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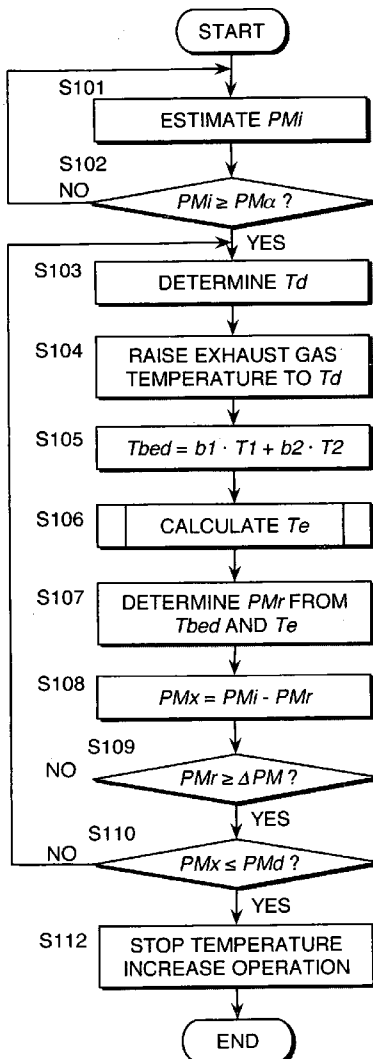
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(57)

ABSTRACT

To regenerate a diesel particulate filter (10) which traps particulate matter contained in the exhaust gas of a diesel engine (20), a controller (16) raises the temperature of the exhaust gas through fuel injection control of a fuel injector (23), and thus burns the particulate matter trapped in the filter (10). The controller (16) controls the fuel injector (23) to raise the temperature of the exhaust gas to a higher temperature as the amount of particulate matter trapped in the filter (10) decreases, thereby-realizing effective regeneration while preventing the temperature of the filter (10) from becoming excessively high.

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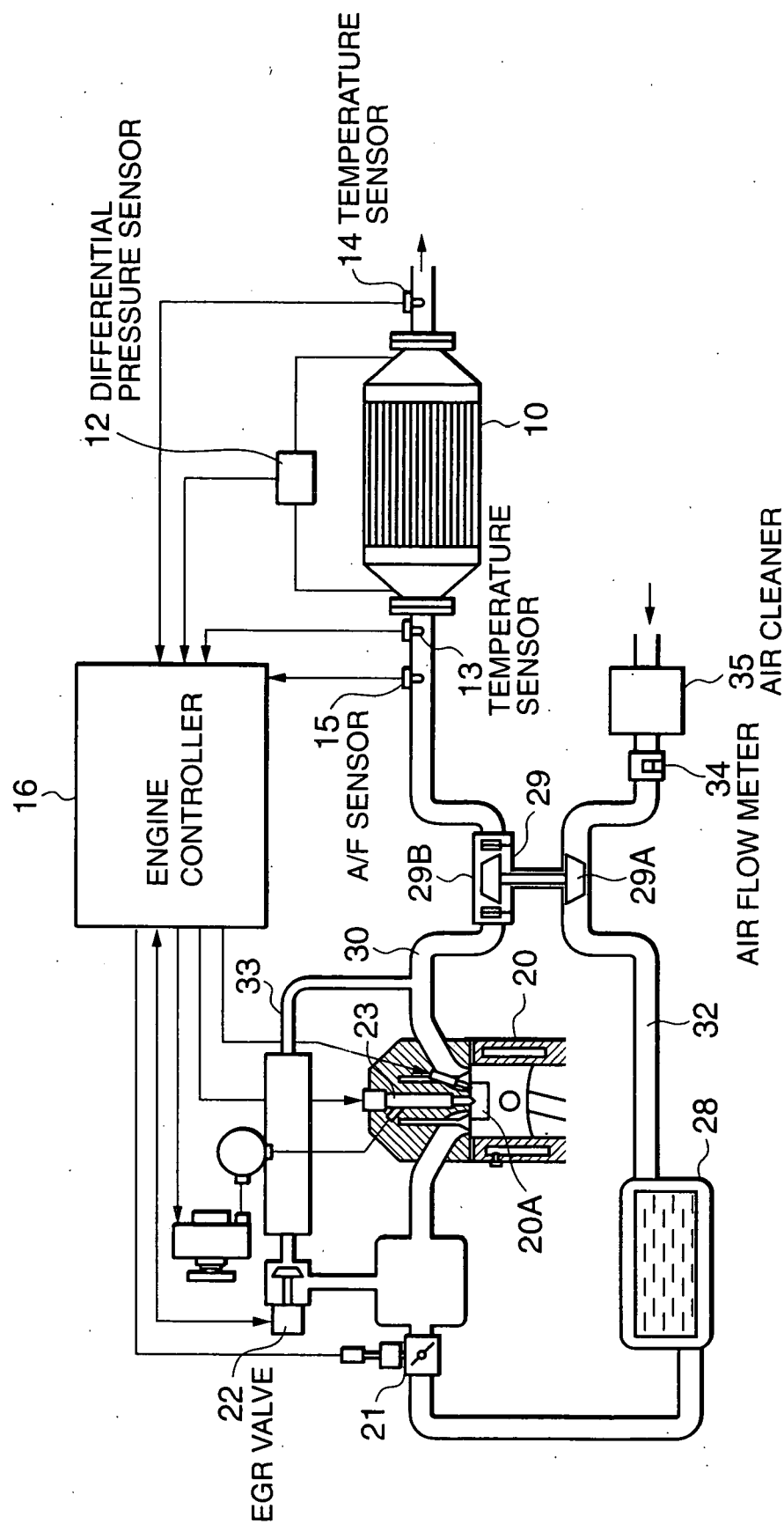


FIG.1

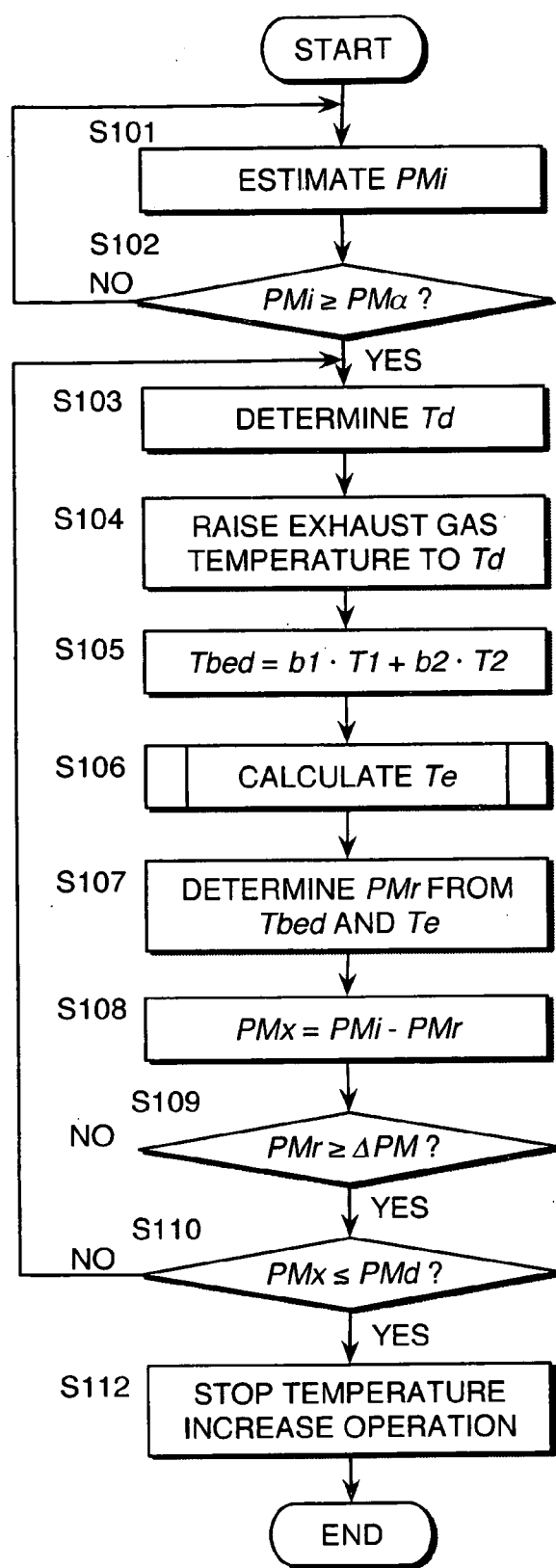


FIG. 2

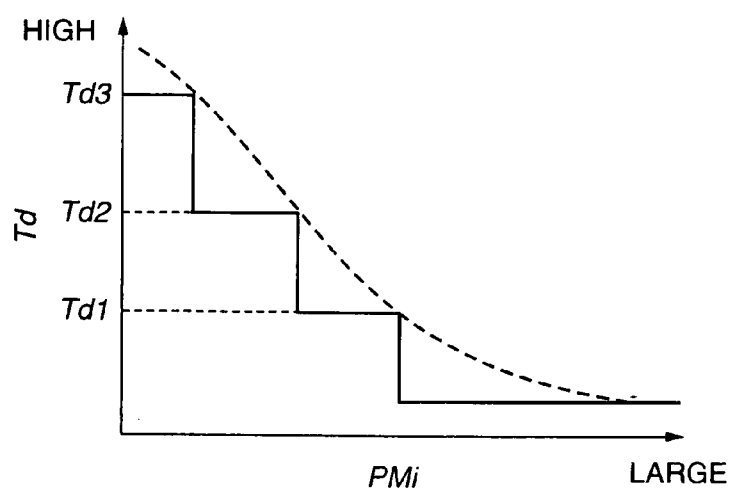


FIG.3

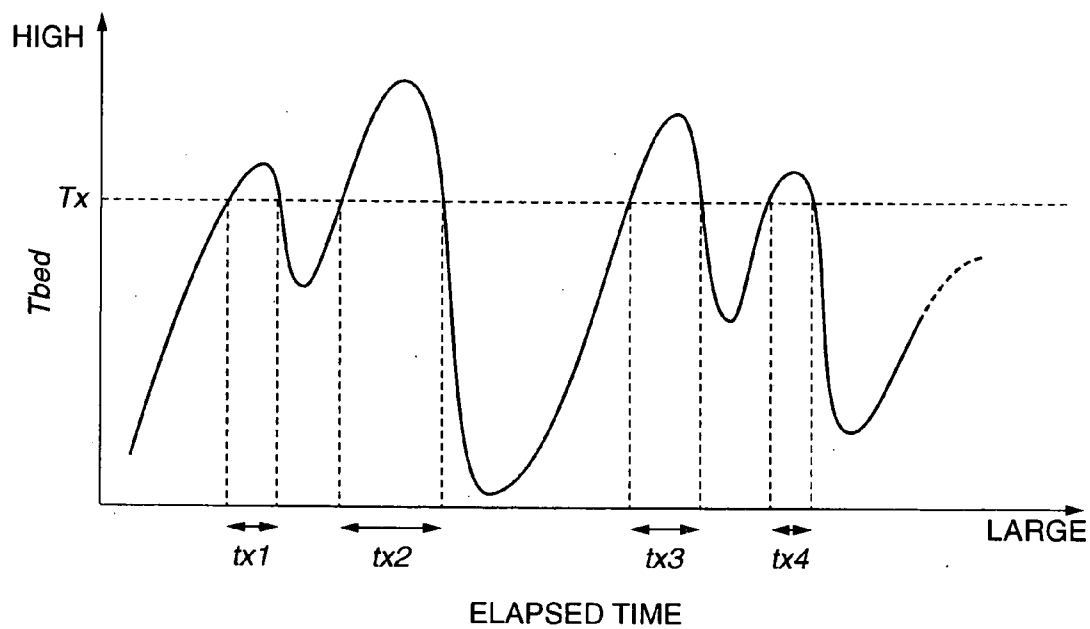


FIG.4

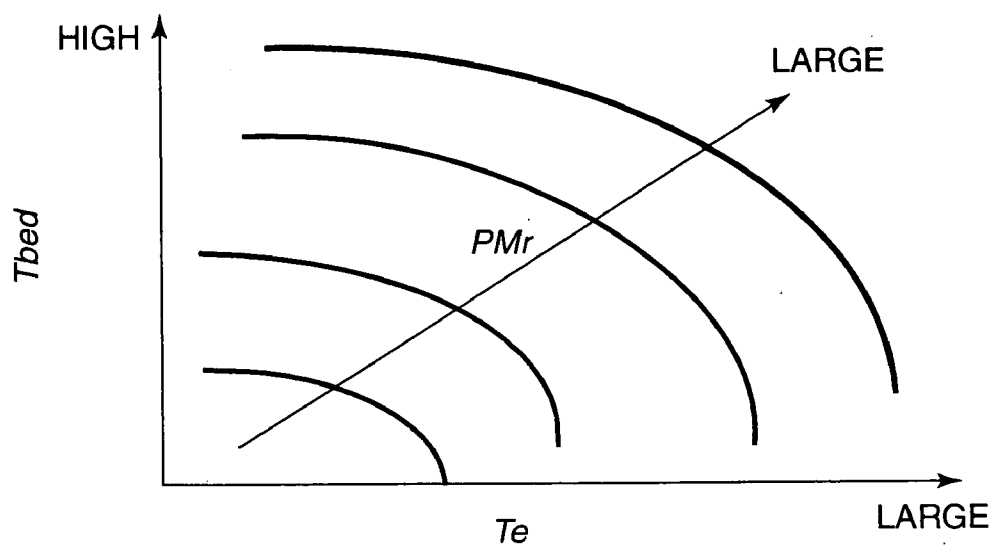


FIG. 5

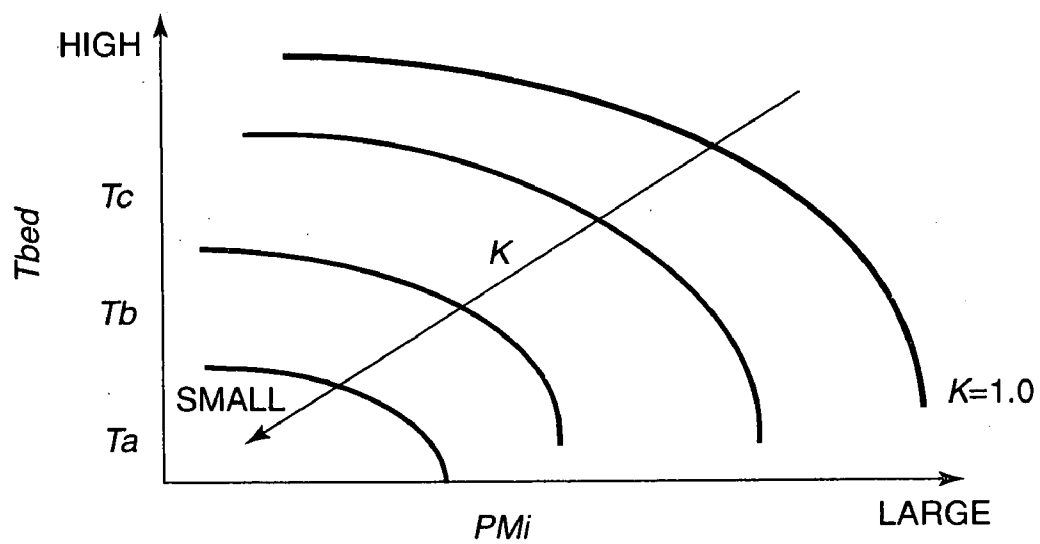


FIG. 9

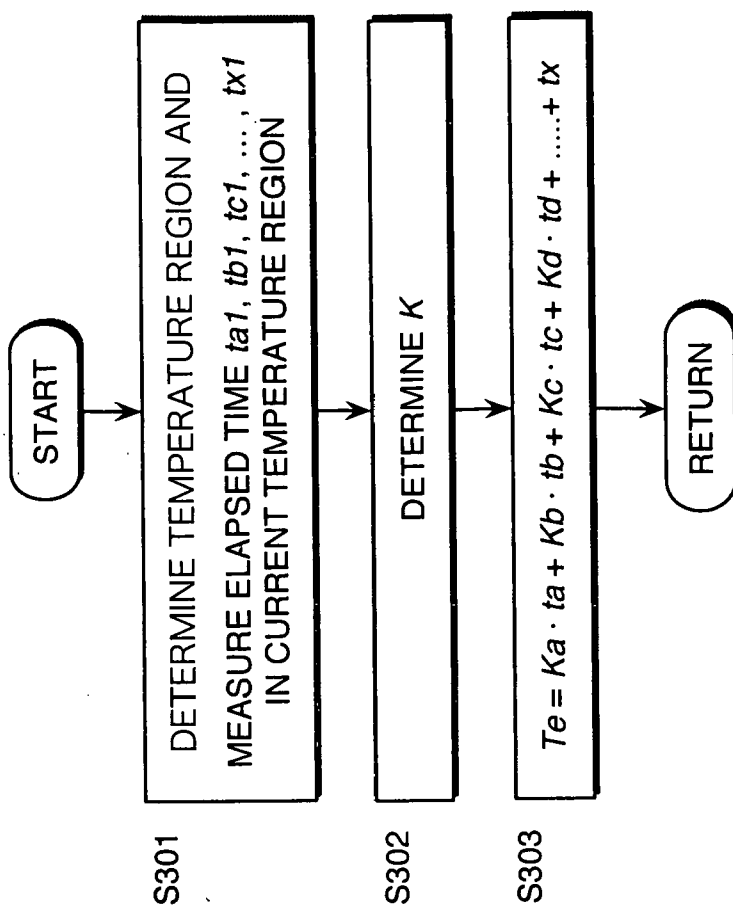


FIG. 10

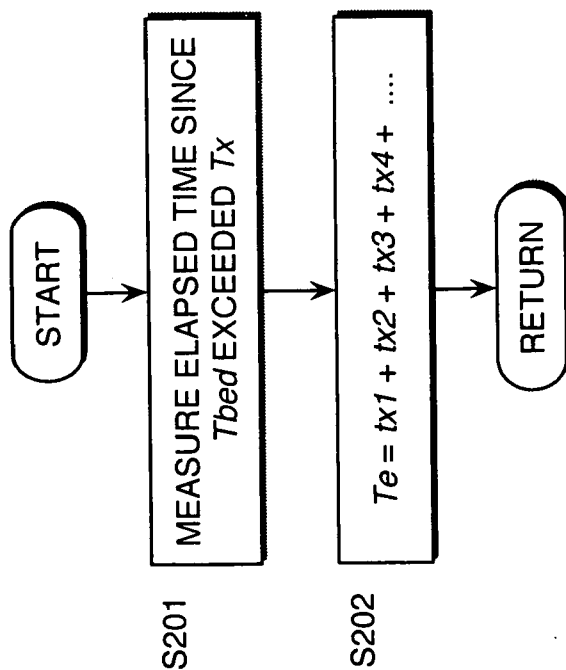


FIG. 6

FIG. 7A

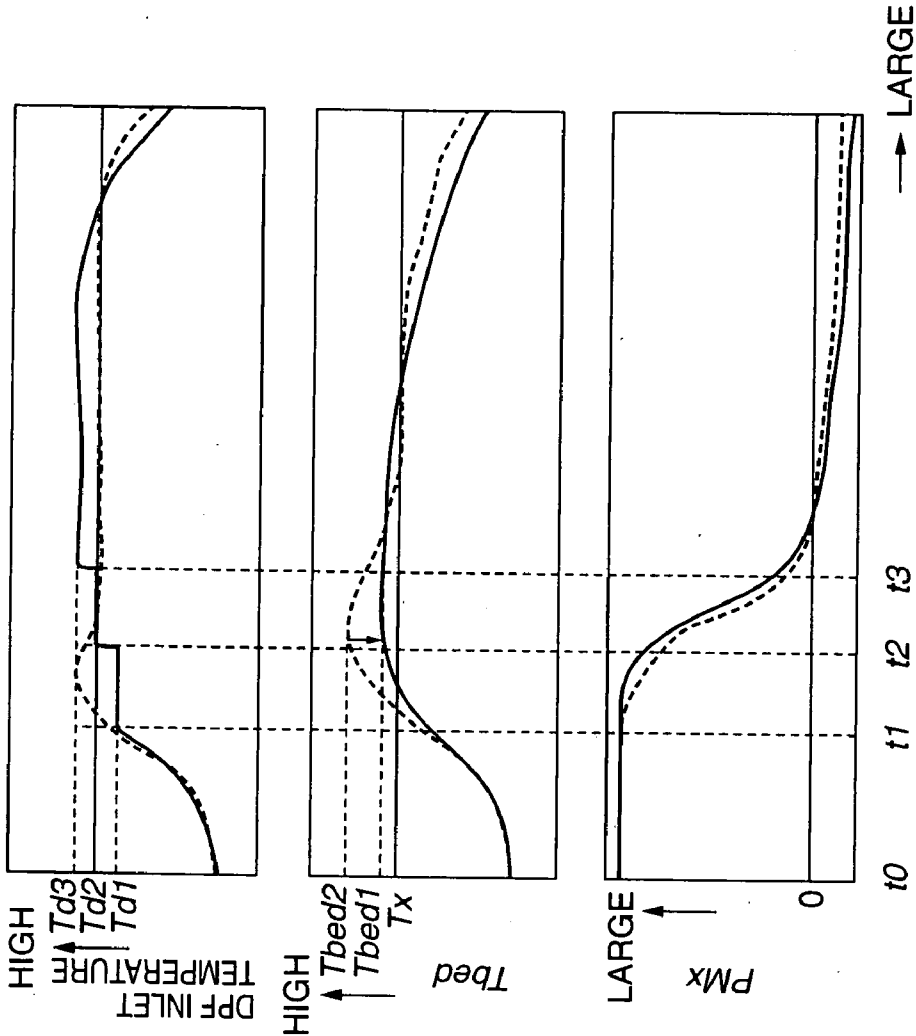


FIG. 7B

FIG. 7C

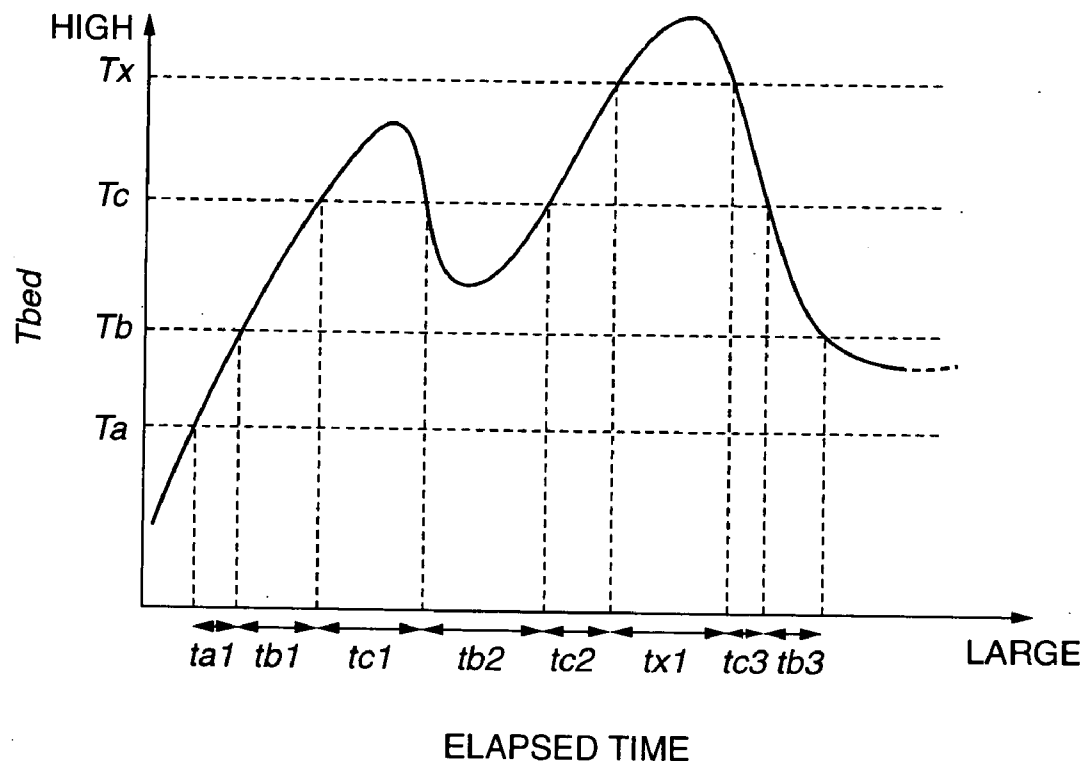


FIG.8

REGENERATION CONTROL OF DIESEL PARTICULATE FILTER

FIELD OF THE INVENTION

[0001] This invention relates to regeneration control of a filter which traps particulate matter contained in the exhaust gas of a diesel engine.

BACKGROUND OF THE INVENTION

[0002] A well known measure to decrease black smoke discharged from a diesel engine of a vehicle is to use a diesel particulate filter (hereinafter referred to as DPF) which traps particulate matter contained in the exhaust gas of the diesel engine.

[0003] When the amount of trapped particulate matter reaches a certain level, the DPF performs regeneration by burning the trapped particulate matter, and thus becomes able to trap particulate matter again. In order to burn the particulate matter, the temperature of the exhaust gas is raised by fuel injection control, or the temperature of the DPF is raised using a heater.

SUMMARY OF THE INVENTION

[0004] However, the operating condition of a diesel engine for a vehicle varies constantly, and hence it is not always possible to remove all of the particulate matter trapped in the DPF in one regeneration operation. As a result, regeneration ends with a part of the particulate matter remaining in the DPF. Such a state will be referred to as partial regeneration in the following description.

[0005] If particulate matter trapping is resumed in a partially regenerated state, errors are likely to occur when estimating the amount of particulate matter trapped in the DPF in order to determine the next regeneration timing.

[0006] Tokkai Hei 5-106427, published by the Japan Patent Office in 1993, proposes a method in which, following partial DPF regeneration, the DPF is heated by a heater until an end face of the DPF reaches a set temperature, and the required heating time is measured. Meanwhile, a fixed amount of air is supplied to the DPF before and after partial regeneration, and a difference in the flow velocity thereof is measured. Thus the amount of particulate matter remaining in the DPF is precisely estimated on the basis of the required heating time and the difference in the flow velocities of air. The start timing of the next regeneration is determined in consideration of the amount of particulate matter remaining in the DPF.

[0007] This prior art turns on the heater which is installed in the DPF when regeneration of the DPF is determined to be necessary. In the course of regeneration, the particulate matter trapped in the DPF burns due to the high temperature produced by the heater, and heat produced by the combustion of the particulate matter further raises the temperature of DPF. As a result, the temperature of DPF may rise excessively, which promotes early deterioration of the catalyst or substrate supporting the catalyst in the DPF.

[0008] It is therefore an object of this invention to maintain the temperature of DPF during regeneration in a preferable range.

[0009] In order to achieve the above object, this invention provides a regeneration device for a diesel particulate filter which traps particulate matter contained in an exhaust gas of a diesel engine. The device comprises a mechanism which raises a temperature of the exhaust gas in order to burn the particulate matter trapped in the filter. The mechanism is configured to raise the temperature of the exhaust gas to a higher temperature as an amount of particulate matter trapped in the filter decreases.

[0010] Preferably, the device further comprises a sensor which detects an amount of particulate matter trapped in the filter, and a programmable controller programmed to set a target exhaust gas temperature such that the target exhaust gas temperature is increased as the amount of the particulate matter trapped in the filter decreases, and control the mechanism to raise the exhaust gas temperature to the target exhaust gas temperature.

[0011] This invention also provides a regeneration method for a diesel particulate filter which traps particulate matter contained in an exhaust gas of a diesel engine. The method comprises raising the temperature of the exhaust gas to a higher temperature as an amount of particulate matter trapped in the filter decreases.

[0012] The details as well as other features and advantages of this invention are set forth in the remainder of the specification and are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic diagram of an engine for use in a vehicle, comprising a DPF regeneration device according to this invention.

[0014] FIG. 2 is a flowchart illustrating a DPF regeneration control routine executed by an engine controller according to this invention.

[0015] FIG. 3 is a diagram showing the characteristic of a map of an amount of trapped particulate matter PM_i , which is stored by the engine controller.

[0016] FIG. 4 is a timing chart showing an example of temporal change in a DPF bed temperature T_{bed} .

[0017] FIG. 5 is a diagram showing the characteristic of a map of an amount of burned particulate matter PM_r , which is stored by the engine controller.

[0018] FIG. 6 is a flowchart illustrating a subroutine for calculating an effective regeneration time T_e executed by the engine controller.

[0019] FIGS. 7A-7C are timing charts showing temporal change in a DPF inlet temperature, the DPF bed temperature T_{bed} , and a remaining amount of particulate matter PM_x as a result of the execution of the DPF regeneration control routine.

[0020] FIG. 8 is a timing chart showing temporal change in the DPF bed temperature T_{bed} for describing a computational algorithm of an effective regeneration time T_e according to a second embodiment of this invention.

[0021] FIG. 9 is a diagram showing the characteristic of a map of an effective regeneration time temperature coefficient K , which is stored by an engine controller according to the second embodiment of this invention.

[0022] **FIG. 10** a flowchart illustrating a subroutine for calculating the effective regeneration time T_e executed by the engine controller according to the second embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Referring to **FIG. 1** of the drawings, a diesel engine **20** for a vehicle comprises an intake passage **32** and an exhaust passage **30** connected to a combustion chamber **20A**.

[0024] The diesel engine **20** burns a mixture of air that is aspirated into the combustion chamber **20A** from the intake passage **32** and fuel that is injected into the combustion chamber **20A** by a fuel injector **23** by means of compression ignition. The combustion gas is discharged from the exhaust passage **30** as exhaust gas.

[0025] An air cleaner **35**, a compressor **29A** of a turbocharger **29**, an inter cooler **28**, and an intake throttle **21** are provided on the intake passage **32**. The intake air in the intake passage **32** is purified by the air cleaner **35**, compressed by the compressor **29A**, cooled by the inter cooler **28**, and then aspirated into the combustion chamber **20A** via the intake throttle **21**.

[0026] A turbine **29B** of the turbocharger **29** and a DPF **10** are provided on the exhaust passage **30**. The exhaust gas that is discharged from the combustion chamber **20A** into the exhaust passage **30** drives the turbine **29B** to rotate. The exhaust gas is then discharged into the atmosphere after trapping particulate matter in the DPF **10**.

[0027] A part of the exhaust gas in the exhaust passage **30** is recirculated into the intake air via an exhaust gas recirculation passage (EGR passage) **33**. The EGR passage **33** connects the exhaust passage **30** upstream of the turbine **29B** to the intake passage **32** downstream of the intake throttle **21**. An exhaust gas recirculation valve (EGR valve) **22** for regulating the exhaust gas recirculation flow (EGR flow) is provided on the EGR passage **33**.

[0028] The DPF **10** traps particulate matter contained in the exhaust gas in the exhaust passage **30**, and regenerates by burning the trapped particulate matter at a predetermined regeneration temperature. A known ceramic porous filter may be used as the DPF **10**.

[0029] Regeneration of the DPF **10** is performed by raising the exhaust gas temperature through control of the fuel injection amount and fuel injection timing of the fuel injector **23** in response to signals output from an engine controller **16**. Fuel injection control to raise the exhaust gas temperature includes well-known methods such as post-injection and injection timing retardation.

[0030] The engine controller **16** is constituted by a micro-computer comprising a central processing unit (CPU), read-only memory (ROM), random access memory (RAM), a clock, and an input/output interface (I/O interface). The controller may be constituted by a plurality of microcomputers.

[0031] To control regeneration of the DPF **10**, detection data from an air flow meter **34** which detects the intake air amount, a differential pressure sensor **12** which detects the differential pressure between the inlet and outlet of the DPF

10, a temperature sensor **13** which detects the exhaust gas temperature upstream of the DPF **10**, a temperature sensor **14** which detects the exhaust gas temperature downstream of the DPF **10**, and an air/fuel ratio sensor (A/F sensor) **15** which detects from the oxygen concentration in the exhaust gas the air/fuel ratio of the air/fuel mixture supplied to the combustion chamber **20A** are input respectively into the engine controller **16** as signals. A universal exhaust gas oxygen sensor or a less expensive oxygen sensor may be used as the A/F sensor **15**.

[0032] Next, referring to **FIG. 2**, a control routine for regenerating the DPF **10**, which is executed by the engine controller **16**, will be described. The engine controller **16** starts the routine together with the beginning of an operation of the diesel engine **20**. As soon as the routine ends, the next execution of the routine begins, and hence the routine is executed substantially constantly while the diesel engine **20** is operative.

[0033] First, in a step **S101**, the engine controller **16** estimates an amount of trapped particulate matter PM_i in the DPF **10** on the basis of the differential pressure detected by the differential pressure sensor **12**.

[0034] Next, in a step **S102**, the engine controller **16** determines whether or not the amount of trapped particulate matter PM_i has reached a reference trapped amount PM_α for regenerating the DPF **10**. The reference trapped amount PM_α for regenerating the DPF **10** is determined in advance through experiment.

[0035] If the amount of trapped particulate matter PM_i has not reached the reference trapped amount PM_α for regenerating the DPF **10**, the engine controller **16** repeats the process from the step **S101**.

[0036] When the amount of trapped particulate matter PM_i has reached the reference trapped amount PM_α for regenerating the DPF **10**, the engine controller **16** determines in a step **S103** a target DPF inlet temperature T_d from the amount of trapped particulate matter PM_i .

[0037] This determination is performed by looking up a map previously stored in the ROM and having the characteristic shown in **FIG. 3**. According to this map, the target DPF inlet temperature T_d decreases as the amount of trapped particulate matter PM_i increases. If the amount of trapped particulate matter PM_i is large, then the amount of particulate matter that is burned by a regeneration operation of the DPF **10** increases, and hence the temperature of the DPF **10** becomes likely to rise excessively as a result of the combustion heat.

[0038] By setting the target DPF inlet temperature T_d to decrease as the amount of trapped particulate matter PM_i increases, such excessive rises in temperature can be prevented.

[0039] The dotted line in the figure denotes the characteristic of the target DPF inlet temperature T_d that gradually decreases according to increases in the amount of trapped particulate matter PM_i . In practice, however, the target DPF inlet temperature T_d may be set to vary in a step-wise fashion as shown by the solid line in the figure. It is preferable to set the number of steps to more than three. If the target DPF inlet temperature T_d is set vary in a step-wise

fashion, it takes only several values, e.g., Td1, Td2 and Td3 in the figure, thereby simplifying temperature control of the DPF 10.

[0040] Next, in a step S104, an operation to raise the temperature of the exhaust gas is begun in order to realize the target DPF inlet temperature Td. This operation is performed by means of fuel injection control such as retardation of the fuel injection timing, or post-injection whereby additional fuel is injected following normal fuel injection. In cases where the regeneration device comprises a heater, the exhaust gas temperature may be raised using the heater.

[0041] Next, in a step S105, the engine controller 16 estimates a bed temperature Tbed of the DPF 10 from an exhaust gas temperature T1 upstream of the DPF 10, which is detected by the temperature sensor 13, and an exhaust gas temperature T2 downstream of the DPF 10, which is detected by the temperature sensor 14, in accordance with the following equation (1).

$$T_{bed}=b1 \cdot T1+b2 \cdot T2 \quad (1)$$

[0042] where, b1, b2=experimentally determined constants.

[0043] Next, in a step S106, the engine controller 16 calculates an effective regeneration time Te.

[0044] This calculation is performed by the execution of a subroutine shown in FIG. 6.

[0045] The effective regeneration time Te is a cumulative value of the time during which the bed temperature Tbed of the DPF 10 exceeds a target bed temperature Tx. The target bed temperature Tx is set to a temperature at which regeneration of the DPF 10 is performed reliably, or in other words a temperature at which the particulate matter is burned reliably. The target bed temperature Tx varies according to the amount of trapped particulate matter PMi.

[0046] For example, when the amount of trapped particulate matter PMi is 4.0 gram/liter, the target bed temperature Tx is 580 degrees Centigrade. When the amount of trapped particulate matter PMi is 2.0 gram/liter, the target bed temperature Tx is 600 degrees Centigrade.

[0047] Referring to FIG. 4, the bed temperature Tbed of the DPF 10 exceeds the target bed temperature Tx in time slots corresponding to tx1-tx4.

[0048] In a step S201 of FIG. 6, the engine controller 16 measures a time elapsed since the bed temperature Tbed exceeded the target bed temperature Tx using the clock function of the microcomputer which constitutes the engine controller 16.

[0049] In a next step S202, the engine controller 16 calculates a cumulative value of the durations of time during which the bed temperature Tbed exceeded the target bed temperature Tx as the effective regeneration time Te by the following equation (2).

$$Te=tx1+tx2+tx3+tx4+. . . \quad (2)$$

[0050] After the processing of the step S202, the engine controller terminates the subroutine, and also terminates the processing of the step S106.

[0051] Whenever the bed temperature Tbed of the DPF 10 is updated in the step S105, the engine controller 16 recalculates the effective regeneration time Te in this way.

[0052] Next, in a step S107, the engine controller 16 refers to a map having the characteristic shown in FIG. 5 and stored in the ROM in advance to determine an amount of burned particulate matter PMr from the bed temperature Tbed of the DPF 10 and the effective regeneration time Te. As shown in the map, the amount of burned particulate matter PMr increases as the bed temperature Tbed of the DPF 10 rises and the effective regeneration time Te lengthens.

[0053] Next, in a step S108, the engine controller 16 calculates an amount of remaining particulate matter PMx in the DPF 10 from the amount of burned particulate matter PMr and the amount of trapped particulate matter PMi, which was calculated in the step S101, using the following equation (3).

$$PMx=PMi-PMr \quad (3)$$

[0054] Next, in a step S109, the engine controller 16 compares the amount of burned particulate matter PMr to a predetermined target amount of burned particulate matter ΔPM. If the amount of burned particulate matter PMr has not reached the target amount of burned particulate matter ΔPM, the engine controller 16 repeats the process from the step S106 onward. It should be noted that during this repetition period, the particulate matter trapped in the DPF 10 continues to be burned.

[0055] When the amount of burned particulate matter PMr reaches the target amount of burned particulate matter ΔPM in the step S109, the engine controller 16 compares the amount of remaining particulate matter PMx in the DPF 10 to a target amount of remaining particulate matter PMd in a step S110. The target amount of remaining particulate matter PMd corresponds to an allowable amount of particulate matter remaining in the DPF 10 at the end of a regeneration operation. This value is set in advance through experiment in accordance with the traveling condition of the vehicle. When the traveling condition is suitable for regeneration of the DPF 10, the target amount of remaining particulate matter PMd is set to 0.0 gram/liter. In other words, the DPF 10 should be regenerated completely. Under conditions other than the above, providing that the reference trapped amount PMα is set to 4.0 gram/liter, the target amount of remaining particulate matter PMd may be set to 2.0 gram/liter, half the amount of the reference trapped amount PMα.

[0056] If the remaining amount of particulate matter PMx has not reached the target amount of remaining particulate matter PMd, the engine controller 16 repeats the process from the step S103 onward. In this case, the target DPF inlet temperature Td is reset in the step S103 on the basis of the amount of remaining particulate matter PMx instead of the amount of trapped particulate matter PMi in the DPF 10. The operation to raise the temperature of the exhaust gas is then executed in the step S104 on the basis of the newly set target DPF inlet temperature Td.

[0057] Estimation of the bed temperature Tbed of the DPF 10 is also executed anew in the step S105, whereupon the newly estimated bed temperature Tbed of the DPF 10 is used to repeat the processing of the steps S106-S109.

[0058] By means of this process, a regeneration operation of the DPF 10 is executed with a different target DPF inlet temperature Td every time the amount of burned particulate matter PMr trapped in the DPF 10 reaches the target amount

of burned particulate matter ΔPM , and the regeneration operation is executed continuously until the amount of remaining particulate matter PM_x reaches the target amount of remaining particulate matter PM_d .

[0059] When the amount of remaining particulate matter PM_x reaches the target amount of remaining particulate matter PM_d in the step S110, regeneration of the DPF 10 is complete. In this case, in a step S111, the engine controller 16 ends the operation to raise the temperature of the exhaust gas that was begun in the step S104. Following the processing of the step S111, the engine controller 16 ends the routine.

[0060] It should be noted that, as described above, the engine controller 16 begins to execute the next routine immediately after ending the current routine.

[0061] By executing the routine in FIG. 2 continuously while the diesel engine 20 is operative in the manner described above, a regeneration operation of the DPF 10 is performed whenever the amount of trapped particulate matter PM_i in the DPF 10 reaches the reference trapped amount PM_{α} .

[0062] According to this invention as described above, the time during which the DPF bed temperature T_{bed} exceeds the target bed temperature T_x is cumulatively calculated as the effective regeneration time T_e , and the amount of burned particulate matter PM_r is determined on the basis of the effective regeneration time T_e . Hence the amount of burned particulate matter PM_r that is burned by the operation to raise exhaust gas temperature, and the amount of remaining particulate matter PM_x in the DPF 10, can be learned accurately.

[0063] Referring to FIGS. 7A-7C, variation in the DPF inlet temperature, the DPF bed temperature T_{bed} and the amount of remaining particulate matter PM_x according to the execution of this DPF regeneration control routine will be described

[0064] The solid line in each figure denotes variation when the above DPF regeneration control routine is executed, whereas the dotted line in each figure denotes a case where regeneration of the DPF is performed with the target DPF inlet temperature T_d set to a fixed value.

[0065] At a time t_0 , when regeneration of the DPF is started, the target DPF inlet temperature T_d is set to the first target value T_{d1} in the step S103. As shown in FIG. 7A, the first target value T_{d1} is the lowest among the three candidate target values T_{d1} , T_{d2} and T_{d3} . The reason why the lowest target value T_{d1} is applied is that the amount of trapped particulate matter PM_i in the DPF 10 is large when regeneration of the DPF 10 is determined in the step S102.

[0066] As a result of fuel injection control to raise the temperature of the exhaust gas, at a time t_1 , the DPF inlet temperature reaches the first target value T_{d1} . The controller 16 then controls the fuel injection to stop raising the temperature of the exhaust gas further, while burning of the trapped particulate matter is continued. Since the target DPF inlet temperature T_d is set to the lowest target value T_{d1} , although the DPF bed temperature T_{bed} may exceed the target bed temperature T_x and reach a temperature T_{bed1} that is slightly higher than the target bed temperature T_x due

to the combustion heat of the trapped particulate matter in the DPF 10, it will not rise far above the target bed temperature T_x .

[0067] At a time t_2 , when the amount of burned particulate matter PM_r has reached the target amount of burned particulate matter ΔPM , the engine controller 16 raises the target DPF inlet temperature T_d to a second target value T_{d2} that is higher than the previous value T_{d1} . The controller 16 then controls the fuel injection so as to raise the temperature of the exhaust gas until the DPF inlet temperature reaches the second target value T_{d2} . After the time t_2 , since the amount of remaining particulate matter PM_x has decreased, the heat produced by burning of the remaining particulate matter is less than that produced in the time period t_1 - t_2 , and hence the DPF bed temperature T_{bed} is kept at the temperature T_{bed1} despite the higher target DPF inlet temperature T_{d2} . After the target DPF inlet temperature T_{d2} is reached, the engine controller 16 controls the fuel injection to stop raising the temperature of the exhaust gas further.

[0068] At a time t_3 , when the amount of burned particulate matter PM_r has again reached the target amount of burned particulate matter ΔPM , the engine controller 16 then raises the target DPF inlet temperature T_d to a third target value T_{d3} that is the highest among the three candidate target values T_{d1} , T_{d2} and T_{d3} .

[0069] The controller 16 then controls the fuel injection so as to raise the temperature of the exhaust gas until the DPF inlet temperature reaches the new target DPF inlet temperature T_{d3} . Since the amount of remaining particulate matter PM_x decreases further from the time t_2 , although the highest target value T_{d3} for the target DPF inlet temperature T_d is applied, the DPF bed temperature T_{bed} stays in the vicinity of the target bed temperature T_x .

[0070] After the time t_3 , the remaining particulate matter is further burned, and when the amount of remaining particulate matter PM_x finally becomes zero as shown in FIG. 7C, regeneration of the DPF 10 is complete.

[0071] If, unlike in this invention, the target DPF inlet temperature T_d is maintained at a fixed value T_{d2} throughout the regeneration period, the bed temperature of the DPF 10 rises sharply once the trapped particulate matter starts to burn. It continues rising even after it has reached the temperature T_{bed1} as shown in FIG. 7B, and finally reaches a bed temperature T_{bed2} which is much higher than the target bed temperature T_x . Such a high bed temperature risks early deterioration of the catalyst contained in the DPF 10.

[0072] After reaching the temperature T_{bed2} , the bed temperature of the DPF 10 falls as the amount of remaining particulate matter PM_x decreases through combustion. After the time t_3 , the fixed value T_{d2} of the target DPF inlet temperature T_d becomes lower with respect to the target value T_{d3} that is set according to this invention. Since the amount of the remaining particulate matter PM_x has become small at this stage, the heat produced by burning the remaining particulate matter is also small. The fixed target DPF inlet temperature T_{d2} applied at this stage makes the time required for the completion of the regeneration longer than in the case of this invention.

[0073] As can be understood from the above, by progressively increasing the target DPF inlet temperature T_d as the amount of remaining particulate matter PM_x decreases, the

bed temperature of the DPF 10 is prevented from rising excessively while the regeneration period is shortened. As a result, the energy consumed for the regeneration operation is minimized by this invention.

[0074] Next, referring to FIGS. 8-10, a second embodiment of this invention will be described.

[0075] The hardware constitution of this embodiment is identical to that of the first embodiment. The engine controller 16 according to this embodiment also executes the routine in FIG. 2. In this embodiment, however, the processing content of the step S106 in FIG. 2 differs from that of the first embodiment.

[0076] In the step S106 in the first embodiment, by executing the subroutine of FIG. 6, the effective regeneration time T_e was calculated as a cumulative value of the time during which the bed temperature T_{bed} of the DPF 10 exceeds the target bed temperature T_x .

[0077] As noted above, the target bed temperature T_x is the temperature at which the particulate matter is burned reliably, but even when the bed temperature T_{bed} of the DPF 10 does not reach the target bed temperature T_x , a part of the particulate matter can be burned as long as the bed temperature T_{bed} exceeds a temperature allowing combustion of the particulate matter. Hence in this embodiment, the amount of remaining particulate matter is calculated in consideration of the amount of particulate matter that is burned in this temperature region.

[0078] Referring to FIG. 8, in the process of reaching the target bed temperature T_x , the bed temperature T_{bed} of the DPF 10 passes through successive temperatures T_a , T_b , T_c , T_d . . . Here, the temperature T_a indicates a minimum temperature allowing combustion of the particulate matter in the DPF 10. In this temperature increase process, time is expressed in the following manner. That is, the increase period from the temperature T_a to T_b is expressed as $ta1$, the increase period from the temperature T_b to T_c is expressed as $tb1$, and the increase period from the temperature T_c to T_d is expressed as $tc1$.

[0079] The areas where the bed temperature T_{bed} falls are also expressed by time periods such as $tc2$, $tb2$, and $ta2$. Thus variation in the bed temperature T_{bed} can be understood by the temperature region and the duration of the region, and the effective regeneration time T_e is cumulatively calculated according to the following equation (4) in order to adopt as the effective regeneration time T_e a value obtained by multiplying the duration of a temperature region by a weighting coefficient K shown in FIG. 9 which corresponds to the temperature region.

$$T_e = K_a \cdot ta + K_b \cdot tb + K_c \cdot tc + K_d \cdot td + \dots + t_x \quad (4)$$

[0080] where, $ta = \sum ta_n$,

[0081] $tb = \sum tb_n$,

[0082] $tc = \sum tc_n$,

[0083] $td = \sum td_n$,

[0084] $tx = \sum tx_n$,

[0085] K_a =the weighting coefficient K of the temperature region from the temperature ta to tb ,

[0086] K_b =the weighting coefficient K of the temperature region from the temperature T_b to T_c ,

[0087] K_c =the weighting coefficient K of the temperature region from the temperature T_c to T_d ,

[0088] K_d =the weighting coefficient K of the temperature region from the temperature T_d to T_x , and

[0089] n =integers starting from 1.

[0090] Referring to FIG. 9, the weighting coefficient K expresses the amount of burned particulate matter per unit time in a certain temperature region, and has a maximum value of 1.0. The weighting coefficient K takes a higher value as the bed temperature T_{bed} rises and the amount of trapped particulate matter PM_i increases. In the region where the bed temperature T_{bed} equals or exceeds the target bed temperature T_x , the weighting coefficient K reaches 1.0.

[0091] The map of the weighting coefficient K of the characteristic shown in FIG. 9 is stored in the ROM of the engine controller 16 in advance for the purpose of this calculation.

[0092] In the step S106 in the routine of FIG. 2, the engine controller 16 executes a subroutine shown in FIG. 10 instead of the subroutine in FIG. 6 of the first embodiment.

[0093] First, in a step S301, the engine controller 16 determines the current temperature region and measures an elapsed time since the start of the current temperature region. In other words, the engine controller 16 measures the time periods, $ta1$, $tb1$, $tc1$, . . . , $tx1$ in FIG. 8.

[0094] In a next step S302, the engine controller 16 determines the weighting coefficient K that is suitable for the current temperature region by referring to the map corresponding to FIG. 9 from the bed temperature T_{bed} of the DPF 10 and the amount of trapped particulate matter PM_i . In other words, the engine controller 16 determines K_a , K_b , K_c , K_d . . . in the equation (4).

[0095] In a next step S303, the engine controller 16 calculates the effective regeneration time T_e by performing the calculation of the equation (4).

[0096] After the processing of the step S303, the engine controller 16 ends the subroutine and thus the processing of the step S106 in FIG. 2.

[0097] To summarize the above, this embodiment is different from the first embodiment in that the engine controller 16 calculates the effective regeneration time T_e using the equation (4) above in place of the equation (2). In other words, even if the bed temperature T_{bed} of the DPF 10 is equal to or lower than the target bed temperature T_x , as long as the bed temperature T_{bed} exceeds the minimum temperature T_a allowing combustion of the particulate matter, the duration of the corresponding temperature region is used in the calculation of the effective regeneration time T_e based on the weighting coefficient K corresponding to the temperature region.

[0098] By calculating the amount of burned particulate matter PM_i in the temperature regions equal to or below the target bed temperature T_x on the basis of the effective regeneration time T_e calculated in this manner, and then calculating the amount of remaining particulate matter PM_x , variation in the amount of remaining particulate matter PM_x

during a regeneration operation of the DPF 10 can be earned with a greater degree of precision.

[0099] The contents of Tokugan 2003-325040, with a filing date of Sep. 17, 2003 in Japan and Tokugan 2003-359635 with a filing date of Oct. 20, 2003 in Japan, are hereby incorporated by reference.

[0100] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, within the scope of the claims.

[0101] The embodiments of this invention in which an exclusive property or privilege is claimed are defined as follows:

What is claimed is:

1. A regeneration device for a diesel particulate filter which traps particulate matter contained in an exhaust gas of a diesel engine, comprising:

a mechanism which raises a temperature of the exhaust gas in order to burn the particulate matter trapped in the filter, the mechanism being configured to raise the temperature of the exhaust gas to a higher temperature as an amount of particulate matter trapped in the filter decreases.

2. The regeneration device as defined in claim 1, wherein the device further comprises a sensor which detects an amount of particulate matter trapped in the filter and a programmable controller programmed to set a target exhaust gas temperature such that the target exhaust gas temperature is increased as the amount of the particulate matter trapped in the filter decreases, and control the mechanism to raise the exhaust gas temperature to the target exhaust gas temperature.

3. The regeneration device as defined in claim 2, wherein the engine controller is further programmed to increase the target exhaust gas temperature more than three times in a step-wise fashion during the regeneration of the diesel particulate filter.

4. The regeneration device as defined in claim 2, wherein the device further comprises a sensor which detects a temperature of the filter, and the engine controller is further programmed to cumulatively calculate a time during which the temperature of the filter exceeds a target temperature as an effective regeneration time, and estimate an amount of burned particulate matter in the filter.

5. The regeneration device as defined in claim 4, wherein the engine controller is further programmed to determine, when the filter temperature does not exceed the target temperature, whether or not the filter temperature exceeds a

temperature allowing combustion of the particulate matter, which is lower than the target temperature, and calculate a value obtained by multiplying the time during which the filter temperature exceeds the temperature allowing combustion of the particulate matter by a predetermined coefficient, combined with the time during which the filter temperature exceeds the target temperature, as the effective regeneration time.

6. The regeneration device as defined in claim 5, wherein the engine controller is further programmed to determine the coefficient based on the temperature of the filter.

7. The regeneration device as defined in claim 5, wherein the engine controller is further programmed to determine the coefficient based on the amount of particulate matter trapped in the filter.

8. The regeneration device as defined in claim 4, wherein the engine controller is further programmed to memorize the amount of particulate matter trapped in the filter at a timing when the mechanism begins to raise the temperature of the exhaust gas as an initial trapped amount, calculate an amount of remaining particulate matter in the filter by subtracting the amount of burned particulate matter from the initial trapped amount, and control the mechanism to stop raising the temperature of the exhaust gas when the amount of remaining particulate matter has decreased to a predetermined target amount.

9. The regeneration device as defined in claim 1, wherein the diesel engine further comprises a combustion chamber, and the mechanism comprises a fuel injector which injects fuel into the combustion chamber and varies a fuel injection amount and a fuel injection timing in accordance with a signal from the engine controller.

10. A regeneration device for a diesel particulate filter which traps particulate matter contained in an exhaust gas of a diesel engine, comprising:

means for raising a temperature of the exhaust gas in order to burn the particulate matter trapped in the filter, the means being configured to raise the temperature of the exhaust gas to a higher temperature as an amount of particulate matter trapped in the filter decreases.

11. A regeneration method for a diesel particulate filter which traps particulate matter contained in an exhaust gas of a diesel engine, the engine comprising a mechanism which raises a temperature of the exhaust gas in order to burn the particulate matter trapped in the filter, the method comprising:

controlling the mechanism to raise the temperature of the exhaust gas to a higher temperature as an amount of particulate matter trapped in the filter decreases.

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