



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
06.04.2016 Bulletin 2016/14

(51) Int Cl.:
F02D 41/30 (2006.01) **F02D 41/12** (2006.01)
F02D 41/04 (2006.01)

(21) Application number: **15186820.5**

(22) Date of filing: **25.09.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(72) Inventors:
• **YAMAGUCHI, Takafumi**
Tokyo, 108-8410 (JP)
• **KANAYAMA, Kuniki**
Tokyo, 108-8410 (JP)
• **NAKAMOTO, Keita**
Tokyo, 108-8410 (JP)

(30) Priority: **30.09.2014 JP 2014200453**

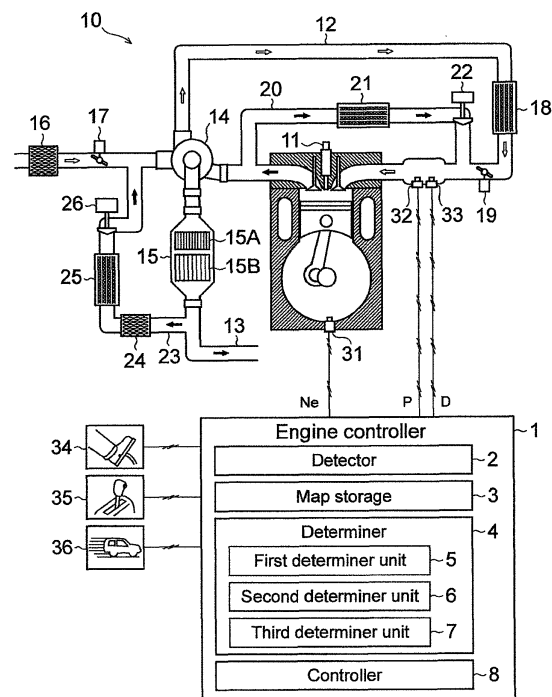
(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(71) Applicant: **Mitsubishi Jidosha Kogyo Kabushiki Kaisha**
Tokyo 108 (JP)

(54) **ENGINE CONTROLLER**

(57) A controller (1) of an engine performing a premixed combustion operation and a diffusion combustion operation that are switchable in accordance with the traveling state of a vehicle, includes a detector (2) detecting a sudden-deceleration request for sudden deceleration of the vehicle, on the basis of a driving operation from a driver, and a determiner (7) forbidding the premixed combustion operation and permitting the diffusion combustion operation during detection of the sudden-deceleration request at the detector (2).

FIG. 1



Description**FIELD**

[0001] The present invention relates to a controller of an engine performing a premixed combustion operation and a diffusion combustion operation that are switchable in accordance with the traveling state of a vehicle.

BACKGROUND

[0002] Many kinds of technique have been recently proposed to switch the combustion state in engine cylinders in accordance with the traveling state of a vehicle, that is, to perform both premixed combustion and diffusion combustion in one engine. The premixed combustion is a state of burning a premix of fuel and oxygen (oxidant) in, for example, a spark-ignition gasoline engine that injects fuel into an intake port. The diffusion combustion is a state of burning a somewhat inhomogeneous mixture of fuel and oxygen (combustion with diffusion of fuel and oxygen) in, for example, a compression-ignition diesel engine that injects fuel directly into the cylinders.

[0003] Diesel engines achieving these two burning states are called premixed charge compression ignition (PCCI) engines, homogeneous charge compression ignition (HCCI) engines, and controlled auto ignition (CAI) engines. Another technique has been also developed today in order to achieve the two burning state in one spark-ignition gasoline engines. This technique conduces to premixed compression self-igniting combustion in the gasoline engines.

[0004] The premixed combustion, combustion of a lean mixture, has a lower combustion temperature and emits less NO_x (nitrogen oxide) and soot than the diffusion combustion. Achieving the premixed combustion in the engine of a vehicle of which NO_x and soot emission is regulated improves the emission performance of the vehicle. (See Japanese Patent No. 5447294 and No. 3931900.)

SUMMARY**TECHNICAL PROBLEMS**

[0005] Unfortunately, the premixed combustion often generates loud noise (undesired sound) because the combustion reaction proceeds and finishes in a shorter time than in the diffusion combustion. Hence, it is difficult to maintain the quietness of the vehicle while improving the emission performance and thus to improve the riding comfort (feeling of driving).

[0006] An object of the present invention, which has been conceived in light of the problems described above, is to provide an engine controller that improves the emission performance and quietness of a vehicle. Another object of the present invention is to achieve advantageous effects that cannot be achieved through the tradi-

tional art by employing the configurations described below in the embodiments of the present invention.

SOLUTION TO PROBLEMS**[0007]**

(1) A disclosed engine controller for an engine performs a premixed combustion operation and a diffusion combustion switchable in accordance with a traveling state of a vehicle. The engine controller includes a detector detecting a sudden-deceleration request for sudden deceleration of the vehicle, on the basis of a driving operation from a driver, and a determiner forbidding the premixed combustion operation and permitting the diffusion combustion operation during detection of the sudden-deceleration request at the detector.

The premixed combustion operation is an operating state of substantially uniformly distributing fuel and oxygen in the cylinders of the engine and burning the resultant mixture by self-ignition. The diffusion combustion operation is an operating state of generating a somewhat inhomogeneous mixture of the fuel and the oxygen and burning the mixture by self-ignition. The intake-air oxygen level in the premixed combustion operation is controlled to be lower than that in the diffusion combustion operation.

(2) The determiner preferably forbids the premixed combustion operation and permits the diffusion combustion operation after the sudden-deceleration request is not detected anymore and before a predetermined time lapses.

(3) The predetermined time preferably decreases as a speed of the vehicle increases.

(4) The predetermined time is preferably a time until a difference between a target value and an actual value of each of a boost pressure and an intake-air oxygen level of the engine is equal to or smaller than a predetermined value.

(5) The determiner preferably unbans the forbiddance of the premixed combustion operation and permits the premixed combustion operation when a demand load is requested during the forbiddance.

The term "demand load", which is for accelerating the vehicle, is determined on the basis of the driving operation from the driver. The demand load is determined in accordance with, for example, an accelerator-pedal position (the amount of depression of an accelerator pedal).

(6) The determiner preferably determines whether to unban the forbiddance of the premixed combustion operation, using conditions including parameters correlated with the noise level of the engine, when the demand load is requested during the forbiddance.

ADVANTAGEOUS EFFECTS

[0008] The engine controller in accordance with the present invention forbids the premixed combustion operation when a sudden-deceleration request is detected. This prevents noise generation in no-load and low-load states and thus improves the riding comfort. The premixed combustion operation is permitted in a normal-deceleration operation in which a sudden-deceleration request is not detected, resulting in an improvement in emission performance. This improves the emission performance and quietness of the vehicle.

BRIEF DESCRIPTION OF DRAWINGS

[0009] The nature of this invention, as well as other objects and advantages thereof, will be explained in the following with reference to the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures and wherein:

FIG. 1 is a schematic diagram of an engine controller in accordance with an embodiment of the present invention.

FIG. 2A is a graph showing a fuel injection pattern in a diffusion combustion operation.

FIG. 2B is a graph showing a fuel injection pattern in a premixed combustion operation.

FIG. 2C is a graph showing heat release rates.

FIG. 2D is a graph showing cylinder pressures.

FIG. 3 illustrates an example map for switching premixed combustion and diffusion combustion.

FIG. 4 is a graph showing the correlations between the reduction ratio and the predetermined period T_0 .

FIG. 5A illustrates the determination of the combustion mode based on a boost pressure in response to a sudden-acceleration request.

FIG. 5B illustrates the determination of the combustion mode based on an intake-air oxygen level in response to the sudden-acceleration request.

FIG. 6 is a graph showing the correlations between the vehicle speed and the predetermined time T_2 .

FIG. 7A illustrates the determination of the combustion mode based on the boost pressure in response to a sudden-deceleration operation.

FIG. 7B illustrates the determination of the combustion mode based on the intake-air oxygen level in response to the sudden-deceleration operation.

FIG. 8 is a flowchart of the control procedure in a normal operation.

FIG. 9 is a flowchart of the control procedure in a sudden-acceleration operation.

FIG. 10 is a flowchart of the control procedure in a sudden-deceleration operation.

DESCRIPTION OF EMBODIMENTS

[0010] An engine controller will now be described with

reference to the accompanying drawings. The embodiments described below are merely examples, and various modifications and technological applications that are not described in the embodiments should not be excluded from scope of the invention. The configurations according to the embodiments may be modified in various ways without departing from the scope of the embodiment. Such configurations may also be selected and/or be combined appropriately.

[1. Engine]

[0011] An engine controller 1 in accordance with this embodiment is applied to a vehicle equipped with an engine 10 illustrated in FIG. 1. FIG. 1 illustrates one of the multiple cylinders formed in the engine 10. The engine 10 is a diesel engine that runs on light oil and is switchable between a diffusion combustion operation and a premixed combustion operation in accordance with the traveling state of the vehicle. The diffusion combustion operation enables diffusion combustion (diffusion compression self-ignition combustion) in the cylinder of the engine 10. The premixed combustion operation enables premixed combustion (premixed compression self-ignition combustion) in the cylinder of the engine 10. The engine 10 in accordance with this embodiment operates in these two combustion states in accordance with the traveling state of the vehicle.

[0012] The cylinder is provided with an intake port and an exhaust port on the top surface, and the intake port and the exhaust port are provided with an intake valve and an exhaust valve, respectively, at their respective openings. The cylinder is provided with a direct injection valve 11 at the upper part in the cylinder in such a manner that the tip of the injection valve protrudes toward a combustion chamber. The direct injection valve 11 is a direct injector for injecting fuel into the cylinder and is connected to a common rail (accumulator) storing high-pressure fuel inside.

[0013] The injection rate of fuel supplied from the direct injection valve 11 and the injection timing are controlled by the engine controller 1. For example, the engine controller 1 sends a control pulse signal to the direct injection valve 11, and then the injection hole of the direct injection valve 11 opens in a period corresponding to the magnitude of the control pulse signal. This enables the fuel injection rate to correspond to the magnitude of the control pulse signal (drive pulse width) and the fuel injection timing to correspond to the time at which the control pulse signal is sent.

[0014] FIG. 2A illustrates a fuel injection pattern in the diffusion combustion operation in the case of four injection stages including a pilot injection stage, a pre-injection stage, a main injection stage, and a post-injection stage. The pilot injection and the pre-injection are performed on a compression stroke. The main injection, which contributes to the engine output most, is performed before or after the top dead center (TDC) just behind the compres-

sion stroke. The post-injection is performed after the TDC, in other words, from a combustion stroke downward. The heat release rate in the diffusion combustion operation is highest immediately after the main injection, as represented by the dashed line in FIG. 2C. The time (ignition delay) from the completion time θ_1 of the main injection to an ignition time θ_2 is relatively short, and ignition may occur in the main injection. The cylinder pressure in the diffusion combustion operation fluctuates relatively gradually, as represented by the dashed line in FIG. 2D.

[0015] FIG. 2B illustrates a fuel injection pattern in the premixed combustion operation. Pilot injection stage, pre-injection stage, and post-injection stage are omitted in the premixed combustion operation, but main injection stage is performed on a compression stroke. Auxiliary after-injection stage is performed before or after the TDC. The heat release rate in the premixed combustion operation is highest after an elapse of a predetermined premixing period from the main injection, as represented by the solid line in FIG. 2C. The ignition delay from the completion time θ_3 of the main injection to an ignition time θ_4 is longer than that in the diffusion combustion operation. The cylinder pressure in the premixed combustion operation varies more sharply than in the diffusion combustion operation, which is graphed in a peaked manner as represented by the solid line in FIG. 2D.

[0016] The engine 10 includes an intake path 12 and an exhaust path 13 with a turbocharger 14 interposed therebetween for supercharging the engine by forcibly feeding air in the intake path 12 into the cylinder using exhaust pressure. The intake path 12 is provided with an air cleaner 16, a low-pressure throttle valve 17, the turbocharger 14, an intercooler 18, and a high-pressure throttle valve 19 in this order from the upstream side. The exhaust path 13 is provided with an exhaust emission controller 15 disposed downstream of the turbocharger 14. The exhaust emission controller 15 includes a diesel oxidation catalyst (DOC) 15A and a diesel particulate filter (DPF) 15B.

[0017] The engine 10 includes a high-pressure EGR path 20 and a low-pressure EGR path 23 for recirculating part of exhaust toward the intake side. The word "EGR" means Exhaust Gas Recirculation. The high-pressure EGR path 20 connects the exhaust path 13 upstream of the turbocharger 14 with the intake path 12 downstream of the high-pressure throttle valve 19. The high-pressure EGR path 20 is provided with a high-pressure EGR cooler 21 and a high-pressure EGR valve 22 disposed on the path. The low-pressure EGR path 23 connects the exhaust path 13 downstream of the turbocharger 14 with the intake path 12 upstream of the intercooler 18. The low-pressure EGR path 23 is provided with a low-pressure EGR filter 24, a low-pressure EGR cooler 25, and a low-pressure EGR valve 26 disposed on the path. The high-pressure EGR valve 22 and the low-pressure EGR valve 26 open variably.

[0018] The engine 10 includes an engine speed sensor

31 that is disposed near a crankshaft and detects an engine speed N_e (rotational number per second). The intake path 12 is provided with a pressure sensor 32 and an oxygen level sensor 33. The pressure sensor 32 detects the pressure (boost pressure P in supercharging) of intake air to be introduced into the cylinder. The oxygen level sensor 33 detects the oxygen level of intake air (intake-air oxygen level D). Both sensors are disposed downstream of the high-pressure throttle valve 19.

[0019] The vehicle includes, at certain positions, an accelerator-pedal position sensor 34 detecting the amount of depression of an accelerator pedal (accelerator-pedal position), a gear-stick position sensor 35 detecting the operation position of a gear stick, and a vehicle speed sensor 36 detecting the vehicle speed. The operation position of the gear stick corresponds to one of the gear positions (for example, first gear, second gear, ..., and sixth gear) of a transmission mounted in the vehicle. As the ordinal number increases (from a lower position toward a higher position), the reduction ratio decreases. The information detected by the sensors 31-36 is sent to the engine controller 1.

[2. Engine Controller]

[0020] The vehicle equipped with the engine 10 includes the engine controller 1 (engine electronic control unit). The engine controller 1 controls a wide variety of systems, such as an ignition system, a fuel system, an intake/exhaust system, and a valve system, and controls the rate of air flow to the cylinders of the engine 10, a fuel injection rate, a fuel injection timing, and the amount of EGR, on the engine 10. The engine controller 1 is connected to other electronic controllers, such as a transmission ECU, an air-conditioner ECU, a brake ECU, a vehicle-control ECU, and a vehicle-body ECU, and the sensors 31-36 via an on-vehicle network.

[0021] The engine controller 1 is an electronic integrated device including, for example, a microprocessor, such as a central processing unit (CPU) and a MPU (Micro Processing Unit), read-only memory (ROM), random-access memory (RAM), and nonvolatile memory. The microprocessor includes a control unit (control circuit), an arithmetic unit (arithmetic circuit), and cache memory (registers). The ROM, RAM and nonvolatile memory store programs and data being worked on. The engine controller 1 memorizes content of control as an application program, for example, in the ROM, RAM, and nonvolatile memory, and a removable medium. After the content of the program is loaded into memory space in the RAM, the microprocessor executes the program.

[0022] The engine controller 1 in accordance with this embodiment performs "combustion switching control" that switches the premixed combustion operation and the diffusion combustion operation in accordance with the traveling state of the vehicle. The traveling state of the vehicle is determined on the basis of the information detected by the sensors 31-36, for example. With refer-

ence to FIGs. 2A and 2B, the combustion states (the premixed combustion and the diffusion combustion) in the cylinder are switched through control of the fuel injection rate and the fuel injection timing and adjustment of the rate of air flow and the amount of EGR. The engine controller 1 includes a detector 2, a map storage 3, a determiner 4, and a controller 8, for executing the combustion switching control.

[2-1. Detector]

[0023] The detector 2 detects driving operations from a driver to be referred to in the combustion switching control and retrieves information on the gear position of the transmission, the elapsed time from when the gear position has changed to the current position, a sudden-acceleration request, a sudden-deceleration request, and a demand load. The current gear position of the transmission is determined on the basis of the information on the operation position of the gear stick detected by the gear-stick position sensor 35. The elapsed time is measured every time the operation position of the gear stick is shifted. The sudden-acceleration request, the sudden-deceleration request, and the demand load are detected on the basis of the driving operations from the driver. The information on the gear position, the elapsed time, the sudden-acceleration request, the sudden-deceleration request, and the demand load is sent to the determiner 4.

[0024] In this embodiment, the sudden-acceleration request, the sudden-deceleration request, and the demand load are detected on the basis of the accelerator-pedal position detected by the accelerator-pedal position sensor 34. If the accelerator-pedal position is positive (the accelerator pedal is depressed), for example, the detector 2 determines that a demand load is requested. If the rate of change of the accelerator-pedal position over time is a predetermined positive value or higher, the detector 2 determines that sudden acceleration is requested. As illustrated in FIG. 3, the operating point of the engine 10 moves in the direction in which the engine load E_c and speed N_e increase, in response to the sudden-acceleration request. For example, the operating point R_1 and the operating point R_2 move toward the upper right after the detection of the sudden-acceleration request.

[0025] If the rate of change of the accelerator-pedal position over time is a predetermined negative value or lower, the detector 2 determines that sudden deceleration is requested. The operating point moves in the direction in which the engine load E_c and speed N_e decrease, in response to the sudden-deceleration request. For example, the operating point R_3 and the operating point R_4 in FIG. 3 move toward the lower left after the detection of the sudden-deceleration request. The sudden-deceleration request may be detected with reference to the amount of depression of a brake pedal, the rate of change of brake fluid pressure over time, the

amount of depression of a clutch pedal, and the operation of the gear stick to the neutral position, instead of the accelerator-pedal position.

5 [2-2. Map Storage]

[0026] The map storage 3 stores a control map containing the correlations between the traveling state of the vehicle and the combustion state. The traveling state of the vehicle is determined on the basis of at least one, preferably both of the engine load E_c and the engine speed N_e . The engine load E_c is a parameter corresponding to an output request to the engine 10 and calculated on the basis of the accelerator-pedal position detected by the accelerator-pedal position sensor 34, the vehicle speed, the rate of air flow, and the intake pressure, for example. It is preferred that the traveling state of the vehicle be determined in consideration of the outside temperature, outside pressure, and engine-cooling water temperature.

[0027] With reference to FIG. 3, the control map in this embodiment contains the correlations between the combustion state and the operating point determined by the engine load E_c and speed N_e for each gear position. The region M1 indicates the area in which the premixed combustion operation is performed when the operation position of the gear stick is in the first gear. The region M2 including the region M1 indicates the area in which the premixed combustion operation is performed when the operation position is in the second gear. In like manner, the region M3 including the regions M1 and M2 indicates the area in which the premixed combustion operation is performed when the operation position is in the third gear. The region M4 including the regions M1-M3 indicates the area in which the premixed combustion operation is performed when the operation position is in the fourth or higher gear. The region C outside the regions M1-M4 indicates the area in which the diffusion combustion operation is performed (that is, the premixed combustion operation is not performed) in any gear position.

[0028] Table 1 shows the correlations between the engine load E_c and the regions M1-M4 and between the engine speed N_e and the regions M1-M4. The magnitude relations of N_{e1} - N_{e5} and E_{c1} - E_{c4} are expressed as $N_{e1} < N_{e2} < N_{e3} < N_{e4} < N_{e5}$ and $E_{c1} < E_{c2} < E_{c3} < E_{c4}$. These values may be default values (constant, fixed values) or variables (variable values) calculated on the basis of traveling conditions of the vehicle, such as outside temperature, outside pressure, and engine-cooling water temperature.

[Table 1]

	Engine Speed N_e	Engine Load E_c
Region M1	$N_{e1} \leq N_e \leq N_{e3}$	$E_{c1} \leq E_c \leq E_{c2}$
Region M2	$N_{e1} \leq N_e \leq N_{e4}$	$E_{c1} \leq E_c \leq E_{c2}$

(continued)

	Engine Speed N_e	Engine Load E_c
Region M3	$N_{e1} \leq N_e \leq N_{e2}$	$E_{c1} \leq E_c \leq E_{c2}$
	$N_{e2} \leq N_e \leq N_{e5}$	$E_{c1} \leq E_c \leq E_{c3}$
Region M4	$N_{e1} \leq N_e \leq N_{e2}$	$E_{c1} \leq E_c \leq E_{c2}$
	$N_{e2} \leq N_e \leq N_{e5}$	$E_{c1} \leq E_c \leq E_{c4}$

[0029] The region of the premixed combustion operation on the map expands as the ordinal number of gear positions increases. For example, the region for the premixed combustion operation expands in the direction of the increasing engine speed N_e (to the right) in the second gear, in comparison with in the first gear. This indicates that the upper limit of the engine speed N_e among the operational conditions of the premixed combustion operation increases as the reduction ratio of the gear position decreases.

[0030] The region for the premixed combustion operation expands in the direction of the increasing engine load E_c (upward) in addition to the direction of the increasing engine speed N_e (to the right) in the third gear, in comparison with in the second gear. This indicates that the upper limit of the engine load E_c among the operational condition of the premixed combustion operation increases as the reduction ratio of the gear position decreases.

[0031] The reduction ratios in the first gear and the second gear are referred to as a first reduction ratio and a second reduction ratio, respectively. The second reduction ratio is lower than the first reduction ratio.

[0032] The region for the premixed combustion operation is determined such that the upper limit of the engine speed N_e is higher at a reduction ratio below the first reduction ratio (for example, in the second gear) than at a reduction ratio being equal to or above the first reduction ratio (for example, in the first gear) ($N_{e4} > N_{e3}$).

[0033] The region for the premixed combustion operation is determined such that the upper limit of the engine load E_c is higher at a reduction ratio below the second reduction ratio (for example, in the third gear) than at a reduction ratio being equal to or above the second reduction ratio (for example, in the second gear) ($E_{c3} > E_{c2}$).

[0034] The region for the premixed combustion operation expands in two directions, the direction of the increasing engine speed N_e (to the right) and the direction of the increasing engine load E_c (upward) on the map. The increasing ordinal number of gear positions expands the region for the premixed combustion operation, not in these two directions equally, but in the direction of the increasing engine speed N_e in priority to the direction of the increasing engine load E_c . That is, the third gear is the lowest gear position in which the region for the premixed combustion operation expands in the direction of the increasing engine load E_c , and the second gear, having a higher reduction ratio than the third gear, is the

lowest gear position in which the region expands in the direction of the increasing engine speed N_e . Such map setting enables the region for the premixed combustion operation to expand in the direction to prevent the generation of noise from the engine 10.

[2-3. Determiner]

[0035] The determiner 4 determines whether the traveling state of the vehicle satisfies the operational conditions of the premixed combustion operation. The determiner 4 includes a first determiner unit 5, a second determiner unit 6, and a third determiner unit 7. The first determiner unit 5 makes a basic determination based on the operating point. In contrast, the second determiner unit 6 makes an exceptional determination against the basic determination in a sudden-acceleration operation, and the third determiner unit 7 makes an exceptional determination in a sudden-deceleration operation. The determination at the first determiner unit 5 is accepted in a normal operation other than the sudden-acceleration and sudden-deceleration operations. The determinations in the sudden-acceleration and sudden-deceleration operations are different from that in the normal operation because change in the traveling state due to these two operations varies the level of noise generated at the engine 10 and noise masking effect (the likelihood of transmitting the noise to a passenger).

[A. First Determiner Unit]

[0036] The first determiner unit 5 determines the operational conditions of the premixed combustion operation with reference to the control map stored in the map storage 3. When the operating point determined by the engine load E_c and speed N_e of the vehicle is in the region for the premixed combustion operation determined on the basis of the gear position at that time, the first determiner unit 5 determines that the operational conditions of the premixed combustion operation are satisfied.

[0037] For example, in the first gear, if the operating point is in the region M1 ($N_{e1} \leq N_e \leq N_{e3}$ and $E_{c1} \leq E_c \leq E_{c2}$), the operational conditions of the premixed combustion operation are determined to be satisfied. In the third gear, it is determined whether the operating point is in the region M3 ($N_{e1} \leq N_e \leq N_{e2}$ and $E_{c1} \leq E_c \leq E_{c2}$, or $N_{e2} \leq N_e \leq N_{e5}$ and $E_{c1} \leq E_c \leq E_{c3}$).

[0038] Immediately after the gear position is changed in the transmission, however, the air flow rate, the amount of EGR, and the operating point of the engine 10 vary transiently, causing an unstable combustion state. Thus, after the gear position is changed and before a predetermined period (predetermined time) T_0 elapses, the operational conditions of the diffusion combustion operation are determined to be satisfied, regardless of the determination of the operational conditions of the premixed combustion operation. The results of determination are

sent to the controller 8.

[0039] The predetermined period T_0 may be determined in accordance with, for example, the following schemes:

Scheme 1: A default value (for example, a few seconds) is applied;

Scheme 2: A variable determined for each gear position (reduction ratio) is applied; and

Scheme 3: A elapsed time for stabilizing the boost pressure P and the intake-air oxygen level D is applied.

[0040] In Scheme 2, the predetermined period T_0 is determined in accordance with the gear position or the reduction ratio of the transmission. In this case, it is preferred to define the correlations between the gear position (reduction ratio) and the predetermined period T_0 in a control map. Scheme 3 can prevent the combustion stability from lowering due to delays in intake and supercharge. For example, the predetermined period T_0 is determined by the time until the differences ΔP and ΔD between the target values and the actual values of the boost pressure P and the intake-air oxygen level D are equal to or smaller than predetermined values. That is, the predetermined period T_0 is set in accordance with a convergence period that starts when the gear position changes and that ends when the differences ΔP and ΔD are equal to or smaller than predetermined values.

[0041] The actual values of the boost pressure P and the intake-air oxygen level D may be values detected by the pressure sensor 32 and the oxygen level sensor 33. The target values of the boost pressure P and the intake-air oxygen level D may be calculated on the basis of, for example, the accelerator-pedal position, the vehicle speed, the rate of air flow, and the intake pressure. Schemes 2 and 3 may be combined such that the predetermined values that are thresholds of the differences ΔP and ΔD between the target values and the actual values decrease as the ordinal number of gear positions increases.

[0042] This embodiment employs Scheme 2 in which the predetermined period T_0 is determined shorter as the reduction ratio decreases. FIG. 4 illustrates the correlations between the reduction ratio and the predetermined period T_0 . As the ordinal number of gear positions decreases, the elapsed time for determining the start conditions of the premixed combustion operation extends. As the ordinal number of gear positions increases, the time shortens. This is because the combustion state is less stable in a higher reduction ratio than in a lower reduction ratio.

[B. Second Determiner Unit]

[0043] The second determiner unit 6 makes a determination when the detector 2 detects a sudden-acceleration request in the premixed combustion operation, us-

ing conditions including parameters correlated with the noise level of the engine 10. The determination is made at least during the detection of the sudden-acceleration request, preferably additionally after the sudden-acceleration request is not detected anymore and before a predetermined time T_1 elapses. The predetermined time T_1 may be a default value (for example, a few seconds) or a variable determined in accordance with the operating state of the engine 10 (for example, a value determined in accordance with the engine load E_c and speed N_e).

[0044] Specific parameters correlated with the noise level of the engine 10 include physical quantities on which the ratio of components in the mixture introduced into the cylinders is reflected, such as the boost pressure P and the intake-air oxygen level D of the engine 10. These parameters are physical quantities affecting the combustion rate (combustion speed) of the mixture. The intake-air temperature, the humidity, and the intake-air density may be used in addition to these parameters.

[0045] The operational conditions of the premixed combustion operation, i.e., the conditions of continuing the premixed combustion operation when the detector 2 detects a sudden-acceleration request in the premixed combustion operation, indicate that "Condition 1 or Condition 2 is satisfied, or, Condition 3 or Condition 4 is satisfied". The operational conditions of the premixed combustion operation may be that "Condition 1 or Condition 2 is satisfied, and, Condition 3 or Condition 4 is satisfied" in consideration of noise control effect in the premixed combustion operation.

Condition 1: The boost pressure P is lower than a first lower limit P_1 . ($P < P_1$)

Condition 2: The boost pressure P is equal to or higher than the first lower limit P_1 and lower than a first upper limit P_2 , and the difference ΔP between the target value and the actual value of the boost pressure P is equal to or larger than a first predetermined value ΔP_{TH} . ($P_1 \leq P \leq P_2$ and $\Delta P_{TH} < \Delta P$)

Condition 3: The intake-air oxygen level D is lower than a second lower limit D_1 . ($D < D_1$)

Condition 4: The intake-air oxygen level D is equal to or higher than the second lower limit D_1 and lower than a second upper limit D_2 , and the difference ΔD between the target value and the actual value of the intake-air oxygen level D is equal to or larger than a second predetermined value ΔD_{TH2} . ($D_1 \leq D \leq D_2$ & $\Delta D_{TH2} \leq \Delta D$)

[0046] In Conditions 1-4, the first upper limit P_2 is higher than the first lower limit P_1 , and the second upper limit D_2 is higher than the second lower limit D_1 ($P_1 < P_2$ and $D_1 < D_2$). The term "lower limit" refers to a lower limit capable of proper diffusion combustion, and the term "upper limit" refers to an upper limit capable of proper premixed combustion.

[0047] FIG. 5A illustrates the determinations of Conditions 1 and 2. For the determination based on the boost

pressure P , when a sudden-acceleration request is detected in the premixed combustion operation, the second determiner unit 6 determines the quantitative relationships between the boost pressure P and the first lower and upper limits P_1 and P_2 . For example, a boost pressure P lower than the first lower limit P_1 satisfies Condition 1; thus, the premixed combustion operation is performed. A boost pressure P equal to or higher than the first upper limit P_2 does not satisfy Conditions 1 or 2; thus, the diffusion combustion operation is performed.

[0048] If the boost pressure P is between the first lower limit P_1 and the first upper limit P_2 , the determination is made on the basis of the difference ΔP between the target value and the actual value of the boost pressure P . With reference to FIG. 5A, the target value of the boost pressure P grows gradually in response to the sudden-acceleration request. The actual value of the boost pressure P varies so as to gradually approach the target value with a delay in supercharge. Even through a transient variation in the boost pressure P , the premixed combustion operation is continued as long as the difference ΔP is smaller than the first predetermined value ΔP_{TH} . The actual value of the boost pressure P may overshoot when the target value varies slightly with time (inclines slightly). If the difference ΔP is equal to or larger than the first predetermined value ΔP_{TH} , the premixed combustion operation is switched to the diffusion combustion operation, preventing an excess increase in noise.

[0049] The first lower limit P_1 , first upper limit P_2 , and first predetermined value ΔP_{TH} may be default values or variables determined in accordance with the operating state of the engine 10. In this embodiment, these values are determined in accordance with the engine load E_c and speed N_e . For example, the map storage 3 stores the control map containing the correlations between each of the first lower limit P_1 , first upper limit P_2 , and first predetermined value ΔP_{TH} and the operating point determined by the engine load E_c and speed N_e .

[0050] FIG. 5B illustrates the determinations of Conditions 3 and 4. For the determination based on the intake-air oxygen level D , when a sudden-acceleration request is detected during the premixed combustion operation, the second determiner unit 6 determines the quantitative relationships between the intake-air oxygen level D and the second lower and upper limits D_1 and D_2 . For example, the intake-air oxygen level D lower than the second lower limit D_1 satisfies Condition 3; thus, the premixed combustion operation is performed. The intake-air oxygen level D equal to or higher than the second upper limit D_2 does not satisfy Conditions 3 or 4; thus, the diffusion combustion operation is performed. If the intake-air oxygen level D is between the second lower limit D_1 and the second upper limit D_2 , the determination is made on the basis of the difference ΔD between the target value and the actual value of the intake-air oxygen level D . A specific method of the determination based on the difference ΔD is in the same manner as that based on the difference ΔP ; thus, its description is omitted. A prede-

termined value to be compared with the difference ΔD is referred to as a second predetermined value ΔD_{TH2} .

[0051] The second lower limit D_1 , second upper limit D_2 , and second predetermined value ΔD_{TH2} may be default values or variables determined in accordance with the operating state of the engine 10. In this embodiment, these values are determined in accordance with the engine load E_c and speed N_e . For example, the map storage 3 stores the control map containing the correlations between each of the second lower limit D_1 , the second upper limit D_2 , and the second predetermined value ΔD_{TH2} and the operating point determined by the engine load E_c and speed N_e .

[0052] The results of determination from the second determiner unit 6 have higher priority over the results of determination from the first determiner unit 5. Even if the first determiner unit 5 determines that the operational conditions of the premixed combustion operation are satisfied, the diffusion combustion operation is performed, instead of the premixed combustion operation, without the satisfaction of Conditions 1-4 in detecting the sudden-acceleration request. If the predetermined time T_1 elapses after the start of the determination at the second determiner unit 6, the results of determination from the first determiner unit 5 are accepted. The determination at the second determiner unit 6 is for the sudden-acceleration request in the premixed combustion operation. If the operating point of the engine 10 goes into the region for the diffusion combustion operation, the second determiner unit 6 stops the determination, and the results of determination from the first determiner unit 5 are accepted.

[0053] When a sudden-acceleration operation on the accelerator transiently increases the engine load E_c , the engine operation is switched between the premixed combustion operation and the diffusion combustion operation in accordance with the conditions including the parameters correlated with the noise level of the engine 10. This switching enables the premixed combustion operation to be continued in a traveling state involving generation of noise to such a level as not to annoy the driver, resulting in an improvement in emission performance. The premixed combustion operation is switched to the diffusion combustion operation in traveling states in which the boost pressure P is equal to or higher than the first upper limit P_2 and the intake-air oxygen level D is equal to or higher than the second upper limit D_2 . This operation prevents an excess increase in noise.

[0054] If the boost pressure P is between the two thresholds P_1 and P_2 , or if the intake-air oxygen level D is between the two thresholds D_1 and D_2 , the differences ΔP and ΔD between the target values and the actual values of the boost pressure P and the intake-air oxygen level D are referred to for the determination. This enables the premixed combustion operation to be switched to the diffusion combustion operation before overshoot due to delays in supercharge and intake, as illustrated in FIGs. 5A and 5B, which further prevents an excess increase in noise.

[C. Third Determiner Unit]

[0055] The third determiner unit 7 makes a determination when the detector 2 detects a sudden-deceleration request. The premixed combustion operation is forbidden at least during the detection of the sudden-deceleration request; instead, the diffusion combustion operation is permitted. In this embodiment, the premixed combustion operation is forbidden additionally after the sudden-deceleration request is not detected anymore and before a predetermined time T_2 elapses.

[0056] The predetermined time T_2 may be determined in accordance with, for example, the following schemes:

Scheme 4: A default value (for example, a few seconds) is applied;

Scheme 5: A variable determined in correspondence with the vehicle speed is applied; and

Scheme 6: A elapsed time for stabilizing the boost pressure P and the intake-air oxygen level D is applied.

[0057] In Scheme 5, the predetermined time T_2 is determined shorter as the vehicle speed increases. In this case, it is preferred to define the correlations between the vehicle speed and the predetermined time T_2 in the control map, as illustrated in FIG. 6, for example. This shortens the period of forbidding the premixed combustion operation in high-speed traveling, resulting in an improvement in emission performance. A slower vehicle speed lengthens the period of forbidding the premixed combustion operation, resulting in an improvement in combustion stability of the engine 10. The vehicle speed may be detected by the vehicle speed sensor 36 or calculated on the basis of the engine load E_c and speed N_e .

[0058] Scheme 6 can prevent the combustion stability from lowering due to delays in intake and supercharge as in Scheme 3. For example, the predetermined time T_2 is determined as the time until the differences ΔP and ΔD between the target values and the actual values of the boost pressure P and the intake-air oxygen level D are equal to or smaller than predetermined values. The actual values of the boost pressure P and the intake-air oxygen level D may be values detected by the pressure sensor 32 and the oxygen level sensor 33. The target values of the boost pressure P and the intake-air oxygen level D may be calculated on the basis of, for example, the accelerator-pedal position, vehicle speed, air flow rate, and intake pressure.

[0059] With reference to FIG. 7A, the target value of the boost pressure P falls down gradually in response to the sudden-deceleration request. The actual value of the boost pressure P varies so as to gradually approach the target value with a delay in supercharge. The determination based on the boost pressure P forbids the premixed combustion operation and instead permits the diffusion combustion operation with the boost pressure P varying transiently. If the difference ΔP is then equal

to or smaller than a third predetermined value ΔP_{TH3} , the forbiddance is unbanned. With reference to FIG. 7B, similarly, the determination based on the intake-air oxygen level D forbids the premixed combustion operation and instead permits the diffusion combustion operation with the intake-air oxygen level D varying transiently. If the difference ΔD is then equal to or smaller than a fourth predetermined value ΔD_{TH4} , the forbiddance is unbanned.

[0060] If the driver requests a demand load during the forbiddance of the premixed combustion operation, however, the forbiddance is unbanned to permit the premixed combustion operation. The detector 2 detects the demand load. The forbiddance may be unbanned when the demand load is requested, or the unbanning of the forbiddance may be determined using the conditions including the parameters, such as the boost pressure P, intake-air oxygen level D, intake-air temperature, humidity, and intake-air density, correlated with the noise level of the engine 10.

[0061] For example, if the difference ΔP is equal to or smaller than a fifth predetermined value ΔP_{TH5} smaller than the third predetermined value ΔP_{TH3} during the determination based on the boost pressure P, the forbiddance is unbanned. If the difference ΔD is equal to or smaller than a sixth predetermined value ΔD_{TH6} smaller than the fourth predetermined value ΔD_{TH4} during the determination based on the intake-air oxygen level D, the forbiddance is unbanned. Such control starts the premixed combustion operation when the demand load increases, on the precondition that the parameters correlated with the noise level of the engine 10 stabilize. This control improves the riding comfort.

[0062] If Schemes 5 and 6 are combined, the predetermined values (the third predetermined value ΔP_{TH3} , fourth predetermined value ΔD_{TH4} , fifth predetermined value ΔP_{TH5} , and sixth predetermined value ΔD_{TH6}) as thresholds of the differences ΔP and ΔD between the target values and the actual values may be determined smaller as the ordinal number of gear positions increases. This shortens the predetermined time T_2 as the vehicle speed increases in consideration of the stability of the boost pressure P and intake-air oxygen level D.

[0063] When the detector 2 detects the sudden-deceleration request, the conditions for forbidding the premixed combustion operation may be determined, instead of immediately forbidding the premixed combustion operation. That is, the conditions for forbidding the premixed combustion operation may be determined with reference to the boost pressure P and intake-air oxygen level D in addition to the differences ΔP and ΔD , as illustrated in FIGs. 7A and 7B. Examples of the conditions for forbidding the premixed combustion operation will now be described.

[0064] Condition 5: The boost pressure P is lower than a third lower limit P_3 .

[0065] Condition 6: The boost pressure P is equal to or higher than the third lower limit P_3 and lower than a

third upper limit P_4 , and the difference ΔP between the target value and the actual value of the boost pressure P is equal to or smaller than the third predetermined value ΔP_{TH3} .

[0066] Condition 7: The intake-air oxygen level D is lower than a fourth lower limit D_3 .

[0067] Condition 8: The intake-air oxygen level D is equal to or higher than the fourth lower limit D_3 and lower than a fourth upper limit D_4 , and the difference ΔD between the target value and the actual value of the intake-air oxygen level D is equal to or smaller than the fourth predetermined value ΔD_{TH4} .

[0068] In Conditions 5-8, the third upper limit P_4 is higher than the third lower limit P_3 , and the fourth upper limit D_4 is higher than the fourth lower limit D_3 ($P_3 < P_4$ and $D_3 < D_4$).

[0069] For the determination based on the boost pressure P , when a sudden-deceleration request is detected, the third determiner unit 7 determines the quantitative relationships between the boost pressure P and the third lower and upper limits P_3 and P_4 . For example, a boost pressure P lower than the third lower limit P_3 satisfies Condition 5; thus, the forbiddance of the premixed combustion operation is unbanned. A boost pressure P equal to or higher than the third upper limit P_4 does not satisfy Conditions 5 or 6; thus, the premixed combustion operation is forbidden (the diffusion combustion operation is performed). If the boost pressure P is between the third lower limit P_3 and the third upper limit P_4 , the determination is made on the basis of the difference ΔP between the target value and the actual value of the boost pressure P . The third lower limit P_3 , third upper limit P_4 , and third predetermined value ΔP_{TH3} may be default values or variables determined in accordance with the operating state of the engine 10. The determination based on the intake-air oxygen level D is made in the same manner.

[2-4. Controller]

[0070] The controller 8 performs the combustion switching control on the basis of the results of detection at the detector 2 and determination at the determiner 4. If the detector 2 detects the sudden-acceleration request, the premixed combustion operation and the diffusion combustion operation are controlled on the basis of the results of determination at the second determiner unit 6. If the detector 2 detects the sudden-deceleration request, the premixed combustion operation and the diffusion combustion operation are controlled on the basis of the results of determination at the third determiner unit 7. If the detector 2 does not detect the sudden-acceleration request or the sudden-deceleration request, the premixed combustion operation and the diffusion combustion operation are controlled on the basis of the results of determination at the first determiner unit 5.

[0071] In the premixed combustion operation, the controller 8 outputs a control signal to the direct injection valve 11 so as to obtain the fuel injection pattern in FIG.

2B, for example. The controller 8 controls the low-pressure throttle valve 17, high-pressure throttle valve 19, high-pressure EGR valve 22, and low-pressure EGR valve 26 such that the ratio of the amount of EGR to the total air flow rate is higher than in the diffusion combustion operation. In the diffusion combustion operation, the controller 8 outputs a control signal to the direct injection valve 11 so as to obtain the fuel injection pattern in FIG. 2A, for example.

[3. Flowchart]

[0072] FIGs. 8-10 are example flowcharts of the procedure of the combustion switching control. The flowchart in a normal operation in FIG. 8 is repeated by the engine controller 1 with predetermined computing cycles. The flowcharts in a sudden-acceleration operation in FIG. 9 and in a sudden-deceleration operation in FIG. 10 are followed when a sudden-acceleration request and a sudden-deceleration request are detected in Steps A11 and A12 in FIG. 8, respectively.

[3-1. Flowchart in Normal Operation]

[0073] In Step A1, the detector 2 retrieves the information on the accelerator-pedal position detected by the accelerator-pedal position sensor 34 and the information on the gear position detected by the gear-stick position sensor 35. Proceeding to Step A2, the gear positions in the previous and current cycles are compared with each other to determine whether the gear stick is operated. The satisfaction of this condition starts a timer T indicating an elapsed time after the start of the current gear position in Step A3, and then the procedure proceeds to Step A4. If the gear stick is not operated, the procedure skips Step A3 and proceeds to Step A4. Steps A4 to A8 correspond to the determinations at the first determiner unit 5.

[0074] Step A4 determines the predetermined period T_0 in accordance with the current gear position. The predetermined period T_0 shortens as the ordinal number of gear positions increases. Step A5 compares the value of the timer T with the predetermined period T_0 to determine whether the predetermined period T_0 elapses after the operation of the gear stick. If the inequality $T < T_0$ is satisfied (that is, if the predetermined period T_0 does not elapse after the operation of the gear stick), the first determiner unit 5 determines that the operational conditions of the diffusion combustion operation are satisfied, in Step A10, regardless of the determination of the operational conditions of the premixed combustion operation. If the inequality $T \geq T_0$ is satisfied, the procedure proceeds to Step A6.

[0075] In Step A6, the timer T stops counting because of the elapse of the predetermined period T_0 . Proceeding to Step A7, the region for the premixed combustion operation is determined in accordance with the current gear position. For example, in the second gear, the region M2 in FIG. 3 is determined as the region for the premixed

combustion operation. In the third gear, the region M3 in FIG. 3 is determined as the region for the premixed combustion operation. In this way, the region for the premixed combustion operation is varied on the basis of the gear position of the transmission.

[0076] In Step A8, the first determiner unit 5 determines whether the operating point of the engine 10 is in the region for the premixed combustion operation. If this condition is satisfied, the operational conditions of the premixed combustion operation are determined to be satisfied in Step A9. If the operating point is outside the region for the premixed combustion operation, the operational conditions of the diffusion combustion operation are determined to be satisfied in Step A10. In this way, the first determiner unit 5 makes a determination based on the operating point of the engine 10 and the control map as illustrated in FIG. 3.

[0077] Step A11 and the subsequent steps determine whether the situation requests a determination at the second determiner unit 6 or the third determiner unit 7. Step A11 follows Step A9, and Step A12 follows Steps A10 and A11. That is, Step A11 is executed only after the execution of Step A9 (when the operational conditions of the premixed combustion operation are satisfied).

[0078] Step A11 determines whether a request for sudden acceleration of the vehicle is detected. For example, if the rate of change in the accelerator-pedal position over time is equal to or higher than a predetermined positive value, sudden acceleration is determined to be requested, and then the flowchart in a sudden-acceleration operation in FIG. 9 is followed. If the rate of change in the accelerator-pedal position over time is lower than the predetermined positive value, the procedure proceeds to Step A12.

[0079] Step A12 determines whether a request for sudden deceleration of the vehicle is detected. For example, if the rate of change in the accelerator-pedal position over time is equal to or lower a predetermined negative value, sudden deceleration is determined to be requested, and then the flowchart in a sudden-deceleration operation in FIG. 10 is followed. If the rate of change in the accelerator-pedal position over time is higher than the predetermined negative value, the premixed combustion operation or the diffusion combustion operation is performed in accordance with the results of determination at the first determiner unit 5 in Step A13. The engine 10 is controlled to be in an operating state corresponding to one of Steps A9 and A10 executed immediately before Step A13.

[3-2. Flowchart in Sudden-acceleration Operation]

[0080] When a sudden-acceleration request is detected during the premixed combustion operation, a sudden-acceleration operation, which corresponds to the determination at the second determiner unit 6, is performed in accordance with the flowchart in FIG. 9.

[0081] Step B1 retrieves the information on the boost pressure P , intake-air oxygen level D , engine load E_c ,

engine speed N_e , and sudden-acceleration request. Step B2 determines the first lower limit P_1 , first upper limit P_2 , first predetermined value ΔP_{TH} , second lower limit D_1 , second upper limit D_2 , and second predetermined value ΔD_{TH2} on the basis of the engine load E_c and speed N_e .

[0082] Step B3 determines whether the boost pressure P is lower than the first lower limit P_1 . If the inequality $P < P_1$ is satisfied, the procedure proceeds to Step B6, and if the inequality $P \geq P_1$ is satisfied, the procedure proceeds to Step B4. A boost pressure P lower than the first lower limit P_1 is suitable for the premixed combustion operation but unsuitable for the diffusion combustion operation.

[0083] Step B4 determines whether the boost pressure P is equal to or higher than the first upper limit P_2 higher than the first lower limit P_1 . If the inequality $P \geq P_2$ is satisfied, the procedure proceeds to Step B10, and if the inequality $P < P_2$ is satisfied, the procedure proceeds to Step B5. A boost pressure P equal to or higher than the first upper limit P_2 is suitable for the diffusion combustion operation but unsuitable for the premixed combustion operation.

[0084] Step B5 determines whether the difference ΔP between the target value and the actual value of the boost pressure P is smaller than the first predetermined value ΔP_{TH} . If the inequality $\Delta P < \Delta P_{TH}$ is satisfied, the procedure proceeds to Step B6, and if the inequality $\Delta P \geq \Delta P_{TH}$ is satisfied, the procedure proceeds to Step B10. A boost pressure P equal to and higher than the first lower limit P_1 and lower than the first upper limit P_2 is suitable for both the premixed combustion operation and the diffusion combustion operation and capable of performing both operations. Thus, Step B5 determines which should be performed, in consideration of the stability (convergence) of the actual value of the boost pressure P following the target value.

[0085] Steps B3 to B5 determine the conditions of the boost pressure P . Steps B6 to B8 determine the conditions of the intake-air oxygen level D . Step B6 determines whether the intake-air oxygen level D is lower than the second lower limit D_1 . If the inequality $D < D_1$ is satisfied, the procedure proceeds to Step B9, and if the inequality $D \geq D_1$ is satisfied, the procedure proceeds to Step B7. An intake-air oxygen level D lower than the second lower limit D_1 is suitable for the premixed combustion operation but unsuitable for the diffusion combustion operation.

[0086] Step B7 determines whether the intake-air oxygen level D is equal to or higher than the second upper limit D_2 higher than the second lower limit D_1 . If the inequality $D \geq D_2$ is satisfied, the procedure proceed to Step B10, and if the inequality $D < D_2$ is satisfied, the procedure proceeds to Step B8. An intake-air oxygen level D equal to or higher than the second upper limit D_2 is suitable for the diffusion combustion operation but unsuitable for the premixed combustion operation.

[0087] Step B8 determines whether the difference ΔD between the target value and the actual value of the in-

take-air oxygen level D is smaller than the second predetermined value ΔD_{TH2} . If the inequality $\Delta D < \Delta D_{TH2}$ is satisfied, the procedure proceeds to Step B9, and if the inequality $\Delta D \geq \Delta D_{TH2}$ is satisfied, the procedure proceeds to Step B10. An intake-air oxygen level D equal to or higher than the second lower limit D_1 and lower than the second upper limit D_2 is suitable for both the premixed combustion operation and the diffusion combustion operation and capable of performing both operations. Thus, Step B8 determines which operation should be performed, in consideration of the stability of the actual value of the intake-air oxygen level D following the target value.

[0088] Depending on the determination of the conditions in Steps B3 to B8, the premixed combustion operation is performed in Step B9, or the diffusion combustion operation is performed in Step B10. The results of determination at the second determiner unit 6 have higher priority over the results of determination at the first determiner unit 5. Even if the operational conditions of the diffusion combustion operation are determined to be satisfied in Step A10 of the flowchart in a normal operation, the execution of Step B9 in the flowchart in a sudden-acceleration operation allows the premixed combustion operation to be performed. Similarly, the diffusion combustion operation is performed through the execution of Step B10, regardless of the determination in Step A9.

[0089] Step B11 determines whether the sudden-acceleration request is not detected anymore. The satisfaction of this condition starts a timer U indicating an elapsed time after the sudden-acceleration request is not detected anymore in Step B12, and then the procedure proceeds to Step B13. If the sudden-acceleration request is detected or the sudden-acceleration request has not been detected anymore in a past computing cycle, the procedure skips Step B12 and proceeds to Step B13.

[0090] Step B13 compares the value of the timer U with the predetermined time T_1 to determine whether the predetermined time T_1 elapses after the sudden-acceleration request is not detected anymore. If the inequality $U < T_1$ (non-lapse of the predetermined time T_1) is satisfied, this flowchart ends, and the flowchart in a sudden-acceleration operation is repeated in the subsequent computing cycle. If the inequality $U \geq T_1$ is satisfied, the timer U stops counting due to the elapse of the predetermined time T_1 in Step B14, and the flowchart in a normal operation is followed in the subsequent computing cycle. After this, the engine is controlled on the basis of the results of determination at the first determiner unit 5.

[3-3. Flowchart in Sudden-deceleration Operation]

[0091] When a sudden-deceleration request is detected, a sudden-deceleration operation, which corresponds to the determination at the third determiner unit 7, is performed in accordance with the flowchart in FIG. 10.

[0092] Step C1 retrieves the information on the boost pressure P, intake-air oxygen level D, engine load Ec, engine speed Ne, sudden-deceleration request, demand

load, and vehicle speed. Step C2 determines the third lower limit P_3 , third upper limit P_4 , third predetermined value ΔP_{TH3} , fourth lower limit D_3 , fourth upper limit D_4 , and fourth predetermined value ΔD_{TH4} on the basis of the engine load Ec and speed Ne.

[0093] Step C3 determines whether the demand load is detected (the accelerator pedal is depressed). If the demand load is not detected, the diffusion combustion operation is performed in Step C11. That is, when the sudden-deceleration request is detected, the premixed combustion operation is forbidden; instead, the diffusion combustion operation is performed until the accelerator pedal is operated. If the demand load is detected, the procedure proceeds to Step C4.

[0094] Steps C4 to C9, as in Steps B3 to B8 in the flowchart in a sudden-acceleration operation, determine the conditions of the boost pressure P and intake-air oxygen level D, which are parameters correlated with the noise level of the engine 10. The boost pressure P is compared with the third lower and upper limits P_3 and P_4 to determine the quantitative relationships therebetween, and it is determined whether the difference ΔP between the target value and the actual value of the boost pressure P is smaller than the third predetermined value ΔP_{TH3} . The intake-air oxygen level D is compared with the fourth lower and upper limits D_3 and D_4 to determine the quantitative relationships therebetween, and it is determined whether the difference ΔD between the target value and the actual value of the intake-air oxygen level D is smaller than the fourth predetermined value ΔD_{TH4} .

[0095] A boost pressure P lower than the third lower limit P_3 is suitable for the premixed combustion operation, and a boost pressure P equal to or higher than the third upper limit P_4 is suitable for the diffusion combustion operation. A boost pressure P equal to or higher than the third lower limit P_3 and lower than the third upper limit P_4 is suitable for both the premixed combustion operation and the diffusion combustion operation; thus, it is determined which operation should be performed, in consideration of the stability of the actual value of the boost pressure P following the target value. Similarly, the determination is made for the intake-air oxygen level D.

[0096] Step C12 subsequent to Steps C10 and C11 determines whether the sudden-deceleration request is not detected anymore. The satisfaction of this condition starts a timer V indicating an elapsed time after the sudden-deceleration request is not detected anymore in Step C13, and then the procedure proceeds to Step C14. If the sudden-deceleration request is detected or the sudden-deceleration request is not detected anymore in a past computing cycle, the procedure skips Step C13 and proceeds to Step C14.

[0097] Step C14 determines the predetermined time T_2 on the basis of the vehicle speed at that time. The predetermined time T_2 shortens as the vehicle speed increases, as illustrated in FIG. 6. Step C15 compares the value of the timer V with the predetermined time T_2 to determine whether the predetermined time T_2 elapses

after the sudden-deceleration request is not detected anymore. If the inequality $V < T_2$ (non-lapse of the predetermined time T_2) is satisfied, this flowchart ends, and the flowchart in a sudden-deceleration operation is repeated in the subsequent computing cycle. If the inequality $V \geq T_2$ is satisfied, the timer V stops counting due to the elapse of the predetermined time T_2 in Step C16, and the flowchart in a normal operation is followed in the subsequent computing cycle. After this, the engine is controlled on the basis of the results of determination at the first determiner unit 5.

[4. Advantageous Effect]

[4-1. In Normal Operation]

[0098]

(1) In the engine controller 1, the first determiner unit 5 changes the operational conditions of the premixed combustion operation depending on the gear position of the transmission. This enables switching between the premixed combustion operation and the diffusion combustion operation in consideration of differences in traveling sound and operation sound among the gear positions. The engine controller 1 accurately determines such a traveling state that the sound generated at the engine 10 is readily masked by sound other than that from the engine 10, for example, a traveling state in which noise generated in the premixed combustion operation is readily blocked. This improves the emission performance and riding comfort and thus improves the emission performance and quietness of the vehicle.

(2) As illustrated in FIG. 3, the engine controller 1 expands the region for the premixed combustion operation in the direction of the increasing engine speed N_e (to the right) as the reduction ratio of the transmission decreases. The engine controller 1 increases the upper limit of the engine speed N_e for performing the premixed combustion operation such that the premixed combustion operation is performed at a high speed of the engine 10. This operation improves the emission performance. Traveling sound readily blocks noise generated in the premixed combustion operation at a high speed of the engine 10, resulting in an improvement in riding comfort.

(3) As illustrated in FIG. 3, the engine controller 1 expands the region for the premixed combustion operation in the direction of the increasing engine load E_c (upward) as the reduction ratio of the transmission decreases. The engine controller 1 increases the upper limit of the engine load E_c for performing the premixed combustion operation such that the premixed combustion operation is performed with a high load of the engine 10. This control improves the emission performance. Traveling sound readily

blocks noise generated in the premixed combustion operation with a high load of the engine 10, resulting in an improvement in riding comfort.

(4) As illustrated in FIG. 3, the second gear is the lowest gear position in which the region for the premixed combustion operation expands in the direction of the increasing engine speed N_e (to the right). The third gear is the lowest gear position in which the region for the premixed combustion operation expands in the direction of the increasing engine load E_c (upward). The engine load E_c has higher priority over the engine speed N_e as to increasing the upper limits thereof; thus, the premixed combustion operation is performed in a traveling state having fine noise block effect, which further improves the riding comfort.

(5) The engine controller 1 determines that the premixed combustion operation is performed when at least the predetermined period T_0 elapses after a change in the gear position. This enables the diffusion combustion operation to be performed if the air flow rate or the amount of EGR varies transiently immediately after a change in the gear stick, for example, thus ensuring the combustion stability. The controller starts the premixed combustion operation, avoiding an unstable combustion state immediately after a change in the gear stick. This control improves the combustion stability of the engine 10.

(6) The predetermined period T_0 is determined shorter as the reduction ratio of the gear position decreases. This improves the combustion stability of the engine 10 and enables prompt start of the premixed combustion operation.

(7) Scheme 3, if employed as the scheme of determining the predetermined period T_0 , prevents the combustion stability from lowering because of delays in intake and supercharge, improving the combustion stability of the engine 10 in the premixed combustion operation.

[4-2. In Sudden-acceleration Operation]

[0099]

(1) When a sudden-acceleration request is detected during the premixed combustion operation, the engine controller 1 determines whether to continue the premixed combustion operation or switch the premixed combustion operation to the diffusion combustion operation, using the conditions including the parameters correlated with the noise level of the engine 10. The use of the conditions including the parameters correlated with the noise level enables the premixed combustion operation to be continued without providing discomfort to the driver, resulting in an improvement in emission performance. The premixed combustion operation is switched to the diffusion combustion operation in such a traveling

state as to increase noise, thus improving the emission performance and riding comfort without an excess increase in noise.

(2) The engine controller 1 uses, as the parameters correlated with the noise level, physical quantities on which the ratio of components in the mixture introduced into the cylinders is reflected and which affect the combustion rate, such as the boost pressure P and intake-air oxygen level D of the engine 10. This enables accurate determination of the timing at which the mixture burns readily, improving the quietness and riding comfort.

The use of the boost pressure P as one of the parameters enables accurate estimation of the volume of air introduced into the cylinders and accurate determination of such an operating state of the engine 10 that noise readily becomes loud. The use of the intake-air oxygen level D enables accurate estimation of the amount of oxygen used for combustion in the cylinders and accurate determination of a variation in the combustion rate, resulting in a further improvement in riding comfort.

(3) When the sudden-acceleration request is detected during the premixed combustion operation, the engine controller 1 compares the boost pressure P or the intake-air oxygen level D with two thresholds (upper and lower limits). As illustrated in FIGs. 5A and 5B, if the boost pressure P is lower than the first lower limit P_1 or the intake-air oxygen level D is lower than the second lower limit D_1 , the premixed combustion operation is continued. If the boost pressure P is equal to or higher than the first upper limit P_2 or the intake-air oxygen level D is equal to or higher than the second upper limit D_2 , the premixed combustion operation is switched to the diffusion combustion operation.

Such determination using two thresholds at different levels enables flexible control when the boost pressure P or the intake-air oxygen level D is between these two thresholds and thus enables the selection of a combustion mode suitable for the operating state of the engine 10.

In response to the sudden-acceleration request in the premixed combustion operation, the engine load E_c increases, and the parameters correlated with the noise level of the engine 10 rise gradually. The premixed combustion operation is continued with the parameters still having small values, thus improving the emission performance without an excess increase in noise. If the parameters then have large values, the premixed combustion operation is switched to the diffusion combustion operation, resulting in a noise reduction effect.

(4) The thresholds may be determined on the basis of the engine load E_c and speed N_e . This provides criteria suitable for any operating state of the engine 10, enabling accurate determination of such a traveling state as to increase noise of the engine 10

and improving noise control effect.

(5) If the parameters are between the two thresholds (upper and lower limits), the engine controller 1 makes a determination on the basis of the differences between the target values and the actual values. As illustrated in FIG. 5A, for example, a difference ΔP smaller than the first predetermined value ΔP_{TH} continues the premixed combustion operation. A difference ΔP equal to or larger than the first predetermined value ΔP_{TH} causes to switch the premixed combustion operation to the diffusion combustion operation. In this way, a combustion mode is selected in consideration of the stability of the parameters correlated with the noise level. Such a selection enables accurate determination of overshoot from the target values of the parameters and a more accurate noise reduction effect.

(6) The predetermined values such as the first predetermined value ΔP_{TH} and second predetermined value ΔD_{TH2} to be compared with the differences between the target values and the actual values may be determined on the basis of the engine load E_c and speed N_e . This provides criteria suitable for any operating state of the engine 10, enabling accurate determination of such a traveling state as to increase noise of the engine 10 and improving the noise control effect.

[4-3. In Sudden-deceleration Operation]

[0100]

(1) As illustrated in FIG. 2D, the cylinder pressure varies more sharply in the premixed combustion operation than in the diffusion combustion operation, causing an increase in combustion noise. Thus, a premixed combustion operation without a heavy load on the engine 10 generates large amounts of noise despite a normal workload on the engine 10 and provides discomfort to the driver.

The engine controller 1 forbids the premixed combustion operation and instead performs the diffusion combustion operation during the detection of the sudden-deceleration request. For example, even if the first determiner unit 5 determines that the operational conditions of the premixed combustion operation are satisfied, the premixed combustion operation is forbidden with the detection of the driver operation to release the accelerator pedal.

In this way, the diffusion combustion operation is performed instead of the premixed combustion operation, in response to the sudden-deceleration request. This prevents noise in a no-load state (low-load state) immediately after the release of the accelerator pedal, resulting in an improvement in riding comfort. The premixed combustion operation is permitted in a normal-deceleration operation, such as an accelerator-releasing operation in which the rate of

change in the accelerator-pedal position over time is equal to or higher than a predetermined negative value, other than the sudden-deceleration operation, resulting in an improvement in emission performance. This improves the emission performance and quietness of the vehicle.

(2) The engine controller 1 forbids the premixed combustion operation and performs the diffusion combustion operation after the sudden-deceleration request is not detected anymore and before the predetermined time T_2 elapses. The premixed combustion operation is forbidden until a variation in the combustion state due to sudden deceleration of the vehicle is stabilized, thus improving the quietness and riding comfort.

(3) As illustrated in FIG. 6, the engine controller 1 determines the predetermined time T_2 shorter as the vehicle speed increases and longer as the vehicle speed decreases. Such setting extends the period of forbidding the premixed combustion operation in a traveling state in which the traveling sound of the vehicle is relatively quiet, resulting in an improvement in quietness. In a traveling state in which the traveling sound of the vehicle is relatively loud, the period of forbidding the premixed combustion operation shortens, resulting in an improvement in emission performance.

(4) As illustrated in FIGs. 7A and 7B, the predetermined time T_2 may be used as the time until the differences between the target values and the actual values of the boost pressure P and the intake-air oxygen level D are equal to or smaller than the predetermined values. In this case, the premixed combustion operation is forbidden until the boost pressure P and intake-air oxygen level D are sufficiently stabilized, and the premixed combustion operation is performed after the stabilization. This further improves the combustion stability of the engine 10 and the quietness.

(5) If a demand load is requested during the forbiddance of the premixed combustion operation, the engine controller 1 unbans the forbiddance and permits the premixed combustion operation. If the accelerator pedal is depressed during the forbiddance of the premixed combustion operation, for example, the premixed combustion operation is performed at an operating point in the region of the premixed combustion operation. In this way, the forbiddance of the premixed combustion operation is unbanned at the timing of the start of acceleration, resulting in an improvement in emission performance. Since the workload on the engine 10 increases in acceleration, noise, if generated by starting the premixed combustion operation, is less prone to provide discomfort to the driver. This prevents decrease in the riding comfort.

(6) The conditions including the parameters, such as the boost pressure P , intake-air oxygen level D ,

intake-air temperature, humidity, and intake-air density, correlated with the noise level of the engine 10 may be additionally used as the conditions for forbidding the premixed combustion operation. In this case, the premixed combustion operation is started at stabilized values of the parameters correlated with the noise level of the engine 10. This further improves the combustion stability of the engine 10 and the quietness.

[5. Modifications]

[0101] The invention should not be limited to the above embodiments and examples. Various modifications may be made without departing from the scope of the invention. The configurations in the embodiments may be selected as needed or combined appropriately.

[0102] In the above embodiments, the correlations between the operating point and the combustion state are defined in the example map in FIG. 3. Instead, the regions M1-M4 may have any shape, and/or any ordinal number of regions may be present on the map. Especially, the preferred shapes of the regions M1-M4 are determined in consideration of the traveling characteristics of the vehicle and the riding comfort.

[0103] The map in FIG. 3 contains the correlations between the operating point in accordance with the engine speed N_e and load E_c and the regions M1-M4. The traveling state of the vehicle may be determined on the basis of at least one of the engine load E_c and speed N_e . The operating point and the combustion state may be correlated with each other using inequalities or equations as shown in Table 1, for example.

[0104] The above embodiments describe the control of diesel engines; however, the control may be applied to gasoline engines. An engine performing at least a premixed combustion operation and a diffusion combustion operation that are switchable in accordance with the traveling state of a vehicle achieves the same advantageous effects as in the embodiments.

[0105] The invention thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

REFERENCE SIGNS LIST

[0106]

- | | |
|---|-------------------------------------|
| 1 | engine controller |
| 2 | detector |
| 3 | map storage |
| 4 | determiner |
| 5 | first determiner unit |
| 6 | second determiner unit (determiner) |
| 7 | third determiner unit |

8	controller		air oxygen level (D) of the engine (10) is equal to or smaller than a predetermined value.
10	engine		
11	direct injection valve		
12	intake path		
13	exhaust path	5	5. The engine controller according to one of Claims 2 to 4, wherein the determiner (7) unbans the forbiddance of the premixed combustion operation and permits the premixed combustion operation when a demand load is requested during the forbiddance.
14	turbocharger		
15	exhaust emission controller		
15A	DOC		
15B	DPF		
16	air cleaner	10	6. The engine controller according to Claim 5, wherein the determiner (7) determines whether to unban the forbiddance of the premixed combustion operation, using conditions including parameters correlated with a noise level of the engine (10), when the demand load is requested during the forbiddance.
17	low-pressure throttle valve		
18	intercooler		
19	high-pressure throttle valve		
20	high-pressure EGR path		
21	high-pressure EGR cooler	15	
22	high-pressure EGR valve		
23	low-pressure EGR path		
24	low-pressure EGR filter		
25	low-pressure EGR cooler		
31	engine speed sensor	20	
32	pressure sensor		
33	oxygen level sensor		
34	accelerator-pedal position sensor		
35	gear-stick position sensor		
36	vehicle speed sensor	25	

Claims

1. A controller (1) of an engine performing a premixed combustion operation and a diffusion combustion operation switchable in accordance with a traveling state of a vehicle, the engine controller comprising:
 - a detector (2) detecting a sudden-deceleration request for sudden deceleration of the vehicle, on the basis of a driving operation from a driver; and
 - a determiner (7) forbidding the premixed combustion operation and permitting the diffusion combustion operation during detection of the sudden-deceleration request at the detector (2).
2. The engine controller according to Claim 1, wherein the determiner (7) forbids the premixed combustion operation and permits the diffusion combustion operation after the sudden-deceleration request is not detected anymore and before a predetermined time (T_2) lapses.
3. The engine controller according to Claim 2, wherein the predetermined time (T_2) decreases as a speed of the vehicle increases.
4. The engine controller according to Claims 2 or 3, wherein the predetermined time (T_2) is a time until a difference between a target value and an actual value of each of a boost pressure (P) and an intake-

FIG. 1

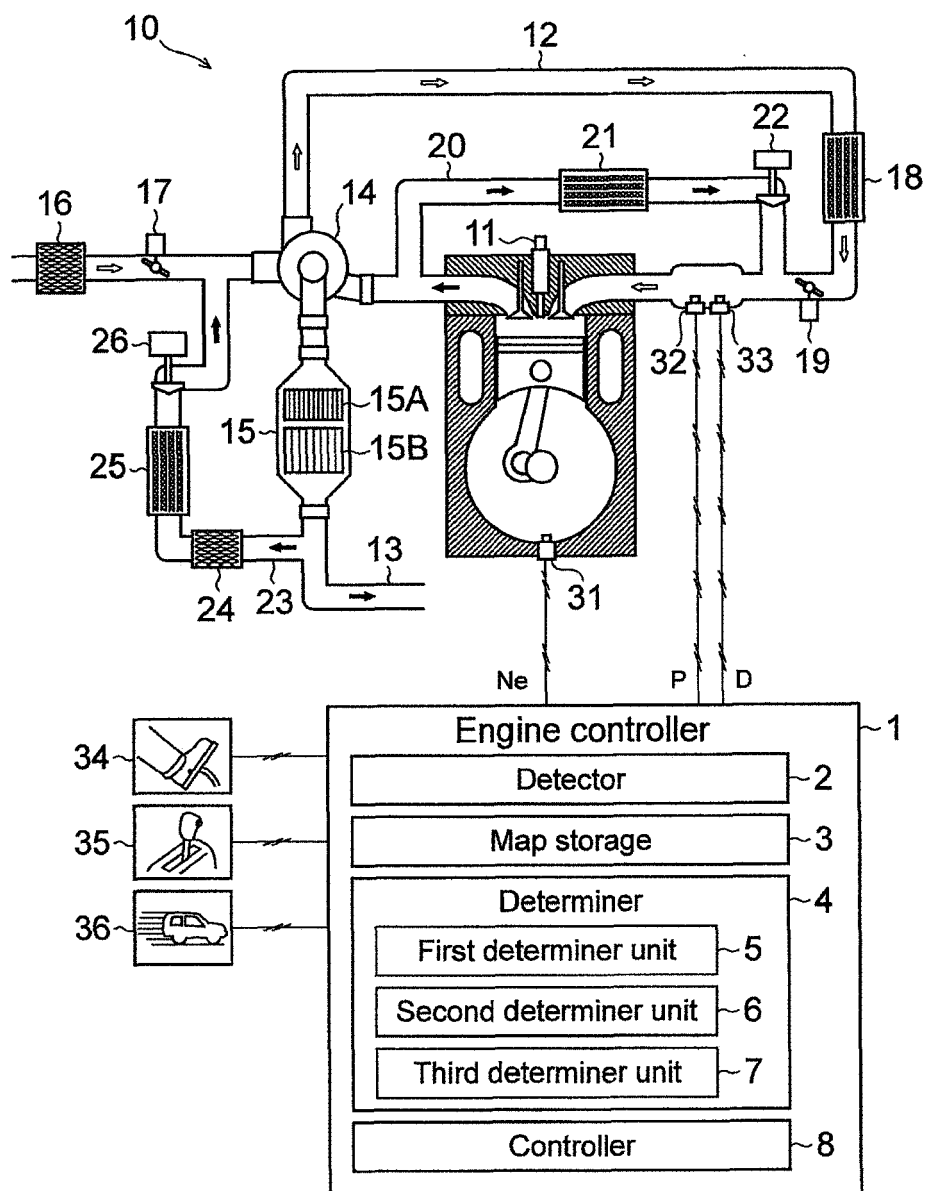


FIG. 2A

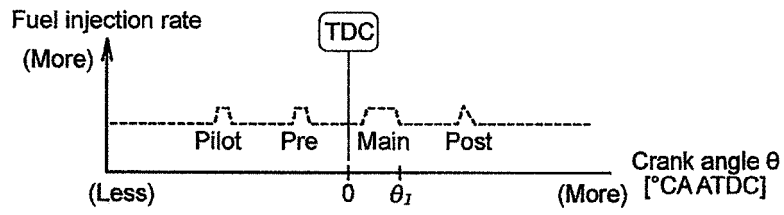


FIG. 2B

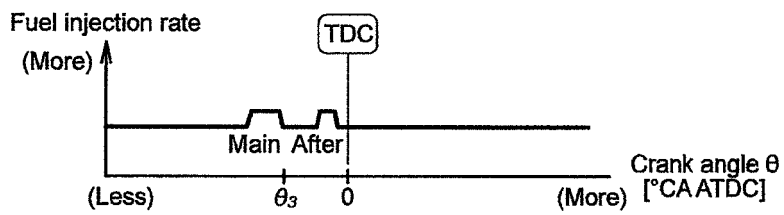


FIG. 2C

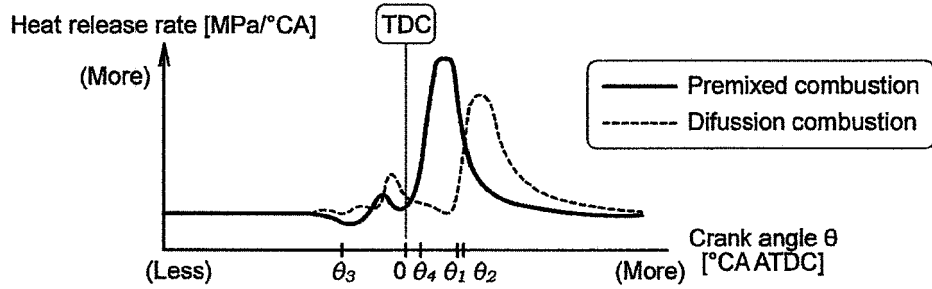


FIG. 2D

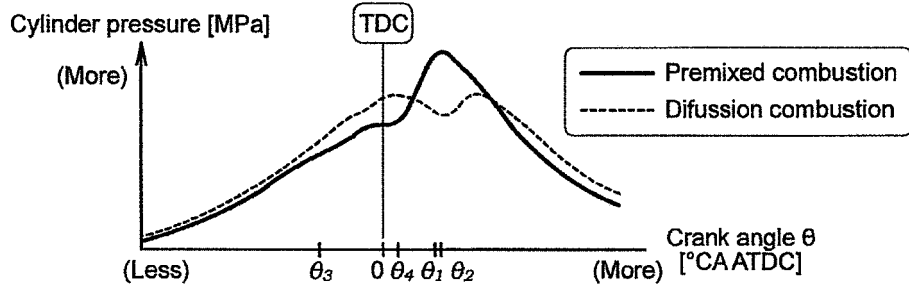


FIG. 3

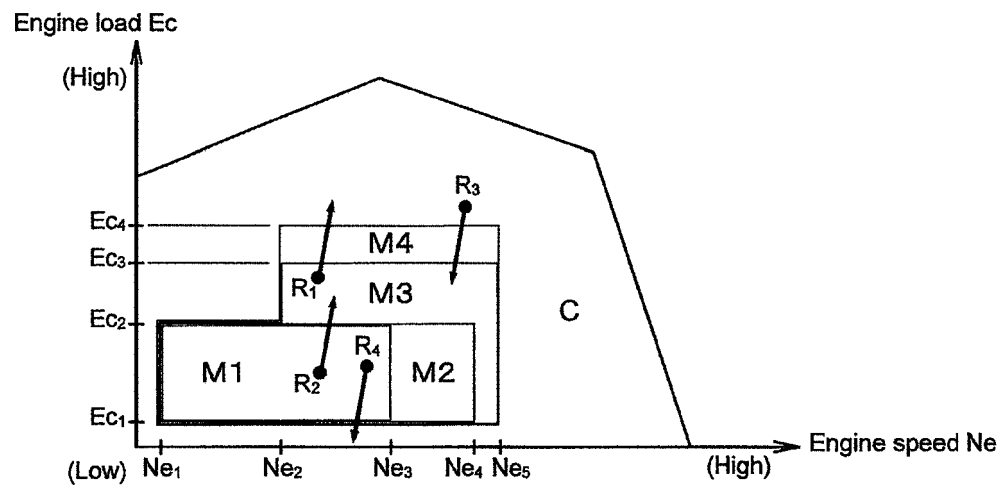


FIG. 4

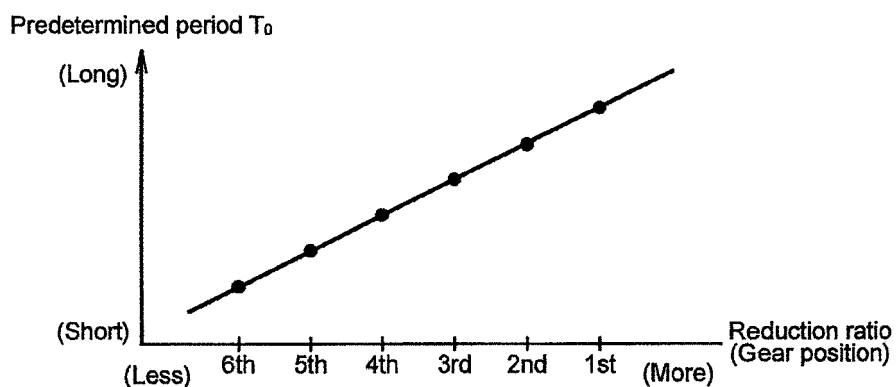


FIG. 5A

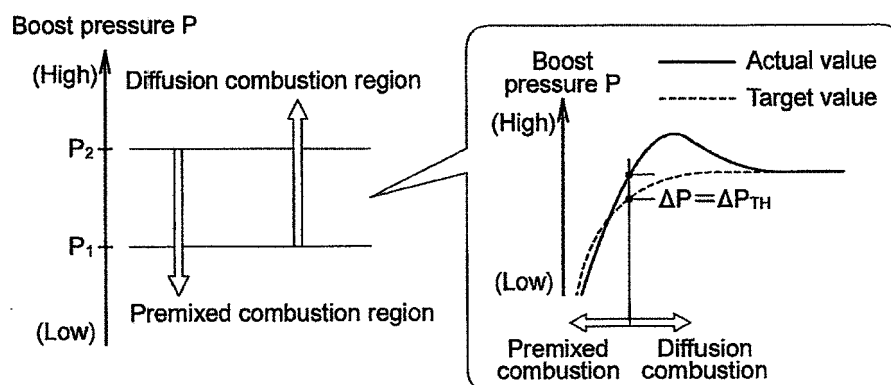


FIG. 5B

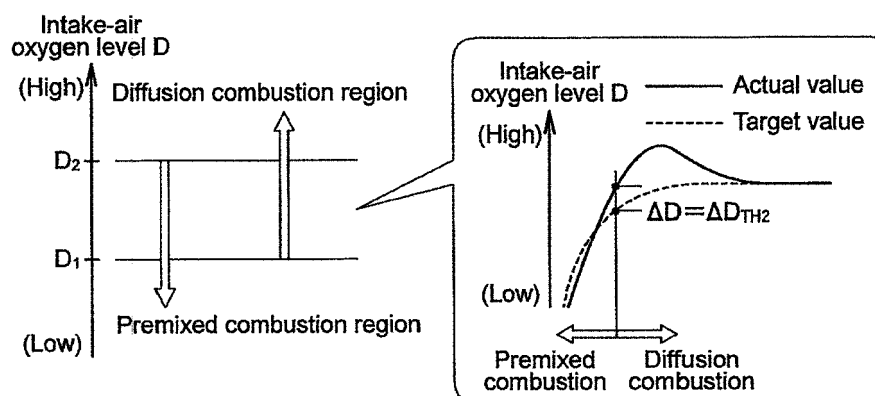


FIG. 6

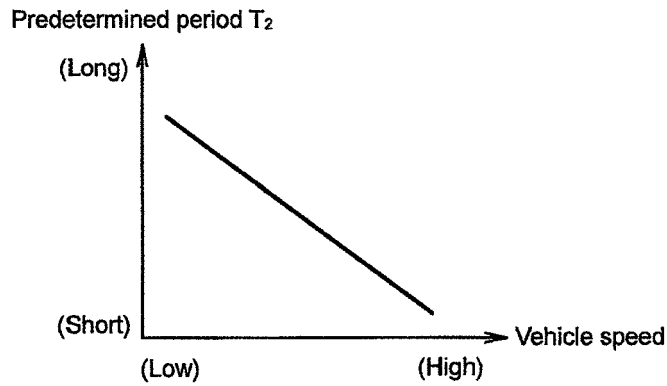


FIG. 7A

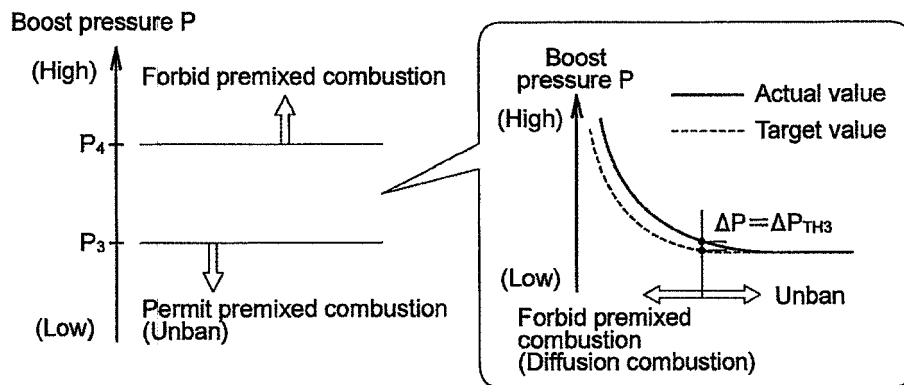


FIG. 7B

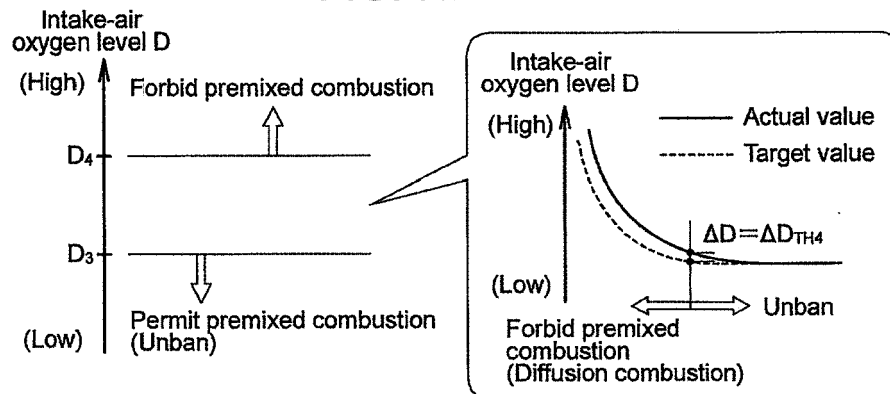


FIG. 8

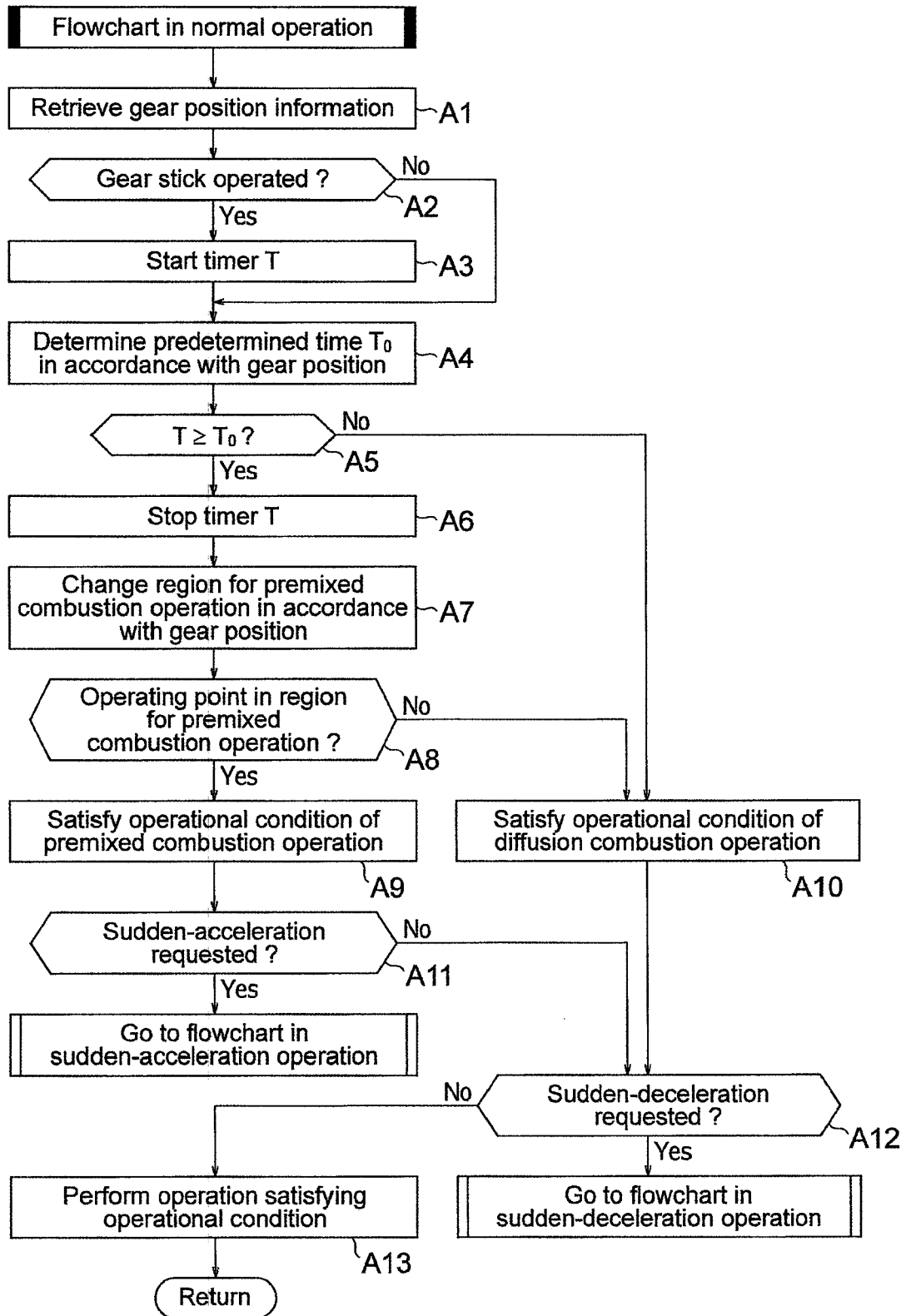


FIG. 9

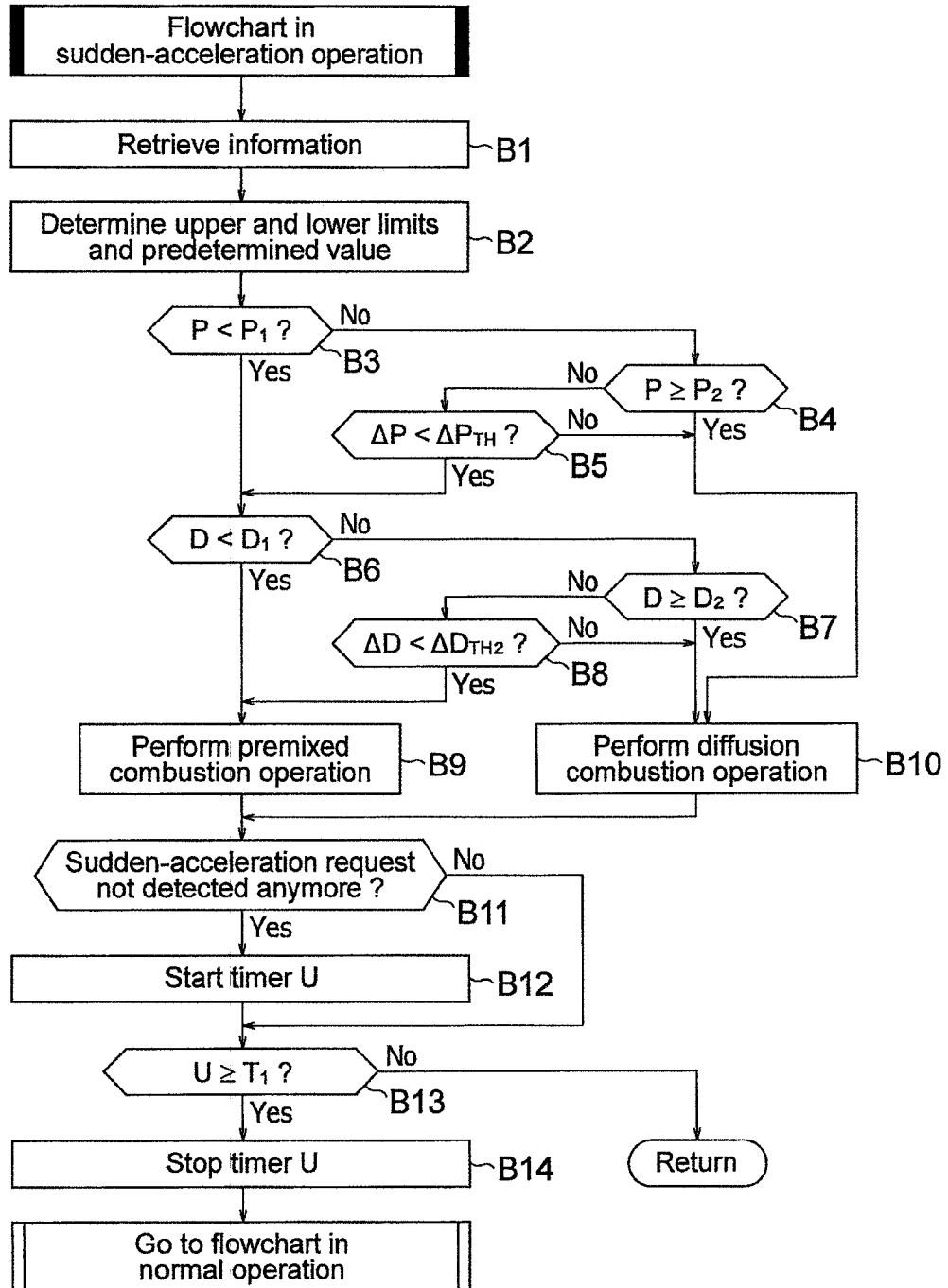
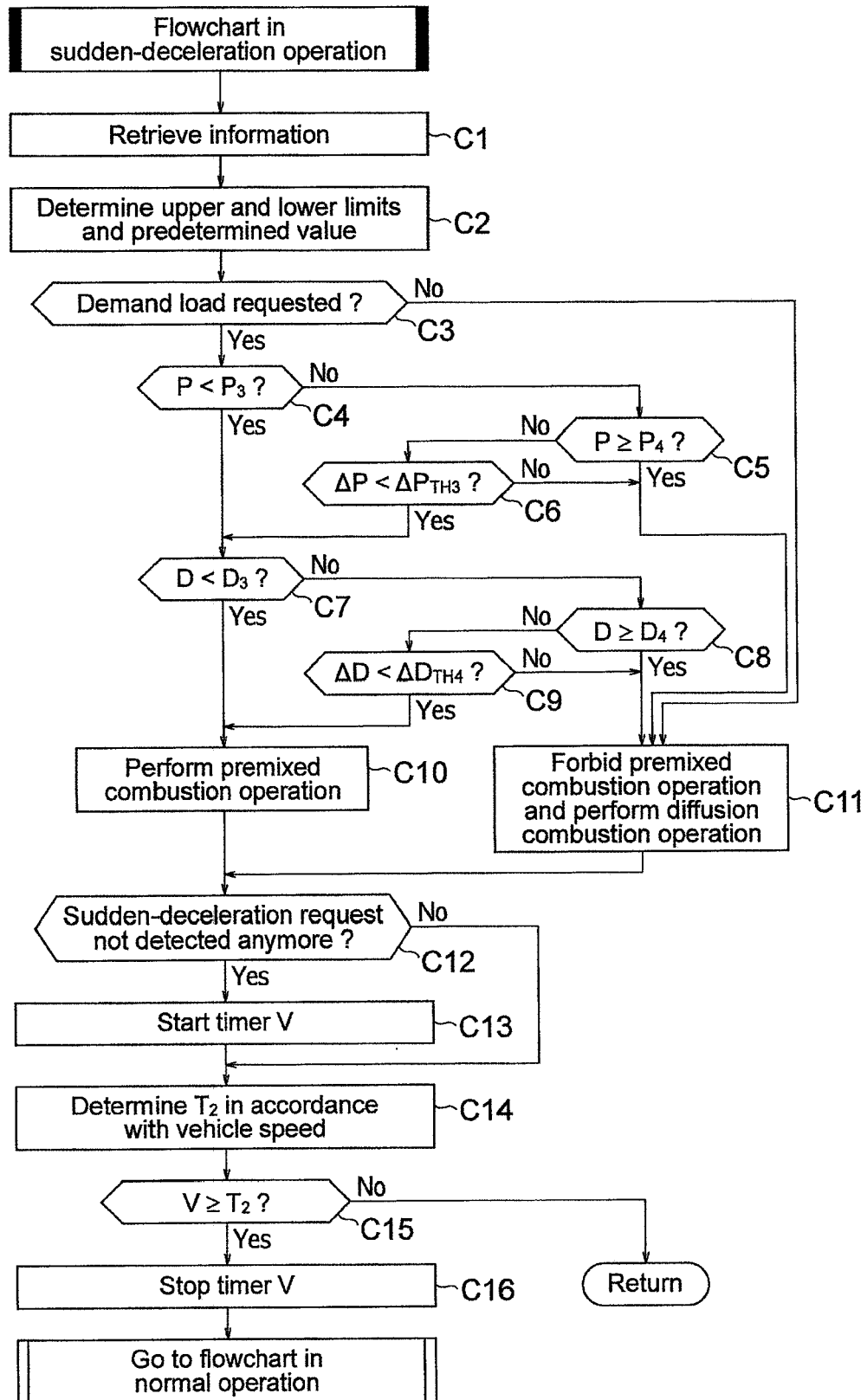


FIG. 10





EUROPEAN SEARCH REPORT

 Application Number
 EP 15 18 6820

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/140629 A1 (SHIRAKAWA TAKASHI [JP]) 31 July 2003 (2003-07-31)	1,3,4	INV. F02D41/30
Y	* paragraph [0064]; figure 2 * * paragraphs [0076] - [0079] * * figures 4-6 *	2,5,6	F02D41/12
Y	JP 2006 046303 A (TOYOTA MOTOR CORP) 16 February 2006 (2006-02-16) * paragraphs [0085], [0088]; figure 6 *	2,5	ADD. F02D41/04
Y	US 2011/320108 A1 (MORINAGA SHINICHI [JP] ET AL) 29 December 2011 (2011-12-29) * paragraphs [0099] - [0100]; figure 8 *	6	
A	JP 2006 214340 A (TOYOTA MOTOR CORP) 17 August 2006 (2006-08-17) * paragraph [0013] *	1-6	
A,D	EP 1 806 493 A1 (ISUZU MOTORS LTD [JP]) 11 July 2007 (2007-07-11) * the whole document *	1-6	
A	JP 2012 041892 A (MAZDA MOTOR) 1 March 2012 (2012-03-01) * paragraph [0022] * * paragraphs [0048] - [0053] * * figures 4-6 *	1-6	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search		Date of completion of the search	Examiner
The Hague		29 February 2016	Spicq, Alexandre
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 15 18 6820

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-02-2016

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2003140629	A1	31-07-2003	CN 1455844 A	12-11-2003
			EP 1383997 A2	28-01-2004
			JP 3972599 B2	05-09-2007
			JP 2002327638 A	15-11-2002
			KR 20030036173 A	09-05-2003
			US 2003140629 A1	31-07-2003
			WO 02090744 A2	14-11-2002

JP 2006046303	A	16-02-2006	JP 4196900 B2	17-12-2008
			JP 2006046303 A	16-02-2006

US 2011320108	A1	29-12-2011	CN 102312740 A	11-01-2012
			DE 102011105855 A1	12-01-2012
			JP 5392293 B2	22-01-2014
			JP 2012031843 A	16-02-2012
			US 2011320108 A1	29-12-2011

JP 2006214340	A	17-08-2006	JP 4419860 B2	24-02-2010
			JP 2006214340 A	17-08-2006

EP 1806493	A1	11-07-2007	CN 101035977 A	12-09-2007
			EP 1806493 A1	11-07-2007
			JP 3931900 B2	20-06-2007
			JP 2006105047 A	20-04-2006
			US 2009070002 A1	12-03-2009
			WO 2006038601 A1	13-04-2006

JP 2012041892	A	01-03-2012	JP 5589673 B2	17-09-2014
			JP 2012041892 A	01-03-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 5447294 B [0004]
- JP 3931900 B [0004]