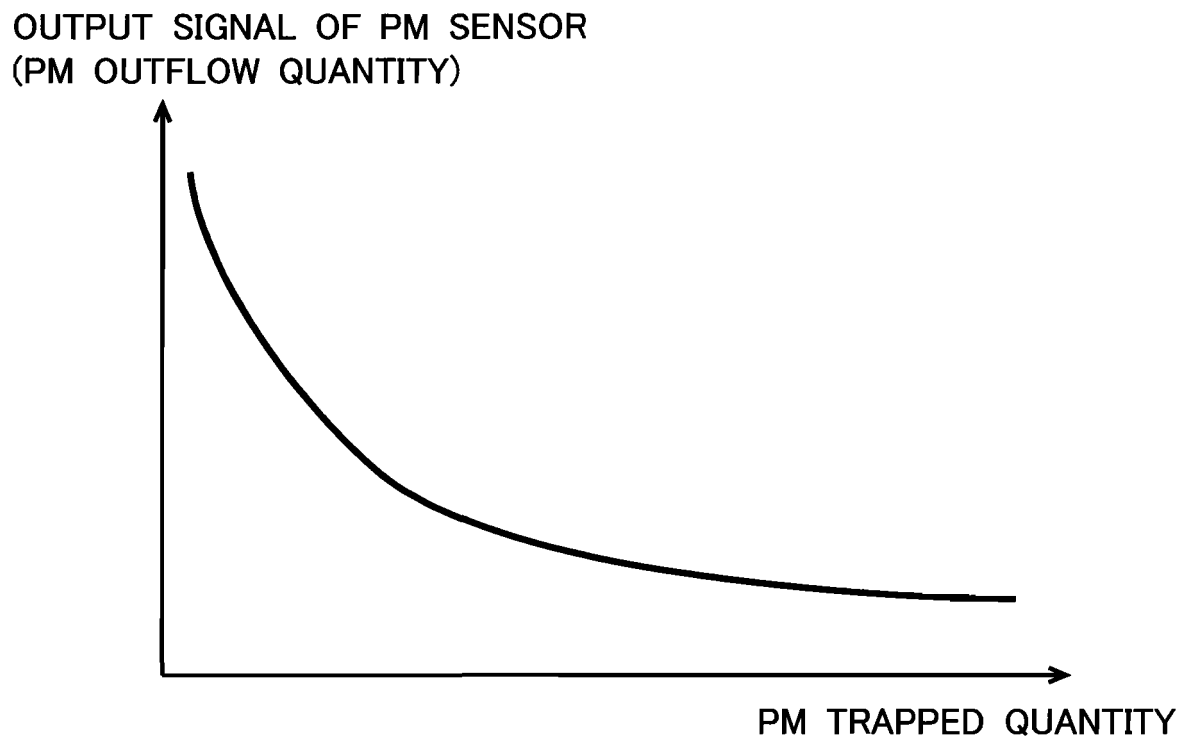


FIG.2

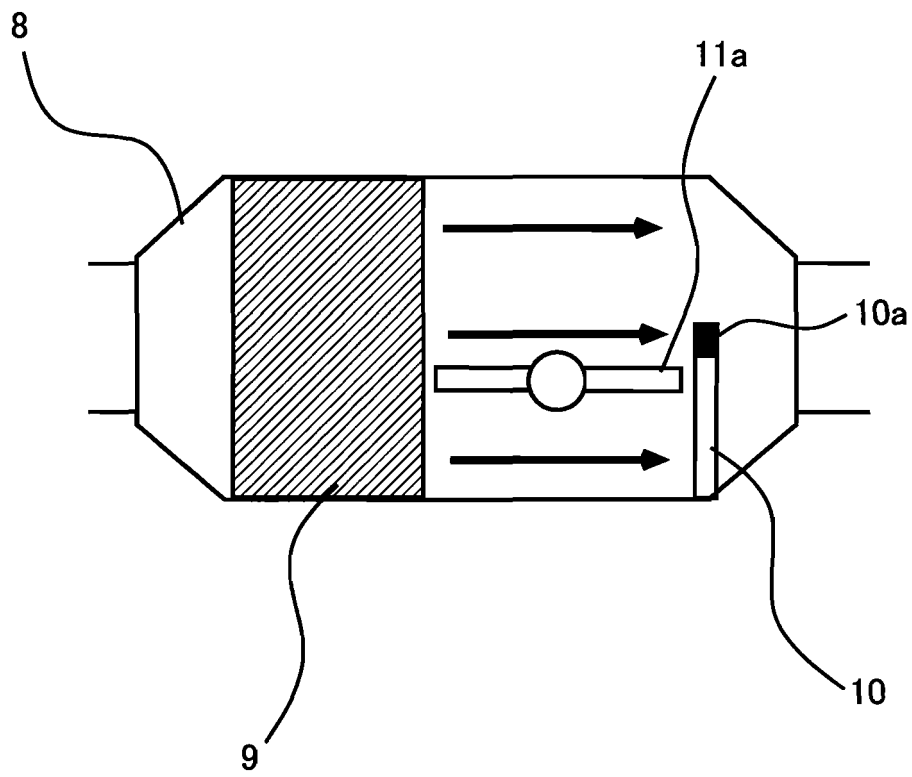


FIG.3

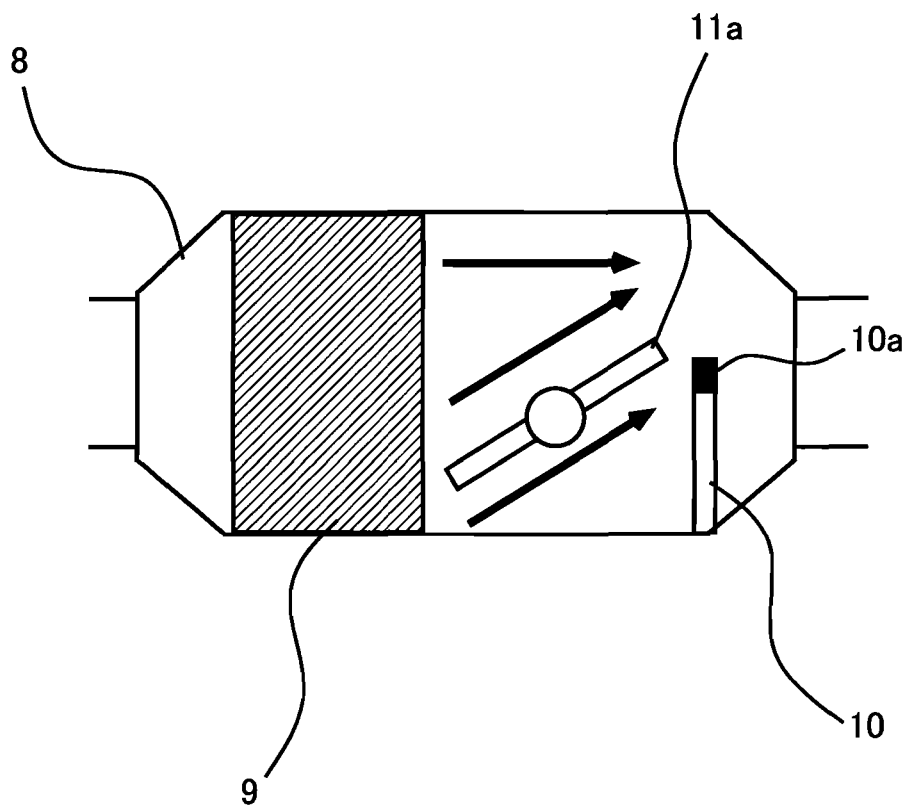


FIG.4

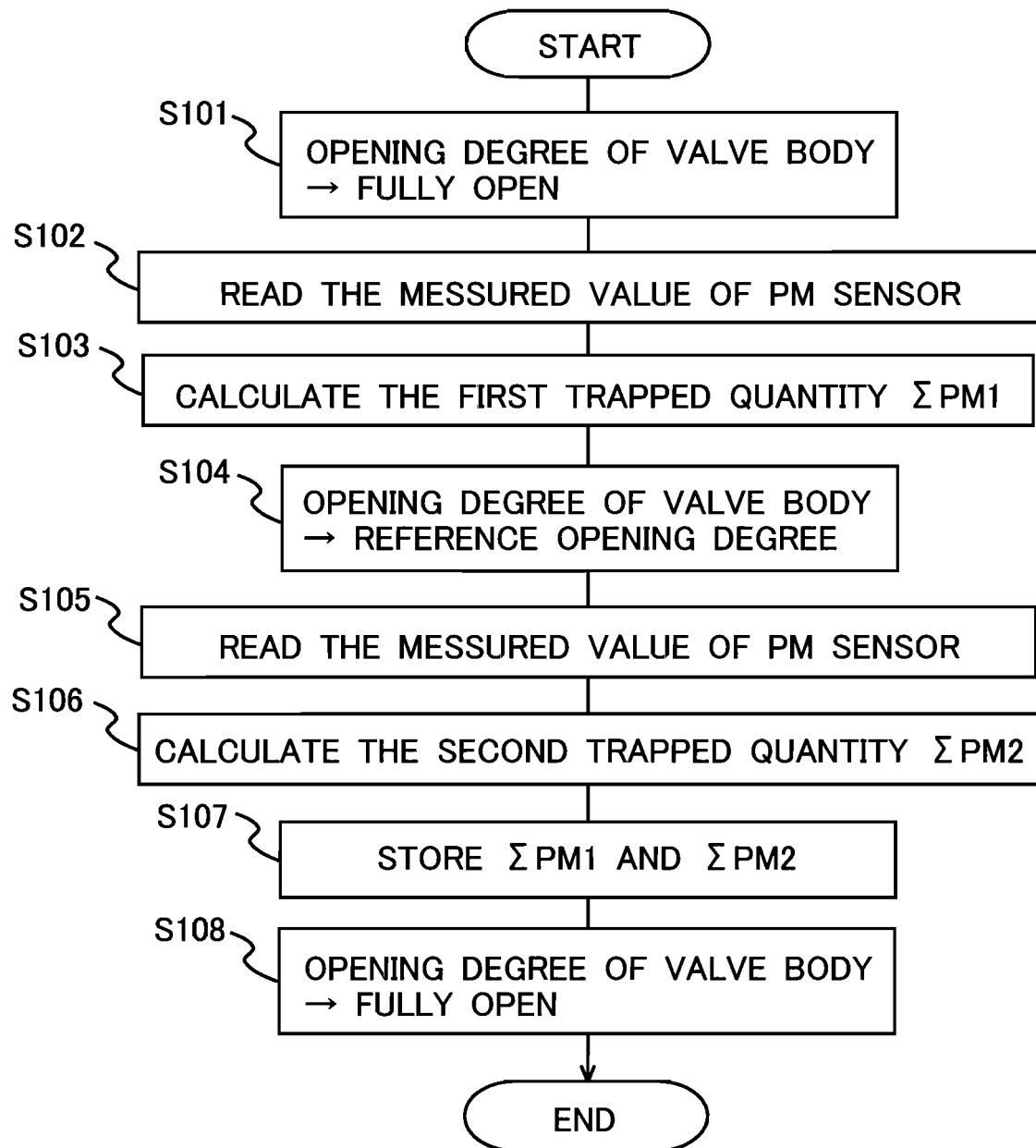


FIG.5

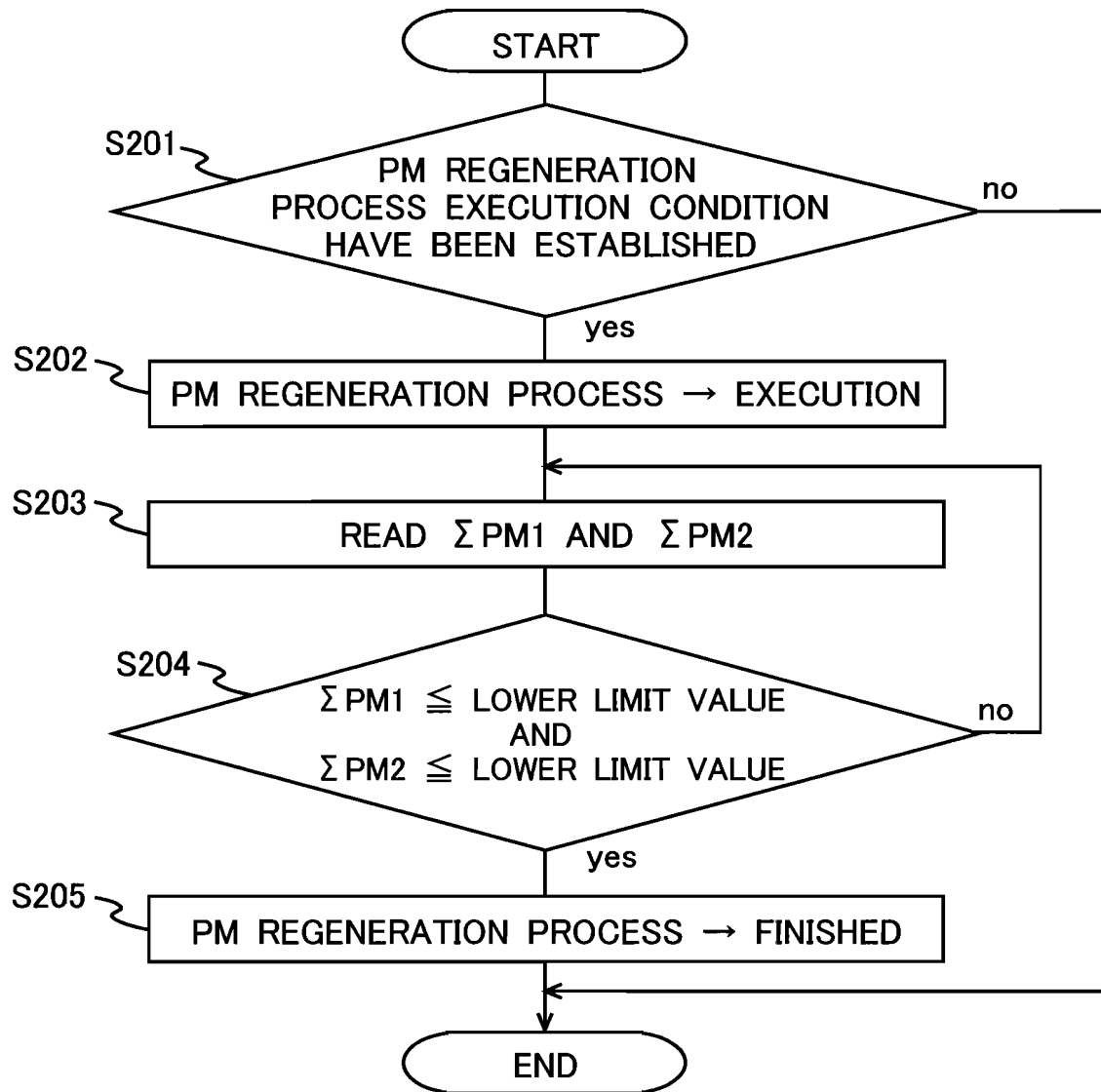


FIG.6

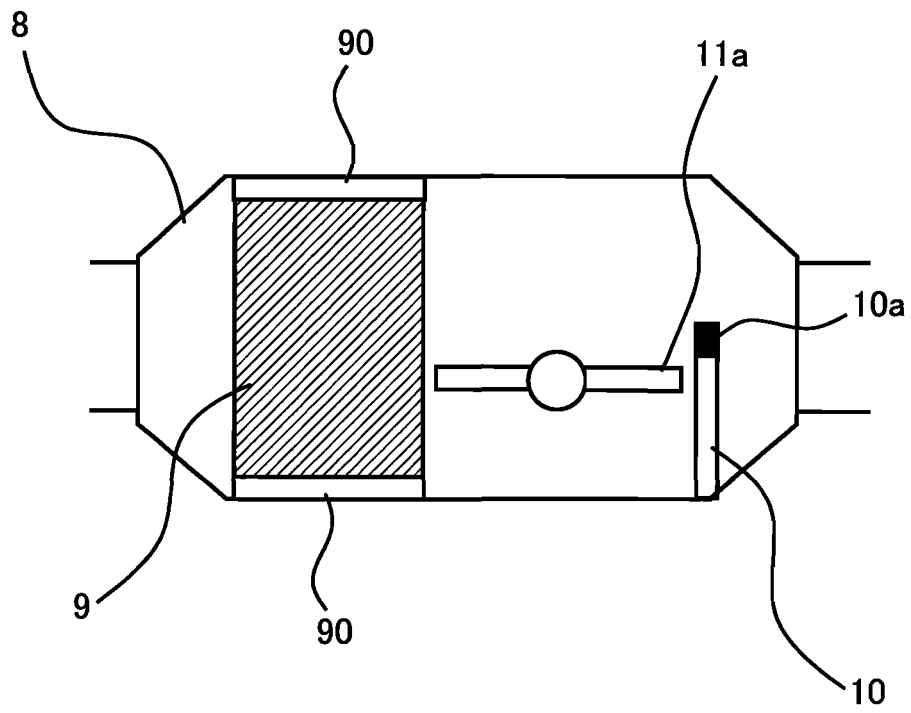


FIG.7

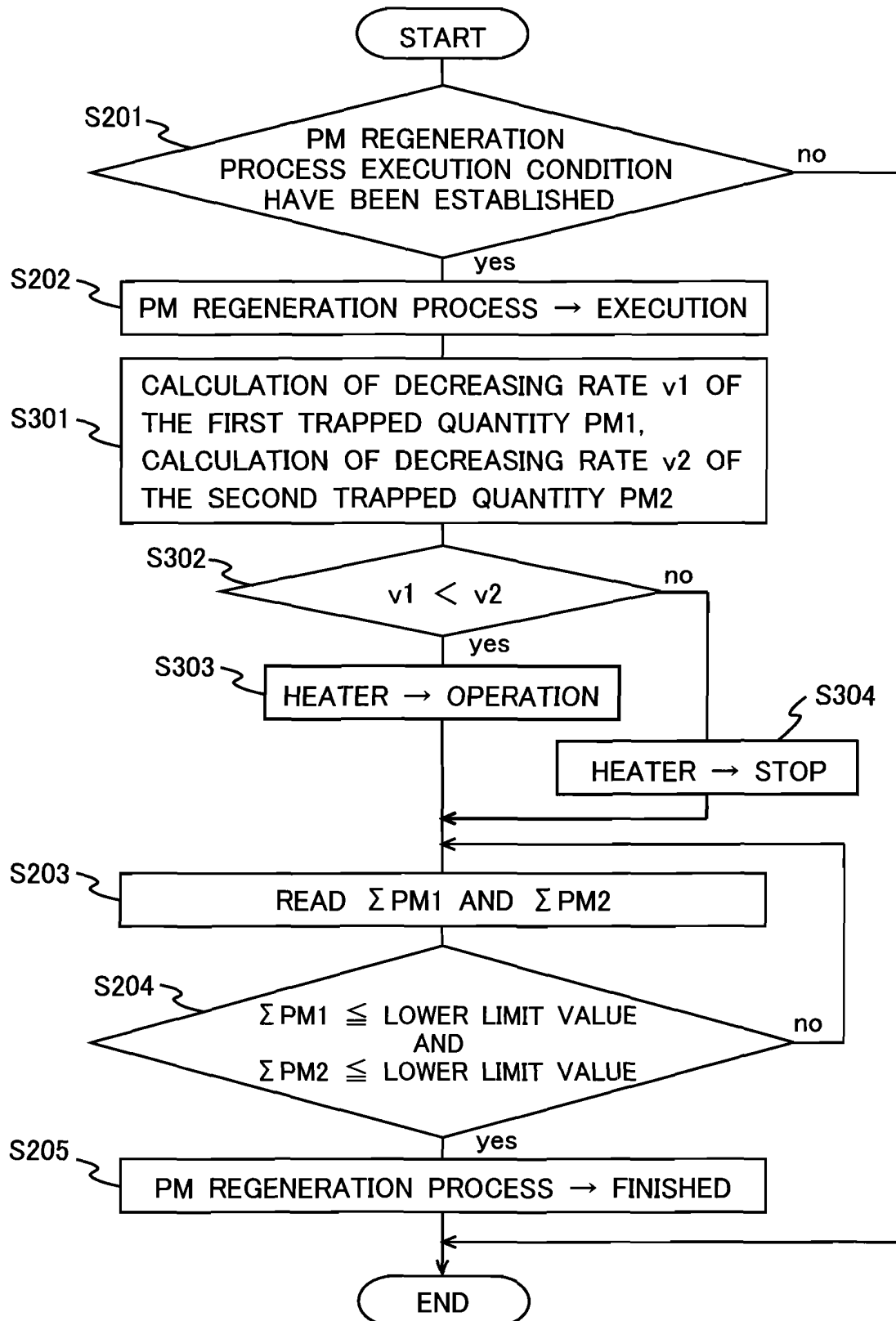


FIG.8

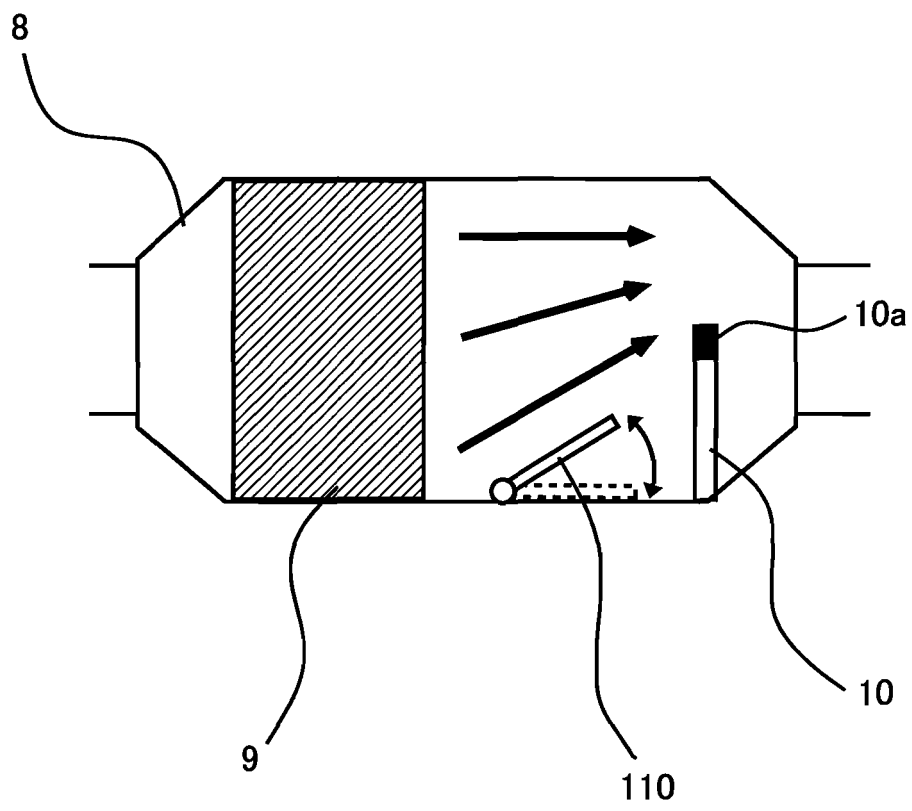


FIG.9

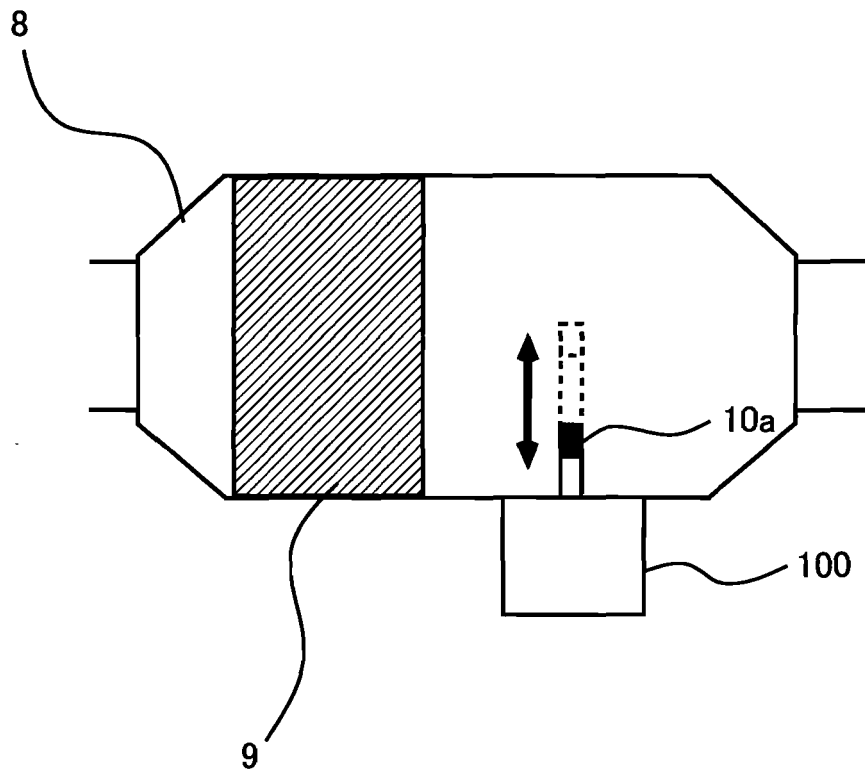


FIG.10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/056323

A. CLASSIFICATION OF SUBJECT MATTER

F01N3/02 (2006.01) i

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)

F01N3/02

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2010

Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-261322 A (Toyota Motor Corp.), 30 October 2008 (30.10.2008), entire text; all drawings (Family: none)	1-7
A	JP 2009-41417 A (Mazda Motor Corp.), 26 February 2009 (26.02.2009), entire text; all drawings (Family: none)	1-7
A	JP 8-296426 A (Nippondenso Co., Ltd.), 12 November 1996 (12.11.1996), entire text; all drawings (Family: none)	1-7



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

01 July, 2010 (01.07.10)

Date of mailing of the international search report

13 July, 2010 (13.07.10)

Name and mailing address of the ISA/

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