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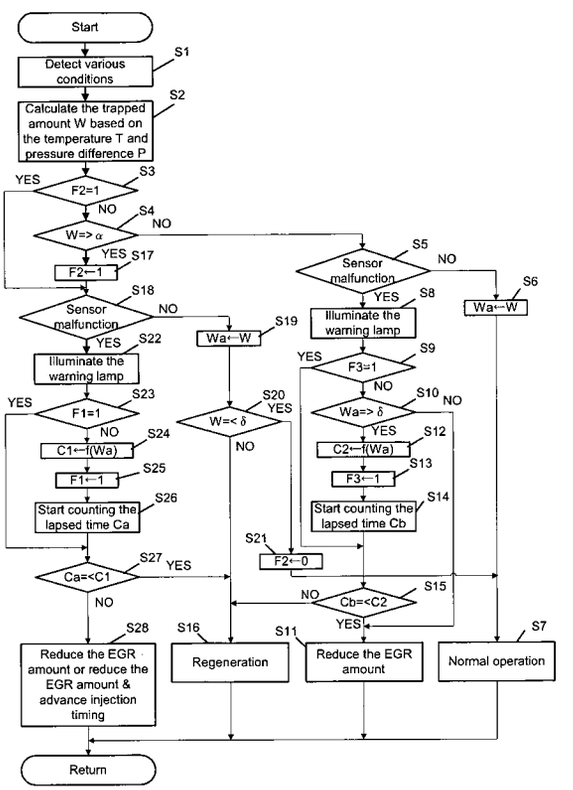
(54) Control apparatus for an engine, engine, control method of an engine, and computer program product

(57) A control apparatus for an engine which prevents the clogging of the filter or accompanying abnormal burnup, even with the occurrence of a failure of a sensor for detecting the amount of the exhausted particulate trapped in the particulate filter. In case that a malfunction is detected in pressure sensors and a temperature sensor for detecting the upstream exhaust-gas pressure, the downstream exhaust-gas pressure, and the second exhaust-gas temperature as parameter values associated with the amount of the exhausted particulate trapped in a particulate filter, a control unit performs a control to suppress the particulate filter from being clogged with the exhausted particulate by controlling the operational condition of an engine in comparison with the case without the detection of the malfunction.

FIG. 4



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Description

[0001] The present invention relates to a control apparatus for an engine, engine, control method of an engine, and computer program product, which are adapted to prevent the clogging of a particulate filter that traps exhausted particulate included in exhaust gas from an engine.

[0002] In general, exhaust gas from a diesel engine includes fine particle called particulate. For trapping and removing the particulate, a particulate filter may be provided in an exhaust passage.

[0003] As an operating period of the engine is prolonged, the amount of the exhausted particulate trapped in the filter increases, causing the filter to be gradually clogged with the particulate. To cope with this, generally, when a predeterminable condition is fulfilled, the removal of the exhausted particulate from the filter, or the filter regeneration is performed.

[0004] In order to make a judgement as to whether or not the predeterminable condition is fulfilled, pressure sensors or the like may be provided for detecting the exhaust-gas pressure on both the inflow side and the outflow side of the filter. A pressure difference between the detections of both the pressure sensors is used to determine the amount of the exhausted particulate having been trapped. For more accurate detection of the amount, a temperature sensor may be additionally provided for detecting the temperature of the filter. The detected temperature is used to compensate for the trapped amount of the exhausted particulate.

[0005] In case of the occurrence of a failure of the sensors, the accurate detection of the amount of the exhausted particulate trapped in the filter is no longer possible, adversely affecting a regeneration control of the particulate filter based on the detection. This may results in the possible clogging of the filter and thus a failure of the filter due to abnormal burnup caused by the clogging, which may eventually leads to melt of the filter.

[0006] To cope with the failure of the sensor, it has been presented that in case of a failure of a pressure-difference sensor used to determine the timing of the regeneration for example, the regeneration timing is alternatively determined in accordance with the cumulative rotational speed of the engine or an interval from the last completion timing of the regeneration (refer to Japanese Unexamined Patent Publication H6-280544, for example).

[0007] However, in the technology disclosed in Japanese Unexamined Patent Publication H6-280544, even for the same cumulative rotational speed, the amount of the exhausted particulate varies with the EGR amount depending on the engine operational condition. That is, the larger amount of the particulate is likely to be exhausted from the engine in an engine operational condition where the EGR amount or the amount of exhaust gas returning from an exhaust system to an intake system is relatively large. Thus, the timing to initiate regeneration, in other words, the fact of clogging of the filter cannot be accurately determined, making it impossible to reliably prevent the problem of the failure of the filter or the like.

[0008] In view of the above, an object of the present invention is to prevent the clogging of the filter or accompanying abnormal burnup, even with the occurrence of a failure of a sensor for detecting the amount of the exhausted particulate trapped in the particulate filter.

[0009] The object is solved according to the invention by a control apparatus for an engine according to claim 1, by an engine according to claim 8, by a control method of an engine according to claim 9, and by a computer program product according to claim 10. Preferred embodiments of the present invention are subject of the dependent claims.

[0010] Accordingly, the present invention prevents the clogging of the filter or accompanying abnormal burnup, even with the occurrence of a failure of a sensor for detecting the amount of the exhausted particulate trapped in the particulate filter.

[0011] In accordance with the present invention, there is provided a control apparatus for an engine being equipped with trapping means for trapping exhausted particulate in an exhaust passage of the engine. The control apparatus comprises: parameter value detection means for detecting at least one parameter value associated with the amount of exhausted particulate trapped in the trapping means; trapped amount estimation or determination or calculating means for estimating or determining or calculating the amount of exhausted particulate trapped in the trapping means based on the parameter value detected by the parameter value detection means; trapped amount judgement or determination means for judging or determining whether or not the trapped amount estimated by the trapped amount estimation means is equal to a specified (predetermined or predeterminable) value or larger; and regeneration means for causing the exhausted particulate trapped in the trapping means to burn out for regenerating the trapping means when the trapped amount judgement or determination means judges or determines that the trapped amount is equal to the specified (predetermined or predeterminable) value or larger. The control apparatus further includes: malfunction detection means for detecting a malfunction of the parameter value detection means; and clogging suppression means for suppressing the clogging of the trapping means. The clogging suppression means suppresses more intensively or further or additionally the trapping means from being clogged with the exhausted particulate by controlling the operational condition of the engine in case that the malfunction detection means detects a malfunction of the parameter value detection means, than the case without the detection of the malfunction.

[0012] Accordingly, in case that the malfunction detection means detects a malfunction of the parameter

value detection means, the clogging of the trapping means with exhausted particulate is more intensively suppressed by the control of the operational condition of the engine, than the case without the detection of the malfunction. This prevents the clogging of the trapping means and a failure thereof due to accompanying abnormal burnup, in case of the occurrence of the parameter value detection means.

[0013] Preferably, the engine may be further equipped with exhaust-gas recirculation means for recirculating the exhaust gas to the intake side in accordance with the engine operational condition and fuel injection control means for adjusting the fuel injection timing. In case that the malfunction detection means detects a malfunction of said parameter value detection means, the clogging suppression means implements at least one of: the reduction of the exhaust-gas amount returning to the intake side by controlling the exhaust-gas recirculation means; and the advance of the injection timing by controlling the fuel injection control means, in comparison with the case without the detection of the malfunction.

[0014] Accordingly, in case that the malfunction detection means detects a malfunction of the parameter value detection means, at least one of the following controls is/are implemented: the reduction of the exhaust-gas amount returning to the intake side by controlling the exhaust-gas recirculation means; and the advance of the injection timing by controlling the fuel injection control means which adjusts the fuel injection timing, in comparison with the case without the detection of the malfunction.

[0015] That is, reducing the amount of exhaust gas returning to the intake side by controlling the exhaust gas recirculation means decreases the amount of the exhausted particulate discharged from the combustion chamber, thereby preventing the clogging and accompanying abnormal burnup. Additionally or otherwise, advancing the fuel injection timing by controlling the fuel injection control means that adjusts the fuel injection timing increases the amount of NO2 discharged from the combustion chamber to promote the burn-out of the exhausted particulate in the trapping means, thereby preventing the clogging and accompanying abnormal burnup. Implementing both prevent them further effectively.

[0016] More preferably, the control apparatus may further comprise trapped amount storage means for storing the trapped amount estimated by the trapped amount estimation means; second trapped amount judgement or determining means for judging or determining whether or not the trapped amount stored immediately prior to the detection of the malfunction is equal to a second specified (predetermined or predeterminable) value or larger in case that the malfunction detection means detects the malfunction of the parameter value detection means; and regeneration period setting means for setting the operational period of the regeneration means in accordance with the trapped amount stored in the trapped amount storage means (preferably immediately) prior to the detection of the malfunction when the second trapped amount judgement means judges or determines that the trapped amount is equal to the second specified (predetermined or predeterminable) value or larger. The clogging suppression means suppresses the clogging after the regeneration means implements the regeneration of the trapping means during the operational period set by the regeneration period setting means when the second trapped amount judgement means judges or determines that the trapped amount stored in the trapped amount storage means (preferably immediately) prior to the detection of the malfunction is equal to the second specified (predetermined or predeterminable) value or larger.

[0017] Accordingly, in case that the malfunction detection means detects the malfunction of the parameter value detection means, the judgement or determination is made as to whether or not the trapped amount stored in the trapped amount storage means immediately prior to the detection of the malfunction is equal to the second specified (predetermined or predeterminable) value or larger. If the trapped amount is judged to be equal to the second specified (predetermined or predeterminable) value or larger, the clogging is suppressed after the regeneration of the trapping means is implemented during the operational period set by the regeneration period setting means and thus the trapped amount of the exhausted particulate is reduced. Thus, the clogging and accompanying abnormal burnup is reliably prevented when a large amount of particulate is trapped.

[0018] Further preferably, the control apparatus may further comprise: trapped amount storage means for storing the trapped amount estimated by the trapped amount estimation means; and/or second trapped amount judgement or determining means for judging or determining whether or not the trapped amount stored immediately prior to the detection of the malfunction is equal to the second specified (predetermined or predeterminable) value or larger in case that the malfunction detection means detects the malfunction of the parameter value detection means. When the second trapped amount judgement means judges or determines that the trapped amount is equal to the second specified (predetermined or predeterminable) value or larger, the clogging suppression means implements both the reduction of the exhaust-gas amount returning to the intake side by controlling the exhaust-gas recirculation means and the advance of the injection timing by controlling the fuel injection control means. When the second trapped amount judgement means judges or determines that the trapped amount is not equal to the second specified (predetermined or predeterminable) value or larger, the clogging suppression means implements only the reduction of the recirculating exhaust-gas amount by controlling the exhaust-gas recirculation means.

[0019] Accordingly, in case that the malfunction de-

tection means detects a malfunction of the parameter value detection means and when the second trapped amount judgement means judges or determining that the trapped amount immediately prior to the occurrence of the malfunction is equal to the second specified (predetermined or predeterminable) value or larger, the exhaust-gas recirculation means is controlled to reduce the recirculation amount of the exhaust gas. This reliably prevents the clogging of the trapping means and accompanying abnormal burnup while preventing the production of noise, which is likely to be intensified by the advance of the injection timing, because of no advance in the injection timing.

[0020] On the other hand, in case that the malfunction detection means detects a malfunction of the parameter value detection means and when the second trapped amount judgement means judges or determines that the trapped amount immediately prior to the occurrence of the malfunction is equal to the second specified (predetermined or predeterminable) value or larger, both the reduction of the exhaust-gas amount returning to the intake side by controlling the exhaust-gas recirculation means; and the advance of the injection timing by controlling the fuel injection control means which adjusts the fuel injection timing, are implemented. This prevents the clogging of the trapping means and accompanying abnormal burnup more reliably than the case with only one of them being implemented.

[0021] If the clogging suppression means consists of a plurality of clogging suppression implementation means including at least EGR amount decreasing means for reducing the exhaust-gas recirculation amount by controlling exhaust-gas recirculation means for recirculating the exhaust gas to the intake side in accordance with the engine operational condition, the EGR amount decreasing means may be preferably operated preceding the other clogging suppression implementation means in case that the malfunction detection means detects a malfunction of the parameter value detection means.

[0022] Accordingly, in case that the malfunction detection means detects a malfunction of the parameter value detection means, the EGR amount decreasing means, which suppresses the clogging by the exhausted particulate more effectively, is operated preceding the other clogging suppression implementation means. This prevents the clogging of the trapping means effectively, while excluding the adverse effect due to the operation of the other clogging suppression implementation means.

[0023] More preferably, the control apparatus may further comprise: trapped amount storage means for storing the trapped amount estimated by the trapped amount estimation means; and second trapped amount judgement means for judging or determining whether or not the trapped amount stored immediately prior to the detection of the malfunction is equal to a second specified (predetermined or predeterminable) value or larger in case that the malfunction detection means detects the malfunction of the parameter value detection means. The clogging suppression means operates the EGR amount decreasing means and the other clogging suppression implementation means when the second trapped amount judgement means judges that the trapped amount is equal to the second specified (predtermined or predeterminable) value or larger.

[0024] Accordingly, both the EGR amount decreasing means and the other clogging suppression implementation means are operated to intensively suppress the clogging of the trapping means.

[0025] Further preferably, the control apparatus may further comprise: trapped amount storage means for storing the trapped amount estimated or calculated or determined by the trapped amount estimation means; and regeneration duration setting means for setting the regeneration duration of the regeneration means in accordance with the ante-malfunction trapped amount stored in the trapped amount storage means immediately prior to the detection of the malfunction in case that the malfunction detection means detects the malfunction of the parameter value detection means during the regeneration of the trapping means. The clogging suppression means substantially suppresses the clogging after the regeneration means continues the regeneration of the trapping means during the regeneration duration set by the regeneration duration setting means, in case that the malfunction detection means detects the malfunction of the parameter value detection means while the regeneration means is implementing the regeneration.

[0026] Accordingly, the regeneration of the filter preferably is continued during the regeneration duration set by the regeneration duration setting means in case that the malfunction detection means detects the malfunction of the parameter value detection means during the regeneration. This reliably reduces the amount of the trapped exhausted particulate, thereby preventing the clogging of the trapping means and accompanying abnormal burnup.

[0027] Moreover, the regeneration duration preferably is set in accordance with the ante-malfunction trapped amount, thereby preventing the unduly temperature rise of the trapping means due to the unnecessarily prolonged regeneration, and thus accompanying failure of the trapping means. Additionally, the clogging suppression means substantially suppresses the clogging after the regeneration means continues the regeneration of the trapping means during the regeneration duration, thereby reliably preventing the trapping means from being clogged and its failure due to abnormal burnup caused by the clogging, in case of the malfunction of the parameter value detection means.

[0028] In accordance with the present invention, there is further provided an engine equipped with the control apparatus according to the present invention or preferred embodiments thereof.

[0029] In accordance with the present invention, there is still further provided a control method of an engine being equipped with trapping means for trapping exhausted particulate in an exhaust passage of the engine. The method comprises the following steps of: detecting at least one parameter value associated with the amount of exhausted particulate trapped in trapping means; estimating or calculating or determining the amount of exhausted particulate trapped in the trapping means based on the detected parameter value; judging or determining whether or not the estimated trapped amount is equal to a specified (predetermined or predeterminable) value or larger; causing the exhausted particulate trapped in the trapping means to burn out for regenerating the trapping means when the estimated trapped amount is judged or determined to be equal to the specified (predetermined or predeterminable) value or larger; detecting a malfunction in the step of detecting at least one parameter value; and substantially suppressing more intensively or further or additionally the trapping means from being clogged with the exhausted particulate by controlling the operational condition of the engine in case that a malfunction is detected in the step of detecting at least one parameter value, than the case without the detection of the malfunction.

[0030] In accordance with the present invention, there is still further provided a computer program product which, when loaded onto a computer for use in a control apparatus for an engine being equipped with trapping means for trapping exhausted particulate in an exhaust passage of the engine, carries out the control method of an engine according to the present invention or preferred embodiments thereof.

[0031] Other features, aspects, and advantages of the present invention will become apparent from the following description of the invention which refer to the accompanying drawings.

FIG. 1 is a system diagram of an engine according to an embodiment of the present invention;

FIG. 2 is a map providing the characteristic of the EGR amount with respect to the engine rotational speed and the engine load;

FIG. 3 is a map used in estimating the trapped amount from a pressure difference and temperature;

FIG. 4 is a flow chart showing an example of the clogging suppression control;

FIG. 5 is an illustration of sensor malfunction;

FIG. 6 is a map showing a regeneration duration with respect to the trapped amount;

FIG. 7 is a map showing an injection timing with respect to the engine rotational speed and the engine load; and

FIG. 8 is a flow chart showing another example of the clogging suppression control.

[0032] An embodiment of the present invention will now be described. It should be understood that even though embodiments are separately described, single features thereof may be combined to additional embodiments.

[0033] The present invention is preferably applied to a diesel engine 1 shown in FIG. 1. The engine 1 is a four-cylinder engine for example, having four pistons 3 (one of which is shown) provided therewith which substantially vertically reciprocate in a cylinder bore of an engine main body 2. A cylinder head of the engine main body 2 is provided with an injector 4 correspondingly to each cylinder. The injector 4 directly injects fuel into a combustion chamber of the cylinder.

[0034] A high-pressure fuel pump 5 and a common rail 6 are arranged in a fuel supply passage between a fuel tank, not shown, and the injector 4. The pump 5 press-feeds fuel from the fuel tank to the common rail 6, and the common rail 6 accumulates the press-fed fuel. When the injector 4 opens its valve, a fuel having been accumulated in the common rail 6 is injected at high pressure through one or more injection bores of the injector 4 preferably directly into the combustion chamber of the cylinder. The amount of the fuel to be injected preferably is controllable by the adjustment of the valve-opening duration of the injector 4 and/or the fuel pressure in the common rail 6. The timing of the fuel injection preferably is controllable by the adjustment of the valve-opening timing of the injector 4. In the drawing, the arrows drawn along the fuel supply passage indicate the direction of fuel flow.

[0035] In an intake passage 10, from the upstream side, there are preferably disposed at least part of the following elements: an air filter 11, an air-sensor such as an air-flow meter 12, a compressor 13 preferably of a turbocharger, an intercooler 14, a throttle valve 15 for adjusting the intake amount, an intake throttle valve opening sensor 16 for detecting the opening degree of the throttle valve 15, an intake-air temperature sensor 17, intake-air pressure sensor 18, and an intake valve 19, in this order.

[0036] In an exhaust passage 20, from the upstream side, there are preferably disposed at least part of the following elements: an exhaust valve 21, preferably a turbine 22 of the turbocharger, a first exhaust-gas temperature sensor 23, an oxidation catalyst converter 24, a second exhaust-gas temperature sensor 25 (as preferred parameter value detection means), an upstream pressure sensor 26 (as preferred parameter value detection means), a particulate filter 27 for trapping exhausted particulate in exhaust gas, a downstream pressure sensor 28 (as preferred parameter value detection means), and a third exhaust-gas temperature sensor 29, in this order. Between a (preferably relatively upstream) portion of the exhaust passage 20 and a (preferably relatively downstream) portion of the intake passage 10, an exhaust gas recirculation (EGR) passage 30 is disposed. In the EGR passage 30, an EGR valve 31 is provided for adjusting or controlling the recircula-

tion amount of the exhaust gas. The particulate filter 27 preferably is coated with oxidation catalyst agents including noble metal such as platinum

[0037] An engine rotational speed sensor 41 is attached or connected preferably to a crankcase of the engine main body 2, and a coolant temperature sensor 42 preferably is attached to a cylinder block (not shown). The common rail 6 is provided with a common rail pressure sensor 43 for detecting the accumulating pressure of fuel. In a passenger compartment, an accelerator pedal position sensor 45 is provided for detecting the operational amount of an accelerator pedal 44.

[0038] A control unit 50 of the engine 1 outputs control signals to the injector 4 and the high-pressure fuel pump 5 in accordance with the intake-air amount, the intake-air temperature, the intake-air pressure, the temperature of the exhaust-gas flowing into the oxidation catalyst converter 24, the temperature of the exhaust-gas flowing out of the particulate filter 27, the pressures upstream and downstream of the filter, the engine rotational speed, the coolant temperature, the fuel pressure in the common rail 6, and/or the engine load, which are detected by the above-described sensors.

[0039] The control unit 50 calculates or determines a target fuel injection amount by compensating for a basic fuel injection amount by use of the coolant temperature and the intake-air temperature. The basic fuel injection amount preferably is determined from the engine rotational speed detected by the engine rotational speed sensor 41 and the engine load detected by the accelerator pedal position sensor 45, with the influence of EGR being considered.

[0040] The control unit 50 adjusts the EGR amount by controlling the EGR valve and the intake throttle valve 15. The EGR amount, as shown in the map of FIG. 2, is reduced for the larger engine load (operational degree of the acceleration pedal) and for the larger engine load.

[0041] The control unit 50 estimates or determines the amount of the exhausted particulate trapped in the particulate filter 27 with reference to the maps shown in FIG. 3 based on the detected pressure difference between the pressure upstream of the particulate filter 27 and the pressure downstream of the particulate filter 27, and the temperature detected by the second exhaust-gas temperature sensor 25. According to the map, the estimated trapped amount increases as the pressure difference increases. When the detected temperature is above a specified (predetermined or predeterminable) standard temperature, pressure loss is reduced in the particulate filter 27. Thus, in this case, a characteristic for high temperature is used, which provides greater trapped amount than that in the standard temperature for the same pressure difference. On the contrary, when the detected temperature is below the specified (predetermines or predeterminable) standard temperature, pressure loss is increased in the particulate filter 27. Thus, in this case, a characteristic for low temperature is used, which provides smaller trapped amount than that in the standard temperature for the substantially same pressure difference. It should be noted that the above estimation or determination is one example, and otherwise the characteristic may be subdivided in more detail with respect to temperature, or a standard characteristic may be multiplied by correction factors varying with temperature.

[0042] When the estimated trapped amount reaches a specified (predetermined or predeterminable) amount or more, the control unit 50 initiates the regeneration or burning-out operation of the exhausted particulate trapped in the particulate filter 27, or the regeneration of the particulate filter 27. That is, the control unit 50 changes the opening degree of the intake throttle valve 15 or the amount of intake air to a smaller degree than that in non-regeneration state (changes the degree to closing side), and preferably initiates additional fuel injection (post injection) during the expansion stroke after a primary fuel injection performed near the top dead center (TDC) of the compression stroke of the piston 3. The post injection aims at oxidizing unburned component, caused by the post injection, in the oxidation catalyst converter 24 and the particulate filter 27 preferably loaded with oxidation catalyst agents to raise the temperature thereof for quickly regenerating the particulate filter 27. The reduction in the opening degree of the intake throttle valve 15 to smaller than that in the non-regenerating state aims at suppressing the particulate filter 27 from being cooled by the flow-in of fresh air for efficiently raising the temperature thereof.

[0043] In case that a malfunction occurs in even any one of the pressure sensors 26, 28, and the second exhaust-gas temperature sensor 25, the estimation or determination of the trapped amount W becomes impossible or the accuracy in the estimation degrades. In this case, the continuation of the normal operational condition of the engine 1 may possibly cause the particulate filter 27 to be clogged and thus a failure may occur in the particulate filter 27. To cope with this, the control apparatus for the engine 1 in accordance with this embodiment implements a control for suppressing the clogging of the particulate filter 27 when a failure occurs in even any one of the pressure sensors 26, 28, and the second exhaust-gas temperature sensor 25.

[0044] The clogging suppression control implemented in case that the sensor malfunction occurs will now be described in detail with reference to the flow chart shown in FIG. 4. As apparent from the above description, the control unit 50 preferably is loaded with a computer program for carrying out the following control flow. The program is preferably stored in a memory (not shown) coupled to the control unit 50.

[0045] First, in step S1, the control unit 50 obtains a variety of values detected by the above-described sensors such as the temperature T of the particulate filter 27 (detected by the second exhaust-gas temperature sensor 25), the exhaust-gas pressure upstream of the particulate filter 27 (detected by the upstream pressure

sensor 26), the exhaust-gas pressure downstream of the particulate filter 27 (detected by the downstream pressure sensor 28), and/or the engine rotational speed. In addition, the control unit 50 calculates or determines the pressure difference between the detected upstream exhaust-gas pressure and the detected downstream exhaust-gas pressure. Then, in step S2, the trapped amount W is calculated or estimated based on the detected temperature T of the particulate filter 27 and/or the pressure difference.

[0046] Next, in step S3, a judgement or determination is made as to whether or not the flag F2 is 1. If NO is judged meaning that the flag F2 is not 1, a judgement or determination is made as to whether or not the trapped amount W is equal to or larger than a specified (predetermined or predeterminable) value α in step S4 (as preferred trapped amount judgement means). The initial value of the flag F2 is 0.

[0047] When the trapped amount W reaches a specified (predetermined or predeterminable) value α or larger, the flag F2 is set to 1 in step S17. When the trapped amount W is decreased to a specified (predetermined or predeterminable) value δ or smaller by the regeneration operation, the flag F2 is reset to 0 in step S21.

[0048] If step S4 judges NO meaning that the trapped amount W is not equal to the predetermined or predeterminable value α or larger, the sequence proceeds to step S5 where a judgement or determination is made as to whether the presence or absence of a malfunction of the pressure sensors 26, 28 and/or second exhaust-gas temperature sensor 25 (as preferred malfunction detection means). Herein, the malfunction of the pressure sensors 26, 28 and/or second exhaust-gas temperature sensor 25 refers to the condition where its output value is out of a specified (predetermined or pretdeterminable) range (normal range) e.g. due to the brake or short in sensor wiring. In step S5, if the output value is in the predetermined or predeterminable range, the absence of a malfunction (NO) is judged. On the other hand, if the output value is out of the predetermined or predeterminable range, the presence of a malfunction (YES) is judged or detected. Here, in case of malfunction of at least one of the pressure sensors 26, 28 and second exhaust-gas temperature sensor 25, the presence of a malfunction (YES) is judged or detected.

[0049] If step S5 judges NO meaning that no sensor malfunction has occurred, the current trapped amount W is stored in step S6, and a normal operation is performed in accordance with the operational condition in step S7. If step S5 judges YES meaning that sensor malfunction has occurred, a warning lamp (not shown) is illuminated in step S8, and a judgement or determination is made as to whether or not the flag F3 is 1 in step S9.

[0050] If step S9 judges NO meaning that the flag F3 is not 1, a judgement or determination is made as to whether or not the trapped amount calculated and stored one cycle before, that is, the trapped amount Wa immediately prior to the occurrence of sensor malfunction (ante-malfunction trapped amount, refer to FIG. 5) is equal to a specified (predetermined or predeterminable) value δ or larger in step S10 (as preferred second trapped amount judgement means). The initial value of the flag F3 is 0. The flag F3 is set to 1 in step S13 when the trapped amount Wa is equal to the predetermined or predeterminable value δ or larger. The predetermined or predeterminable value δ is smaller than the value α.

[0051] If step S10 judges NO meaning that the trapped amount Wa immediately before the occurrence of the sensor malfunction is not equal to the predetermined or predeterminable value δ or larger, EGR is suspended or reduced in its amount in step S11 (as preferred clogging suppression means and/or EGR amount decreasing means). If step S10 judges YES meaning that the trapped amount Wa immediately before the occurrence of the sensor malfunction is equal to the predetermined or predeterminable value δ or larger, a regeneration duration C2 is set based on the trapped amount Wa in step S12 (as preferred regeneration period setting means); the flag F3 is set to 1 in step S13; and the measurement of a lapsed time Cb is initiated in step S14.

[0052] Next, in step S15, a judgement or determination is made as to whether or not the lapsed time Cb is shorter than the regeneration duration C2. If YES is judged meaning that the lapsed time Cb is substantially equal to the regeneration duration C2 or shorter, the regeneration operation is implemented in step S15 (as preferred regeneration means). If NO is judged meaning that the lapsed time Cb is not equal to the regeneration duration C2 or shorter, the EGR amount is decreased in step S11. That is, after the regeneration is implemented during the regeneration duration calculated based on the trapped amount Wa, the EGR amount is decreased.

[0053] On the other hand, if step S4 judges YES meaning that the current trapped amount W is substantially equal to the predetermined or predeterminable value α or larger, the sequence proceeds to step S17 where the flag F2 is set to 1. Next, in step S18, a judgement or determination is made as to whether the presence or absence of a malfunction of at least one of the pressure sensors 26, 28, and the second exhaust-gas temperature sensor 25 in a manner similar to step S5. If NO is judged meaning that no sensor malfunction has occurred, the current trapped amount W is stored as the trapped amount Wa in step S19 (storage means). Then, the sequence proceeds to step S20 where a judgement or determination is made as to whether or not the trapped amount W is equal to a specified (predetermined or predeterminable) value β or smaller, that is, a judgement or determination is made as to whether or not the regeneration control implemented in step S16 has decreased the trapped amount W to or below the predetermined or predeterminable value β. The predetermined or predeterminable value β is smaller than the above-described predeterminable value α.

[0054] If step S20 judges NO meaning that the

trapped amount W is not equal to the predetermined or predeterminable value β or smaller, the regeneration of the particulate filter 27 is implemented in step S16 (as preferred regeneration means). If step S20 judges YES meaning that the trapped amount W is equal to the predetermined or predeterminable value β or smaller, the flag F2 is set to 0 in step S21; a normal operation is controlled based on the operational condition in step S7; and the sequence returns to step S1. In other words, the sequence completes the regeneration of the particulate filter 27 and shifts to a control for the non-regeneration state.

[0055] On the other hand, if step S18 judges YES meaning that sensor malfunction has occurred, the warning lamp (not shown) is illuminated in step S22, and a judgement or determination is made as to whether or not the flag F1 is 1 in step S23.

[0056] If step S23 judges NO meaning that the flag F1 is not 1, the regeneration duration C1 is calculated based on the trapped amount calculated and stored one cycle before, or the trapped amount Wa immediately prior to the occurrence of sensor malfunction in step S24; the flag F1 is set to 1; and the measurement of the lapsed time Ca is initiated in step S26. The regeneration duration C1 is prescribed with respect to the trapped amount Wa as shown in FIG. 6. The value of the regeneration duration C1 increases for the larger trapped amount Wa, up to a specified (predetermined or predeterminable) value of the trapped amount Wa. The regeneration duration C1 is saturated for the trapped amount Wa being equal to the predetermined or predeterminable value and larger. This saturation preferably aims at preventing the particulate filter 27 from overheating during the sensor malfunction.

[0057] Next, in step S27, a judgement or determination is made as to whether or not the lapsed time Ca is shorter than the regeneration duration C1. If YES is judged meaning that the lapsed time Ca is equal to the regeneration duration C1 or shorter, the regeneration is implemented in step S16. If NO is judged meaning that the lapsed time Ca is not equal to the regeneration duration C1 or shorter, only the reduction in the EGR amount, or both the reduction in the EGR amount and the advance of the injection timing is/are implemented in step S28. That is, in case that the sensor malfunction occurs during the regeneration of the particulate filter 27 after the trapped amount W reaches the predetermined or predeterminable value α or larger, the regeneration is implemented during the regeneration duration C1 calculated based on the trapped amount Wa immediately prior to the occurrence of the malfunction. Then, the EGR valve 31 and intake throttle valve 15 are controlled so as to implement the reduction in the EGR or the exhaust-gas amount returning to the intake side and/or the advance of the fuel injection timing (another clogging suppression implementing means), thereby suppressing the clogging of the particulate filter 27. The fuel injection timing preferably is advanced in accordance with the engine rotational speed and/or the engine load (e. g. the operational degree of the acceleration pedal) also during the normal operation. The degree of the advance is increased for the larger engine rotational speed and/or for the larger engine load as shown in FIG. 7 (a). In addition to this, this advance control for suppressing the clogging additionally advances the timing from a basic advancing degree determined with reference to the map or table or relationship of FIG. 7 (a) by a specified (predetermined or predeterminable) advancing degree (2 °, for example), in a specified (predetermined or predeterminable) region (preferably in the advance region for clogging suppression) except the region of high load and high rotational speed shown in FIG. 7 (b). In other words, at the outside of the predetermined or predeterminable region, the additional advance for suppressing the clogging is not implemented, but only the reduction in EGR is implemented. Accordingly, the additional advance for suppressing the clogging increases the NO2 amount discharged from the combustion chamber to promote the burn-out of the exhausted particulate in the particulate filter 27, thereby preventing the clogging and accompanying abnormal burnup. In addition, the reduction in EGR decreases the amount of the exhausted particulate discharged from the combustion chamber, thereby preventing the clogging and accompanying abnormal burnup.

[0058] Next, another example of the suppression control of the clogging will now be described with reference to the flow chart shown in FIG. 8. Step S 31 through S38 are similar or the same as step S1 through S8 in the flow chart shown in FIG. 4, and step S42 through S53 are similar or the same as the step S17 through S27 in the flow chart shown in FIG. 3, respectively. The following description omits their details and mainly focuses on the point of difference.

[0059] If step S35 judges YES meaning that sensor malfunction has occurred, the warning lamp is illuminated in step S38 and a judgement or determination is made as to whether or not the trapped amount Wa calculated and stored a previous cycle, e.g. one cycle before, that is, the trapped amount Wa immediately prior to the occurrence of the sensor malfunction is equal to a specified (predetermined or predeterminable) value δ or larger in step S39 (as preferred second trapped amount judgement means).

[0060] If step S39 judges NO meaning that the trapped amount Wa (immediately) prior to the occurrence of the sensor malfunction is not equal to a specified (predetermined or predeterminable) value δ or larger, the EGR amount is decreased in step S40. If step S39 judges YES meaning that the trapped amount Wa (immediately) prior to the occurrence of the sensor malfunction is equal to a predeterminable value δ or larger, the reduction in EGR and the advance of the injection timing are implemented. That is, based on whether or not the trapped amount Wa (immediately) prior to the occurrence of the malfunction is equal to a predetermi-

nable value δ or larger, a determination is made as to whether only the EGR reduction should be implemented or both the EGR reduction and the advance of the injection timing should be implemented.

[0061] In addition, this flow chart is different from the former in the process to be performed when step S53 (corresponding to step S27 in the flow chart shown in FIG. 3) judges or determines NO, that is, the lapsed time exceeds the regeneration duration C1. Accordingly, if the judgement or determination is NO, both the EGR reduction and the advance of the injection timing are always implemented to intensively suppress the clogging.

[0062] It should be also appreciated that the preferred embodiment of the present invention is described for a diesel engine, but the present invention may apply to gasoline engines or any other engines that may produce carbon particulate. Also, the application of the present invention is not limited to automotive engines, but includes engines in industrial use or engines used for other purposes.

[0063] Moreover, though this embodiment runs the computer program for performing the control of the present invention which has been stored in the memory of the control unit 50, the program may be stored in a storage medium (e.g. CD-ROM) separate from the control unit 50 or may be implemented in a dedicated circuitry, logic component and/or programmable device (e. g. an PROM, EPROM, EEPROM, ASIC).

[0064] Furthermore, it should be appreciated that even though the invention is described with reference to an engine using a throttle valve for controlling the amount of intake-air, the invention is equally applicable to engines where the amount of intake air is controlled in a different way.

[0065] As described above, according to the present invention, in case that a malfunction is detected in pressure sensors and a temperature sensor for detecting the upstream exhaust-gas pressure, the downstream exhaust-gas pressure, and the temperature as parameter values associated with the amount of the exhausted particulate trapped in the particulate filter, the particulate filter is suppressed from being clogged with the exhausted particulate by controlling the operational condition of an engine in comparison with the case without the detection of the malfunction, thereby preventing the clogging of the particulate filter and accompanying abnormal burnup.

Claims

1. A control apparatus for an engine (1), the engine (1) being equipped with trapping means (27) for trapping exhausted particulate in an exhaust passage (20) of the engine (1), comprising,

parameter value detection means (25, 26, 28) for detecting at least one parameter value associated with the amount of exhausted particulate trapped in the trapping means (27);

trapped amount estimation means (50) for estimating the amount of exhausted particulate trapped in the trapping means (27) based on the parameter value detected by said parameter value detection means (25, 26, 28);

trapped amount judgement means (50) for judging whether or not the trapped amount (W) estimated by said trapped amount estimation means (50) is equal to a specified value (α) or larger; and

regeneration means (50) for causing the exhausted particulate trapped in the trapping means (27) to burn out for regenerating the trapping means (27) when said trapped amount judgement means (50) judges that the trapped amount (W) is equal to the specified value (α) or larger,

wherein the control apparatus includes,

malfunction detection means (50) for detecting a malfunction of said parameter value detection means (25, 26, 28); and

clogging suppression means (50) for additionally suppressing the trapping means (27) from being clogged with the exhausted particulate by controlling the operational condition of the engine (1) in case that said malfunction detection means (50) detects a malfunction of said parameter value detection means (25, 26, 28).

2. The control apparatus for an engine (1) as defined in claim 1,

in case that said malfunction detection means (50) detects a malfunction of said parameter value detection means (25, 26, 28), said clogging suppression means (50) implements at least one of: a reduction of the exhaust-gas amount returning to the intake side by controlling an exhaust-gas recirculation means (31) for recirculating the exhaust gas to the intake side in accordance with the engine operational condition; and an advance of the injection timing by controlling a fuel injection control means (50) for adjusting the fuel injection timing, from the case without the detection of the malfunction.

3. The control apparatus for an engine (1) as defined in any one of the preceding claims, further comprising,

trapped amount storage means (50) for storing the trapped amount (W) estimated by said trapped amount estimation means (50);

second trapped amount judgement means (50) for judging whether or not the trapped amount (Wa) stored immediately prior to the detection of the malfunction is equal to a second specified value (δ) or larger in case that said malfunction detection means (50) detects the malfunction of said parameter value detection means (25, 26, 28); and/or

regeneration period setting means (50) for

setting the operational period (C1) of said regeneration means (50) in accordance with the trapped amount (Wa) stored in said trapped amount storage means (50) immediately prior to the detection of the malfunction when the second trapped amount judgement means (50) judges that the trapped amount (Wa) is equal to the second specified value (δ) or larger,

wherein said clogging suppression means (50) suppresses the clogging after said regeneration means (50) implements the regeneration of the trapping means (27) during the operational period (C2) set by said regeneration period setting means (50) when said second trapped amount judgement means (50) judges that the trapped amount (Wa) stored in said trapped amount storage means (50) immediately prior to the detection of the malfunction is equal to the second specified value (δ) or larger.

4. The control apparatus for an engine (1) as defined in any one of the preceding claims, further comprising,

trapped amount storage means (50) for storing the trapped amount (W) estimated by said trapped amount estimation means (50); and

second trapped amount judgement means (50) for judging whether or not the trapped amount (Wa) stored prior to, preferably immediately prior to the detection of the malfunction is equal to the second specified value (δ) or larger in case that said malfunction detection means (50) detects the malfunction of said parameter value detection means (25, 26, 28),

wherein

when said second trapped amount judgement means (50) judges that the trapped amount (Wa) is equal to the second specifiedvalue (δ) or larger, said clogging suppression means (50) implements both the reduction of the exhaust-gas amount returning to the intake side by controlling the exhaust-gas recirculation means (31) and the advance of the injection timing by controlling the fuel injection control means (50); and

when said second trapped amount judgement means (50) judges that the trapped amount (Wa) is not equal to the second specifiedvalue (δ) or larger, said clogging suppression means (50) implements only the reduction of the recirculating exhaust-gas amount by controlling the exhaust-gas recirculation means (31).

5. The control apparatus for an engine (1) as defined in any one of the preceding claims,

wherein said clogging suppression means (50) comprises a plurality of clogging suppression implementation means (50) including at least EGR amount decreasing means (50) for reducing the exhaust-gas recirculation amount by controlling exhaust-gas recirculation means (31) for recirculating the exhaust gas to the intake side in accordance with the engine operational condition, and

said EGR amount decreasing means (50) is operated preceding the other clogging suppression implementation means (50) in case that said malfunction detection means (50) detects a malfunction of said parameter value detection means (25, 26, 28).

6. The control apparatus for an engine (1) as defined in claim 5 further comprising,

trapped amount storage means (50) for storing the trapped amount (W) estimated by said trapped amount estimation means (50); and

second trapped amount judgement means (50) for judging whether or not the trapped amount (Wa) stored prior to, preferably immediately prior to the detection of the malfunction is equal to a second specified value or larger in case that said malfunction detection means (50) detects the malfunction of said parameter value detection means (25, 26, 28),

wherein said clogging suppression means (50) operates said EGR amount decreasing means (50) and the other clogging suppression implementation means (50) when said second trapped amount judgement means (50) judges that the trapped amount (Wa) is equal to the second specifiedvalue (δ) or larger.

7. The control apparatus for an engine (1) as defined in any one of the preceding claims, further comprising,

trapped amount storage means (50) for storing the trapped amount (W) estimated by said trapped amount estimation means (50), and

regeneration duration setting means (50) for setting the regeneration duration (C1) of said regeneration means (50) in accordance with the antemalfunction trapped amount (Wa) stored in said trapped amount storage means (50) immediately prior to the detection of the malfunction in case that said malfunction detection means (50) detects the malfunction of said parameter value detection means (25, 26, 28) during the regeneration of the trapping means (27),

wherein said clogging suppression means (50) suppresses the clogging after said regeneration means (50) continues the regeneration of the trapping means (27) during the regeneration duration (C1) set by said regeneration duration setting means (50), in case that said malfunction detection means (50) detects the malfunction of said parameter value detection means (25, 26, 28) while said regeneration means (50) is implementing the regeneration.

8. An engine (1) equipped with the control apparatus as defined in any one of preceding claims.

9. A control method of an engine, the engine being equipped with trapping means (27) for trapping exhausted particulate in an exhaust passage (20) of the engine (1), comprising the following steps of:

detecting at least one parameter value associated with the amount of exhausted particulate trapped in trapping means (27);
estimating the amount of exhausted particulate trapped in the trapping means (27) based on the detected parameter value;
judging whether or not the estimated trapped amount (W) is equal to a specified value (α) or larger;
causing the exhausted particulate trapped in the trapping means (27) to burn out for regenerating the trapping means (27) when the estimated trapped amount (W) is judged to be equal to the specified value (α) or larger;
detecting a malfunction in said step of detecting at least one parameter value; and
suppressing additionally the trapping means (27) from being clogged with the exhausted particulate by controlling the operational condition of the engine (1) in case that a malfunction is detected in said step of detecting at least one parameter value.

10. Computer program product which, when loaded onto a computer for use in a control apparatus for an engine (1) being equipped with trapping means (27) for trapping exhausted particulate in an exhaust passage (20) of the engine (1), carries out the control method of an engine according to claim 9.

FIG. 1

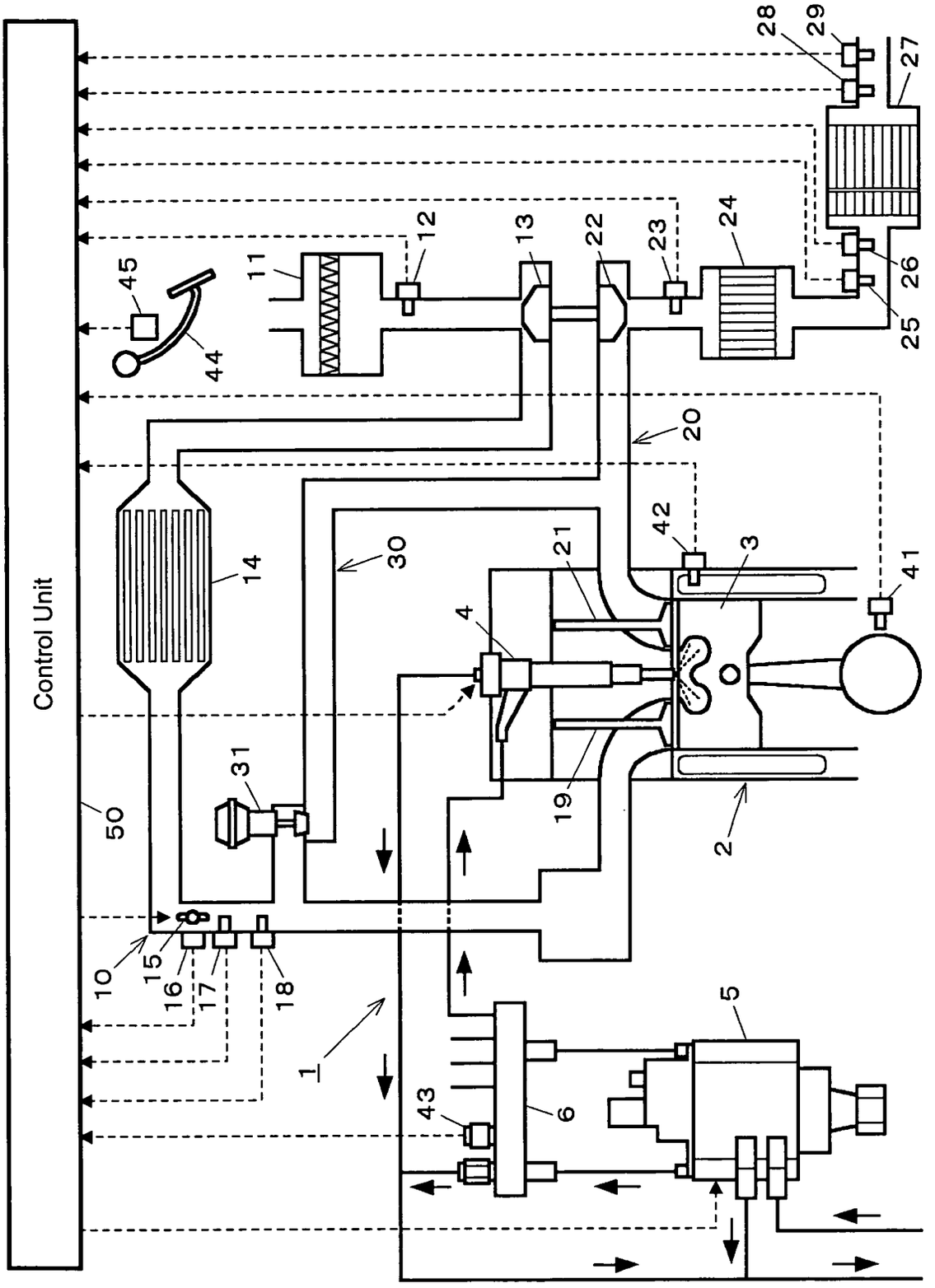

Control Unit
28
29
27
12
13
22
23
24
45
11
26
25
44
20
42
30
21
3
41
14
4
31
19
2
50
10
15
16
17
18
1
5
43
6

FIG. 2

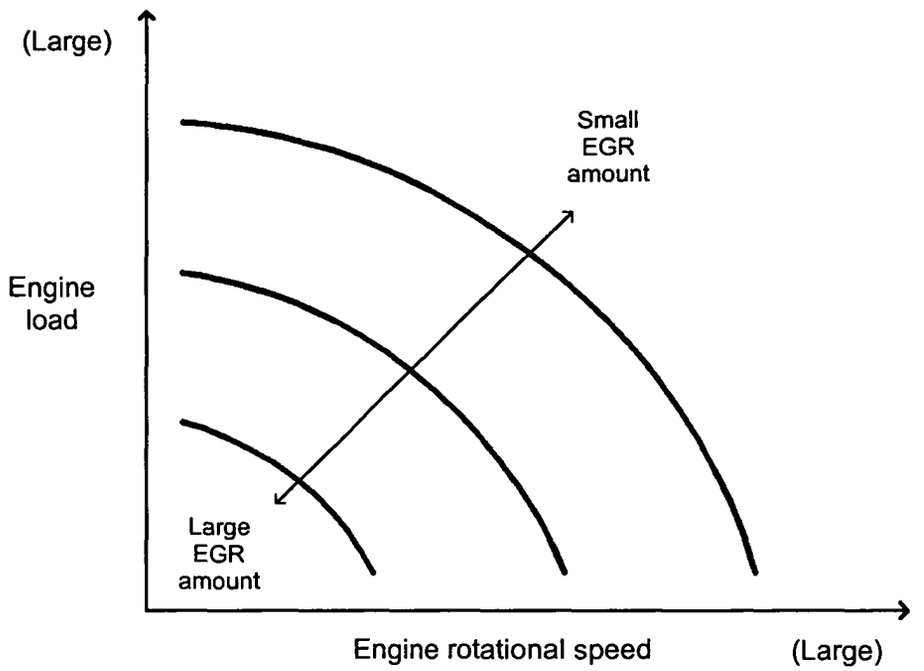

(Large)
Small
EGR
amount
Engine
load
Large
EGR
amount
Engine rotational speed
(Large)

FIG. 3

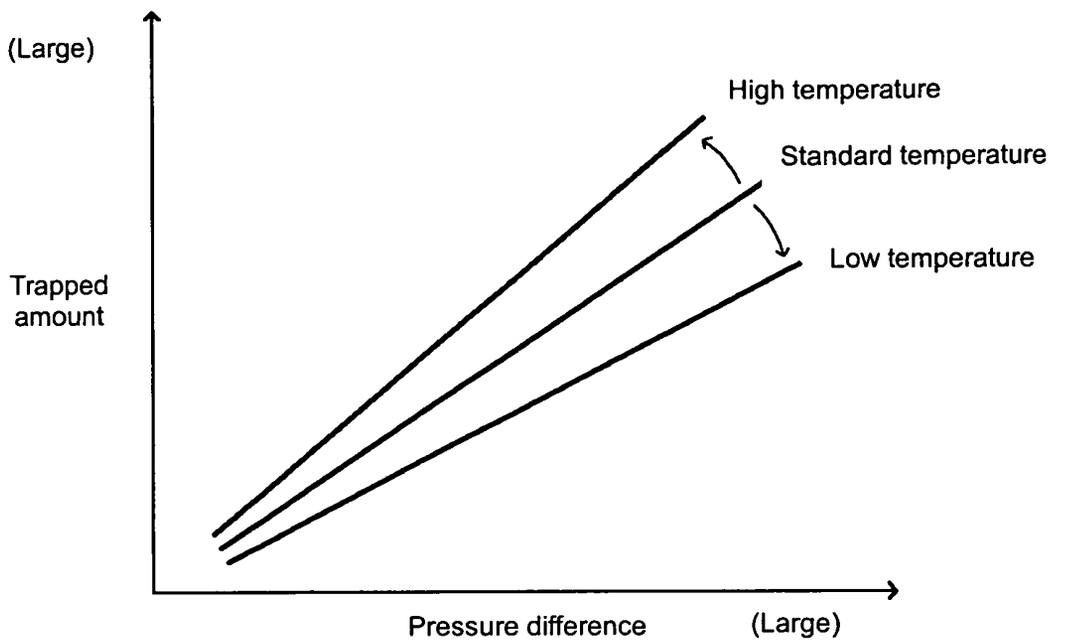

(Large)
Trapped amount
High temperature
Standard temperature
Low temperature
Pressure difference
(Large)

FIG. 4

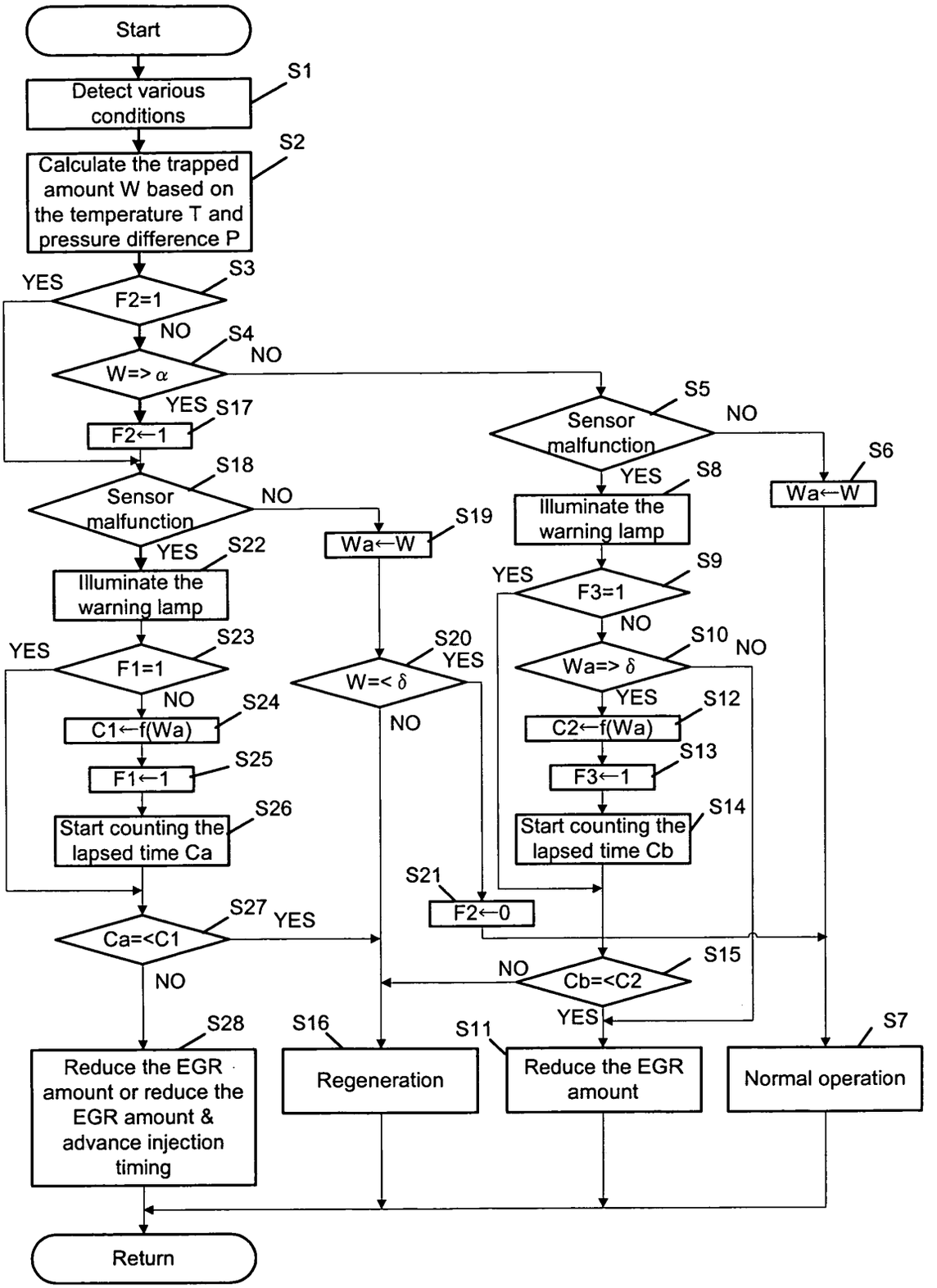

Start
S1
Detect various conditions
S2
Calculate the trapped amount W based on the temperature T and pressure difference P
S3
F2=1
YES
NO
S4
W=> α
NO
YES
S17
F2←1
S18
Sensor malfunction
NO
YES
S22
Illuminate the warning lamp
S23
F1=1
YES
NO
S24
C1←f(Wa)
S25
F1←1
S26
Start counting the lapsed time Ca
S27
Ca=<C1
YES
NO
S28
Reduce the EGR amount or reduce the EGR amount & advance injection timing
S19
Wa←W
S20
W=< δ
YES
NO
S21
F2←0
S5
Sensor malfunction
NO
YES
S8
Illuminate the warning lamp
S9
F3=1
YES
NO
S10
Wa=> δ
NO
YES
S12
C2←f(Wa)
S13
F3←1
S14
Start counting the lapsed time Cb
S15
Cb=<C2
NO
YES
S6
Wa←W
S16
Regeneration
S11
Reduce the EGR amount
S7
Normal operation
Return

FIG. 5

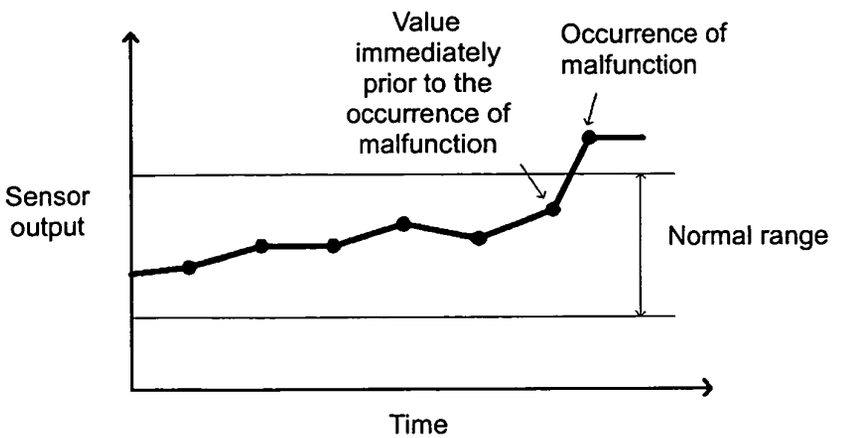

Value immediately prior to the occurrence of malfunction
Occurrence of malfunction
Sensor output
Normal range
Time

FIG. 6

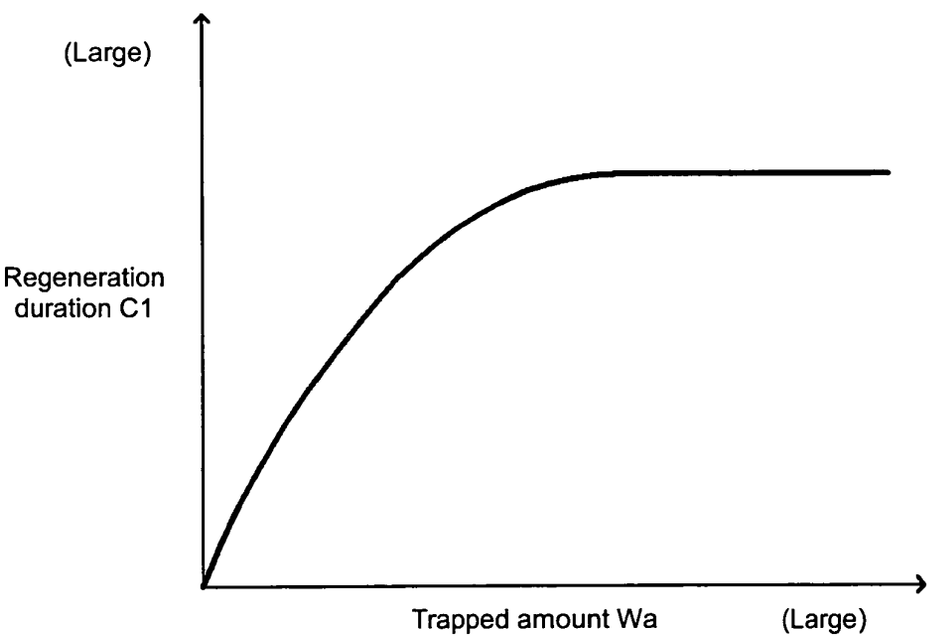

(Large)
Regeneration duration C1
Trapped amount Wa
(Large)

FIG. 7

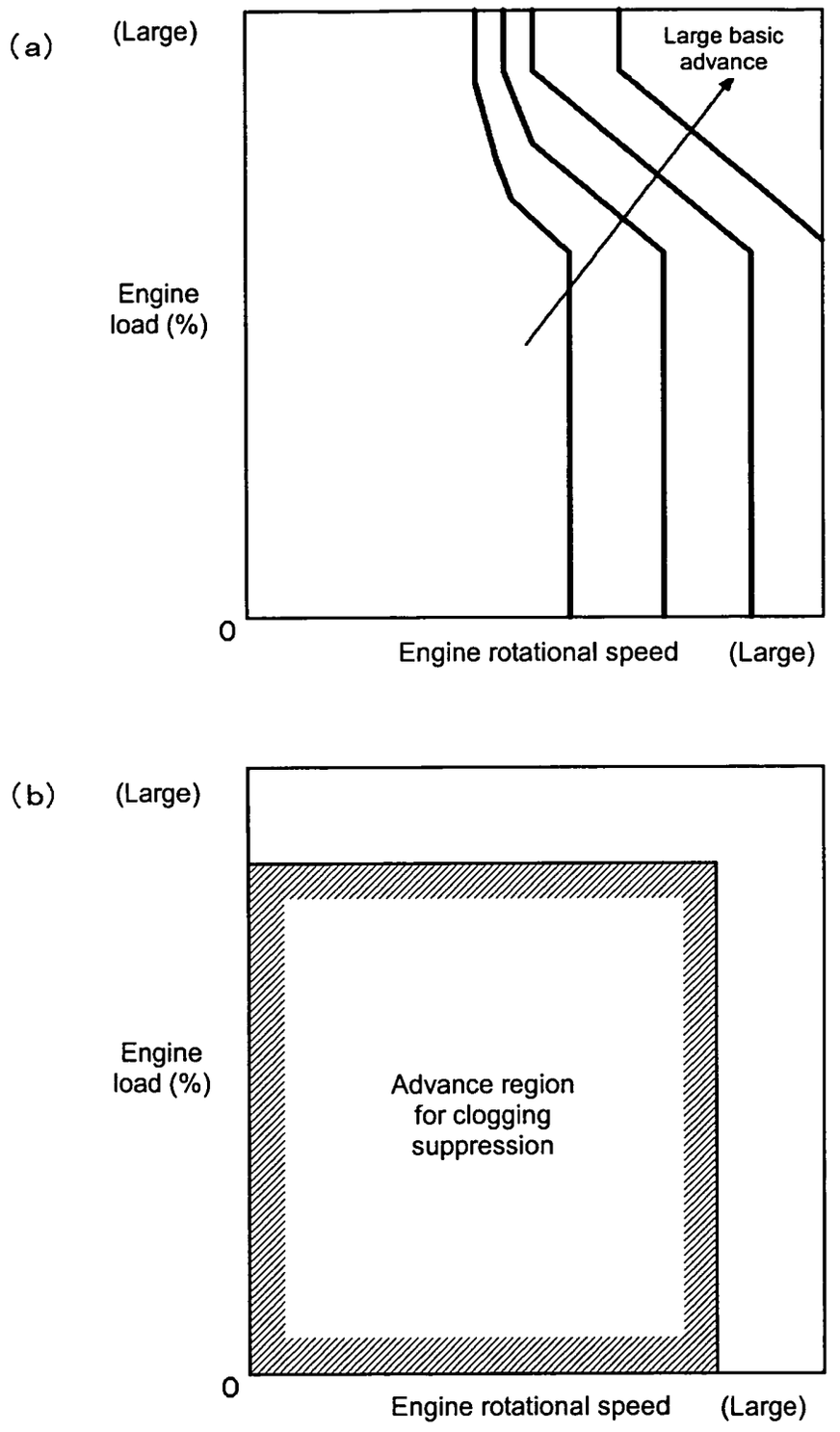
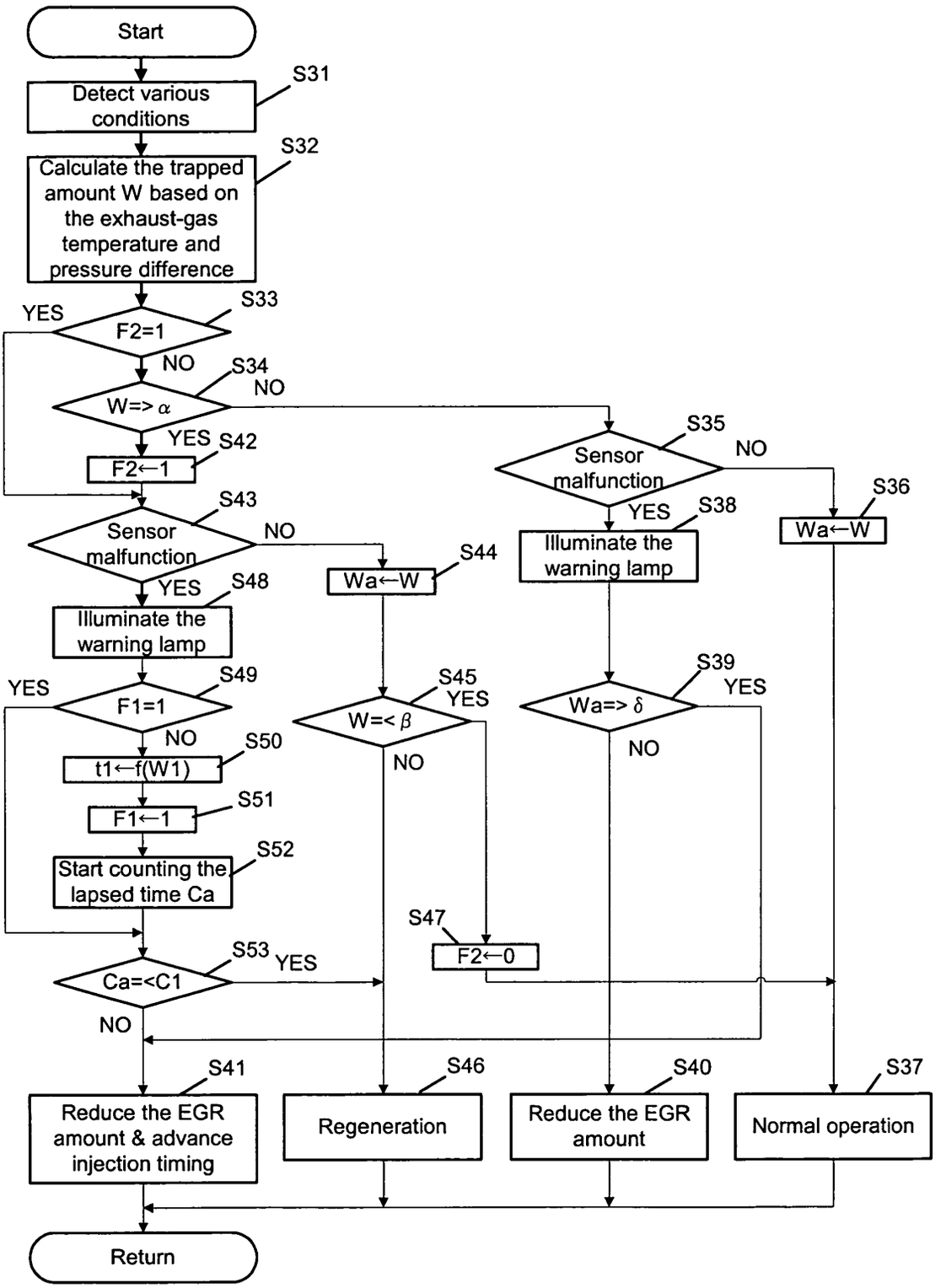

(a)
(Large)
Large basic advance
Engine load (%)
0
Engine rotational speed
(Large)
(b)
(Large)
Engine load (%)
Advance region for clogging suppression
0
Engine rotational speed
(Large)

FIG. 8


Start
Detect various conditions
S31
Calculate the trapped amount W based on the exhaust-gas temperature and pressure difference
S32
F2=1
S33
YES
NO
W=> α
S34
NO
YES
F2←1
S42
Sensor malfunction
S43
NO
YES
Illuminate the warning lamp
S48
F1=1
S49
YES
NO
t1←f(W1)
S50
F1←1
S51
Start counting the lapsed time Ca
S52
Ca=<C1
S53
YES
NO
Wa←W
S44
W=< β
S45
YES
NO
F2←0
S47
Sensor malfunction
S35
NO
YES
Illuminate the warning lamp
S38
Wa=> δ
S39
YES
NO
Wa←W
S36
Reduce the EGR amount & advance injection timing
S41
Regeneration
S46
Reduce the EGR amount
S40
Normal operation
S37
Return

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 7120

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A	WO 02/073011 A (BOSCH GMBH ROBERT ; STROHMAIER RAINER (DE); ZIMMERMANN STEFAN (DE); SO) 19 September 2002 (2002-09-19) * abstract; claim 1; figure 3 * * page 11, line 15 - page 11, line 30 *	1,9	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F02D F01N
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	9 July 2004	Van der Staay, F

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

& : member of the same patent family, corresponding document

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