(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 568 873 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
31.08.2005 Bulletin 2005/35

(51) Int Cl.7: **F02D 41/26**

(21) Application number: **05003317.4**

(22) Date of filing: **16.02.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR LV MK YU

(30) Priority: **18.02.2004 JP 2004040851**

(71) Applicant: **Toyota Jidosha Kabushiki Kaisha**
Toyota-shi, Aichi 471-8571 (JP)

(72) Inventors:
- **Imai, Daichi**
  Toyota-shi, Aichi 471-8571 (JP)
- **Nakayama, Shigeki**
  Toyota-shi, Aichi 471-8571 (JP)
- **Miyake, Teruhiko**
  Toyota-shi, Aichi 471-8571 (JP)
- **Fukuma, Takao**
  Toyota-shi, Aichi 471-8571 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(54) Control apparatus for internal combustion engine

(57) A control apparatus for an internal combustion engine handles a plurality of engine control parameters which influence the emission generation quantity, while dividing them into a plurality of classes in terms of response speed. An empirical formula which obtains the emission generation quantity by use of the plurality of parameters as arguments is solved for each parameter, whereby an equation for obtaining the value of a parameter of a class of interest while using parameters of the remaining classes and the emission generation quantity as arguments is obtained for each parameter. In each of the obtained equations, a target value is used as an argument value of the emission generation quantity, an actual value is used as an argument value of a parameter of a class which is lower in response speed than the class of interest, and a steady-state adequate values is used as an argument value of a parameter of a class which is higher in response speed than the class of interest. The values calculated by these equations are used as target values of the parameters.

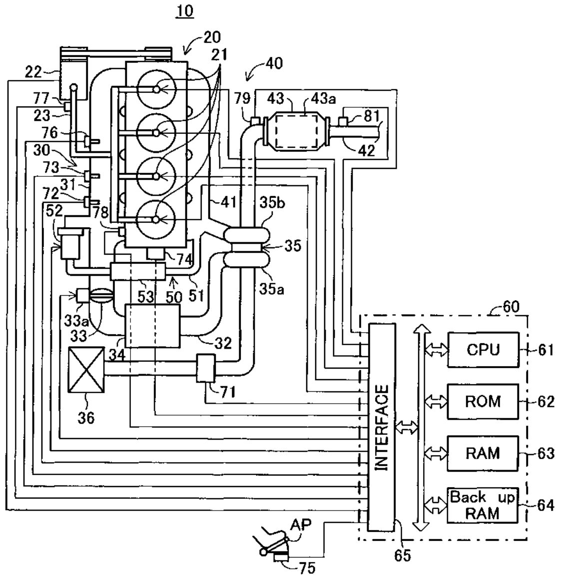


FIG.1

EP 1 568 873 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a control apparatus for an internal combustion engine which controls a predetermined controlled quantity generated upon operation of the engine, such as the quantities of NOx and particulate matter (hereinafter referred to as "PM") contained in exhaust gas discharged from an exhaust passage of the engine.

Description of the Related Art

[0002] In an internal combustion engine such as a spark-ignition engine or a diesel engine, the quantity of NOx, PM, etc. (hereinafter collectively referred to as "emissions") contained in exhaust gas generated upon operation of the engine or the quantity of combustion noise (hereinafter referred to as "CN") must be effectively reduced.

[0003] However, as has been known, when the quantity of EGR gas is increased in order to reduce the generation quantity of NOx, in the case of a diesel engine, the generation quantity of PM increases. That is, in order to minimize the NOx generation quantity in consideration of suppression of an increase in the PM generation quantity and other factors, the NOx generation quantity is desirably controlled to a predetermined target value corresponding to the operation state of the engine. Meanwhile, in order to accurately control the NOx generation quantity to a predetermined target value, the NOx generation quantity must be accurately estimated.

[0004] For such accurate estimation, a control apparatus for an internal combustion engine disclosed in Japanese Patent Application Laid-Open (*kokai*) No. 2002-371893 detects combustion pressure and intake-gas oxygen concentration by use of a cylinder pressure sensor and an intake-gas oxygen concentration sensor, and estimates the quantity of NOx generated upon combustion on the basis of combustion temperature and gas mixture concentration calculated on the basis of the combustion pressure and the intake-gas oxygen concentration, wherein the estimation is performed by use of the extended Zeldovich mechanism, which is a typical known combustion model. Then, EGR gas quantity or the like is controlled so that the estimated NOx generation quantity coincides with the predetermined target value.

[0005] Incidentally, the above-mentioned NOx generation quantity is greatly influenced by a plurality of engine control parameters such as fuel injection timing, fuel injection pressure, and intake-gas oxygen concentration. In other words, a predetermined correlation exists between the NOx generation quantity and these engine control parameters. Accordingly, there can be previously obtained a correlation (specifically, a table, mathematical equation, etc.) between the operation state of the engine and values of a plurality of engine control parameters (hereinafter referred to as "engine control parameter steady-state adequate values") which make the NOx generation quantity coincident with a predetermined target value when the engine is in a steady state in the operation state. For example, such correlation can be obtained through an experiment in which the operation state of the engine is successively changed to and maintained in a plurality of steady states, and in each steady state, there are obtained the optimal values (optimal combination of values) of the engine control parameters which make the NOx generation quantity coincident with a predetermined target value corresponding to the steady state.

[0006] In view of the above, in order to control the NOx generation quantity to the predetermined target value corresponding to the operation state of the engine, there can be employed a configuration designed to repeatedly detect the operation state of the engine; to set, as target values of the engine control parameters, corresponding engine control parameter steady-state adequate values obtained from the detected operation state and the above-described previously obtained correlation; and to control the engine control parameters such that the actual values of the engine control parameters approach (or coincide with) the corresponding target values. This configuration enables controlling the NOx generation quantity to the predetermined target value corresponding to the operation state of the engine without estimating the NOx generation quantity as in the apparatus disclosed in the patent publication.

[0007] In this case, in order to accurately control the NOx generation quantity to the predetermined target value corresponding to the operation state of the engine, all the values (actual values) of the above-described plurality of engine control parameters must quickly follow the target values (i.e., steady-state adequate values) which change in accordance with the operation state of the engine.

[0008] However, in actuality, some variation arises in response speed (speed at which an actual value approaches the corresponding target value) among the engine control parameters. Accordingly, when the engine moves from a certain steady state to an excessive transition state and then returns to the certain steady state, the actual values of the plurality of engine control parameters successively coincide with the corresponding target values (i.e., steady-state adequate values) in descending order of response speed. When the actual value of an engine control parameter having the lowest response speed coincides with the corresponding target value (i.e., steady-state adequate value), the transition state substantially ends, and the engine again operates in the steady state (i.e., all the engine control parameter actual values coincide with the corresponding target values (steady-state adequate values)), whereby the NOx generation quantity accurately coincides with the predetermined target value.

[0009] In other words, the NOx generation quantity follows the predetermined target value at the response speed of an engine control parameter having the lowest response speed. Accordingly, there arises a problem in that when the engine returns from an excessive transition state to the steady state, during a period in which the transition state continues (i.e., in a period in which the actual value of the engine control parameter having the lowest response speed does not coincide with the corresponding target value (steady-state adequate value), a difference may be continuously produced between the actual value of the engine control parameter having the lowest response speed and the target value (steady-state adequate value), and as a result the NOx generation quantity may be continuously maintained at a high level which greatly differs from the predetermined target value.

SUMMARY OF THE INVENTION

[0010] In view of the foregoing, an object of the present invention is to provide a control apparatus for an internal combustion engine which controls a controlled quantity (e.g., NOx) generated upon operation of the engine, and which can cause the actual value of the controlled quantity to accurately follow a target value when the engine is in a transition state.

[0011] A control apparatus for an internal combustion engine according to the present invention comprises operation state obtaining means, controlled quantity target value determination means, engine control parameter actual value obtaining means, engine control parameter steady-state adequate value obtaining means, engine control parameter target value determination means, and control means, wherein a quantity to be controlled (hereinafter referred to as "controlled quantity") is controlled such that the actual value of the controlled quantity approaches a target value of the controlled quantity. The respective means will be described individually.

[0012] The operation state obtaining means obtains operation state of the engine (e.g., engine speed, accelerator opening, load, etc.) by physically detecting the operation state by use of a sensor or estimating the operation state through a predetermined calculation.

[0013] The controlled quantity target value determination means determines the target value of the controlled quantity, which is generated upon operation of the engine, from the obtained operation state (and a table or a mathematical formula which defines the relation between the operation state and the controlled quantity target value). Examples of the controlled quantity include emission generation quantities (e.g., NOx generation quantity and PM generation quantity), CN quantity, and other quantities, which must be prevented from increasing with operation of the engine.

[0014] The engine control parameter actual value obtaining means obtains actual values of a plurality of engine control parameters (e.g., fuel injection timing, fuel injection pressure, and intake-gas oxygen concentration) which influence the actual value of the controlled quantity. With this means, the actual value of each of the engine control parameters is individually obtained through physical detection by use of a sensor or estimation through a predetermined calculation. Since the values of the engine control parameters affect the controlled quantity, a predetermined correlation is present between the controlled quantity and the engine control parameters. Accordingly, the controlled quantity can be represented by a predetermined mathematical formula (empirical formula, function), whose arguments are the respective values of the engine control parameters.

[0015] The engine control parameter steady-state adequate value obtaining means obtains, as engine control parameter steady-state adequate values, respective values of the engine control parameters on the basis of the obtained operation state, the values being necessary for rendering the actual value of the controlled quantity coincident with the controlled quantity target value when the engine is in a steady state in the obtained operation state . With this means, the respective steady-state adequate values of the engine control parameters which change depending on the operation state are individually obtained on the basis of the obtained operation state and through search of a previously prepared, predetermined table or in accordance with a previously prepared, predetermined mathematical formula or the like.

[0016] The engine control parameter target value determination means determines the target values of the engine control parameters which cause the actual value of the controlled quantity to approach the controlled quantity target value, and will be described later in detail. The control means individually (feedback) controls the engine control parameters such that the actual values of the engine control parameters approach the target values of the engine control parameters.

[0017] The engine control parameter target value determination means is configured to handle the engine control parameters while dividing them into a plurality of classes in accordance with response speed at the time when the engine control parameters are controlled by means of the control means. Specifically, the engine control parameters are divided into n classes, where n is at least 2 and not greater the number of the engine control parameters, and each class may contain a single engine control parameter, or two or more engine control parameters.

[0018] The engine control parameter target value determination means includes class-by-class engine control parameter value calculation means. The class-by-class engine control parameter value calculation means calculates, from the controlled quantity target value and the argument values regarding the engine control parameters other than an engine control parameter belonging to a class having the highest response speed (hereinafter referred to as the "fastest class engine control parameter"), at least a value of the fastest class engine control parameter which renders the actual value of the controlled quantity coincident with the controlled quantity target value when the actual values of the engine control parameters other than the fastest class engine control parameter are equal to the argument values.

[0019] Specifically, the class-by-class engine control parameter value calculation means can be obtained by substituting the controlled quantity target value, which is determined by means of the controlled quantity target value determination means, for the value (argument value) of the controlled quantity in a mathematical formula which can be obtained by solving the above-described, predetermined mathematical formula (empirical formula, function), which obtains the controlled quantity while using the values of the engine control parameters as arguments, with respect to the fastest class engine control parameter (in the case where a plurality of fastest class engine control parameters are present, each of the fastest class engine control parameters). In the class-by-class engine control parameter value calculation means obtained in this manner, when corresponding steady-state adequate values are used as the argument values regarding the engine control parameters other than the fastest class engine control parameter, the value of the fastest class engine control parameter calculated by this means coincides with the steady-state adequate value of the fastest class engine control parameter.

[0020] The engine control parameter target value determination means uses, as a target value of the fastest class engine control parameter, a value of the fastest class engine control parameter which the class-by-class engine control parameter value calculation means calculates while using corresponding engine control parameter actual values as (all) the argument values regarding the engine control parameters other than the fastest class engine control parameter. With this operation, the target value of the fastest class engine control parameter differs from the steady-state adequate value of the fastest class engine control parameter insofar as the actual values of the engine control parameters other than the fastest class engine control parameter differ from the corresponding steady-state adequate values.

[0021] As a result of the target value of the fastest class engine control parameter being set in this manner, under the assumption that the actual values of the engine control parameters other than the fastest class engine control parameter are maintained constant, the controlled quantity accurately coincides with (follows) the controlled quantity target value, when the actual value of the fastest class engine control parameter has reached the target value. Further, the response speed of the fastest class engine control parameter is naturally higher than those of the remaining engine control parameters. Therefore, when the engine is in a transition state, the controlled quantity can follow the controlled quantity target value at the response speed of the fastest class engine control parameter (or a response speed close to the response speed of the fastest class engine control parameter).

[0022] Meanwhile, the engine control parameter target value determination means uses, as target values of the engine control parameters other than the fastest class engine control parameter, values which are at least based on the steady-state adequate values of the engine control parameters (e.g., the steady-state adequate values themselves). Accordingly, in the case where the corresponding steady-state adequate values are always used as the target values of the engine control parameters other than the fastest class engine control parameter, when the engine returns from an excessive transition state to the steady state, the actual values of the engine control parameters other than the fastest class engine control parameter successively coincide with the corresponding target values (i.e., steady-state adequate values), from the highest response speed to the lowest response speed. At this time, over a period during which the transition state continues (that is, during a period in which the actual value of the engine control parameter having the lowest response speed does not coincide with the corresponding target value (steady-state adequate value), the controlled quantity continues to follow the controlled quantity target value at the response speed of the fastest class engine control parameter as described above.

[0023] As described above, when the control apparatus for an engine according to the present invention is employed, the controlled quantity (e.g., the NOx generation quantity) can follow the controlled quantity target value at the response speed of the fastest class engine control parameter, irrespective of the response speed of the engine control parameter having the lowest response speed. Therefore, even when the engine is in a transition state, the control apparatus can cause the actual value of the controlled quantity to accurately follow the target value.

[0024] In this case, preferably, the class-by-class engine control parameter value calculation means is configured to calculate, for each class of interest, a value of the engine control parameter belonging to the class of interest on the basis of the controlled quantity target value and the argument values regarding the engine control parameters other than the engine control parameter belonging to the class of interest, the value making the actual value of the controlled quantity coincident with the controlled quantity target value when the actual values of the engine control parameters other than the engine control parameter belonging to the class of interest are equal to the argument values.

[0025] Specifically, the means for calculating the above-mentioned value of the engine control parameter belonging to the class of interest can be obtained by substituting the controlled quantity target value, which is determined by means of the controlled quantity target value determination means, for the value (argument value) of the controlled quantity in a mathematical formula which can be obtained by solving the above-described, predetermined mathematical formula, which obtains the controlled quantity while using the values of the engine control parameters as arguments, with respect to the engine control parameter belonging to the class of interest (in the case where a plurality of engine control parameters belongs to the class of interest, each of the engine control parameters belonging to the class of interest). The above-mentioned class-by-class engine control parameter value calculation means can be obtained by successively changing the class of interest.

[0026] In the class-by-class engine control parameter value calculation means obtained in this manner, when corresponding steady-state adequate values are used as all the argument values regarding the engine control parameters other than the engine control parameter belonging to the class of interest, the value of the engine control parameter belonging to the class of interest calculated by this means coincides with the steady-state adequate value of the engine control parameter belonging to the class of interest.

[0027] Moreover, preferably, the engine control parameter target value determination means is configured to use, for each class of interest, as the target value of the engine control parameter belonging to the class of interest, a value of the engine control parameter belonging to the class of interest calculated by means of the class-by-class engine control parameter value calculation means which uses, as an argument value regarding the engine control parameter belonging to a class having a lower response speed than the class of interest, the corresponding engine control parameter actual value, and uses, as an argument value regarding the engine control parameter belonging to a class having a higher response speed than the class of interest, the corresponding engine control parameter steady-state adequate value.

[0028] By virtue of this configuration, the target value of the engine control parameter belonging to the class having the lowest response speed always coincides with the steady-state adequate value of the engine control parameter having the lowest response speed, and the target value of the engine control parameter belonging to the class of interest differs from the steady-state adequate value of the engine control parameter belonging to the class of interest insofar as the actual value of the engine control parameter belonging to a class which is lower in response speed than the class of interest differs from the corresponding steady-state adequate value. Notably, in this case as well, the value of the fastest class engine control parameter which the class-by-class engine control parameter value calculation means calculates while using corresponding engine control parameter actual values as (all) the argument values regarding the engine control parameters other than the fastest class engine control parameter is used as the target value of the fastest class engine control parameter. Accordingly, when the engine is in a transition state, the controlled quantity can always follow the controlled quantity target value at the response speed of the fastest class engine control parameter (or a response speed close to the response speed of the fastest class engine control parameter).

[0029] In addition, as a result of the target values of the engine control parameters other than the fastest class engine control parameter being set in the above-described manner, when the engine returns from an excessive transition state to the steady state, the target values of the engine control parameters successively coincide with the corresponding steady-state adequate values. Specifically, when the actual value of the engine control parameter belonging to the class having the lowest response speed becomes equal to the corresponding steady-state adequate value, the target value of the engine control parameter belonging to the class having the second lowest response speed coincides with the corresponding steady-state adequate value. After that, when the actual value of the engine control parameter belonging to the class having the second lowest response speed becomes equal to the corresponding steady-state adequate value, the target value of the engine control parameter belonging to the class having the third lowest response speed coincides with the corresponding steady-state adequate value.

[0030] That is, in this case, the target values (accordingly, the actual values) of the engine control parameters successively coincide with the steady-state adequate values from one having the lowest speed toward one having the highest speed. Accordingly, when the engine is returned from the transition state to the steady state, the target values of all the engine control parameters, excepting the engine control parameter belonging to the class having the lowest response speed, are changed from moment to moment. Since the all the engine control parameters, excepting the engine control parameter belonging to the class having the lowest response speed, substantially function so as to effect the control of causing the controlled quantity to always follow the controlled quantity target value at the response speed of the fastest class engine control parameter, the degree of freedom of the control increases.

[0031] In contrast, in the above-described "case where corresponding steady-state adequate values themselves are always used as the target values of the engine control parameters other than the fastest class engine control parameter," since the control of causing the controlled quantity to always follow the controlled quantity target value is performed at the response speed of the fastest class engine control parameter, only the fastest class engine control parameter substantially functions, and the degree of freedom of the control decreases in relative terms. That is, by virtue of the above-described configuration, the degree of freedom of the control increases as compared with the "case where corresponding steady-state adequate values themselves are always used as the target values of the engine control parameters other than the fastest class engine control parameter."

[0032] In the control apparatus for an internal combustion engine according to the present invention, when at least the generation quantity of an emission (NOx generation quantity, PM generation quantity, etc.) is contained in the controlled quantity, preferably, the controlled quantity target value determination means comprises requested acceleration degree index value obtaining means for obtaining a requested acceleration degree index value representing the degree of acceleration requested by a driver of the vehicle on which the engine is mounted; and correction means for correcting the determined controlled quantity target value in accordance with the requested acceleration degree index value to thereby determine a final controlled quantity target value to be used in place of the controlled quantity target value. The requested acceleration degree index value representing the degree of requested acceleration is, for example, change speed of accelerator operation amount (opening), and may be corrected in accordance with, for example, the operation state of the engine.

[0033] In general, as the generation amount of an emission, such as NOx, PM, which is generated upon operation of the engine is controlled to a smaller value, the response of the engine tends to decrease. Meanwhile, the greater degree of acceleration requested by the driver means that higher response is demanded by the driver. That is, in the case where the emission generation amount is always controlled to a predetermined small target value, a sufficient degree of response cannot be obtained when the degree of acceleration requested by the driver is high, whereby drivability deteriorates.

[0034] In view of the above, the controlled quantity target value determined from the operation state of the engine as described above is corrected in accordance with the requested acceleration degree index value (e.g., accelerator opening change speed) so as to determine the final controlled quantity target value. Thus, the controlled quantity target value (i.e., emission generation quantity target value) can be corrected to a greater value in accordance with, for example, accelerator opening change speed. Accordingly, the controlled quantity target value (emission generation quantity target value) can be set in consideration of response intended by the driver, whereby the above-mentioned deterioration in drivability can be suppressed.

[0035] In this case, preferably, the controlled quantity target value determination means comprises transition degree index value obtaining means for obtaining a transition degree index value representing the degree of transition in the operation state of the engine; and the correction means is configured to correct the determined controlled quantity target value in accordance with the transition degree index value to thereby determine the final controlled quantity target value. An example of the transition degree index value representing the degree of transition in the operation state of the engine is a value based on the deviation of the actual value from the steady-state adequate value of the intake air quantity taken into a cylinder per intake stroke.

[0036] In general, as the degree of transition in the operation state of the engine decreases, the response tends to increase. Accordingly, in the case where the degree of transition in the operation state of the engine is sufficiently small, even when the degree of acceleration requested by the driver is large, the drivability can be secured without correction (setting) of the target value of the emission generation quantity to a largish value.

[0037] On the basis of the above knowledge, the control apparatus is configured such that the controlled quantity target value, which has been determined on the basis of the operation state of the engine and corrected in accordance with the requested acceleration degree index value, is corrected in accordance with the transition degree index value so as to obtain the final controlled quantity target value. Thus, the degree of correction in accordance with the requested acceleration degree index value can be reduced in accordance with the degree of transition in the operation state of the engine. Accordingly, the controlled quantity target value (emission generation quantity target value) is prevented from being unnecessarily corrected to a largish value, whereby the emission generation quantity can be further reduced.

[0038] In the case where the control apparatus according to the present invention is configured to control a plurality of controlled quantities (e.g., NOx generation quantity, PM generation quantity, CN quantity, etc.) so that the actual values of the controlled quantities approach corresponding controlled quantity target values, preferably, the correction means comprises correction ratio determination means for determining, for each of the controlled quantity target values, a ratio of degree of the correction in accordance the operation state of the engine, and determines, for each controlled quantity, the degree of correction of the corresponding controlled quantity target value on the basis of the determined ratio.

[0039] Examples of the operation state of the engine for determining a ratio of degree of the correction include the temperature of cooling water of the engine, the state (PM accumulation amount, NOx accumulation amount, etc.) of a catalyst interposed in the exhaust passage of the engine, and the requested acceleration degree index value representing the degree of acceleration requested by the driver of the vehicle.

[0040] Even when the controlled quantity target value is corrected in accordance with the degree of acceleration requested by the driver, depending on the operation state of the engine, the degree of correction must be changed among the plurality of controlled quantity target values. For example, in the case where the PM generation quantity is contained as one of the controlled quantities and the operation state of the engine is such that a large amount of PM has accumulated in the catalyst, the PM generation quantity must be controlled to a smallish value so as to protect the catalyst.

[0041] Accordingly, when the control apparatus is configured as described above such that, for each controlled quantity, the degree of correction of the corresponding controlled quantity target value is determined on the basis of the corresponding ratio of the degree of correction determined on the basis of the operation state of the engine, a plurality of more proper controlled quantity target values can be individually set in accordance with the operation state of the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042]

FIG. 1 a schematic diagram showing the overall configuration of a system in which an engine control apparatus according to an embodiment of the present invention is applied to a four-cylinder internal combustion engine (diesel engine);

FIG. 2 is a functional block diagram of the CPU shown in FIG. 1 when the CPU obtains a deterioration ratio distribution coefficient for each emission;

FIG. 3 shows time charts showing example changes in accelerator opening, accelerator opening change speed absolute value, and a response coefficient which is calculated by means of the response coefficient obtaining means shown in FIG. 2;

FIG. 4 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to obtain engine control parameter actual values, steady-state adequate values, etc.;

FIG. 5 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to obtain a response coefficient;

FIG. 6 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to obtain deterioration ratios of the controlled quantities;

FIG. 7 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to calculate respective target values of the engine control parameters;

FIG. 8 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to control the manner of fuel injection;

FIG. 9 is a table to which the CPU shown in FIG. 1 refers when it executes the routine of FIG. 8;

FIG. 10 is a flowchart showing a routine which the CPU shown in FIG. 1 executes so as to control the engine control parameters.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0043] A control apparatus for an internal combustion engine (diesel engine) according to an embodiment of the present invention will be described with reference to the drawings.

[0044] FIG. 1 schematically shows the overall configuration of a system in which such an engine control apparatus is applied to a four-cylinder internal combustion engine (diesel engine) 10. This system comprises an engine main body 20 including a fuel supply system; an intake system 30 for introducing gas to combustion chambers (cylinder interiors) of individual cylinders of the engine main body 20; an exhaust system 40 for discharging exhaust gas from the engine main body 20; an EGR apparatus 50 for performing exhaust circulation; and an electronic control apparatus 60.

[0045] Fuel injection valves (injection valves, injectors) 21 are disposed above the individual cylinders of the engine main body 20. The fuel injection valves 21 are connected via a fuel line 23 to a fuel injection pump 22 connected to an unillustrated fuel tank. The fuel injection pump 22 is electrically connected to the electronic control apparatus 60. In accordance with a drive signal from the electronic control apparatus 60, the fuel injection pump 22 pressurizes fuel in such a manner that the actual injection pressure (discharge pressure) Pcr of fuel becomes equal to a fuel injection pressure target value Pcrt, which will be described later.

[0046] Thus, fuel pressurized to the fuel injection pressure target value Pcrt is supplied from the fuel injection pump 22 to the fuel injection valves 21. Moreover, the fuel injection valves 21 are electrically connected to the electronic control apparatus 60. In accordance with a drive signal from the electronic control apparatus 60, each of the fuel injection valves 21 opens for a predetermined period of time so as to inject a predetermined amount of fuel directly to the combustion chamber of the corresponding cylinder. In the present embodiment, a predetermined amount of fuel is injected portionwise into a cylinder to which fuel is to be injected (hereinafter referred to as a "fuel injection cylinder") in two stages. The injection in the first stage is called "pilot injection," and the injection in the second stage is called "main injection."

[0047] The intake system 30 includes an intake manifold 31, which is connected to the respective combustion chambers of the individual cylinders of the engine main body 20; an intake pipe 32, which is connected to an upstream-side branching portion of the intake manifold 31 and constitutes an intake passage in cooperation with the intake manifold

31; a throttle valve 33, which is rotatably held within the intake pipe 32; a throttle valve actuator 33a for rotating the throttle valve 33 in accordance with a drive signal from the electronic control apparatus 60; an intercooler 34, which is interposed in the intake pipe 32 to be located on the upstream side of the throttle valve 33; a compressor 35a of a turbocharger 35, which is interposed in the intake pipe 32 to be located on the upstream side of the intercooler 34; and an air cleaner 36, which is disposed at a distal end portion of the intake pipe 32.

[0048] The exhaust system 40 includes an exhaust manifold 41, which is connected to the individual cylinders of the engine main body 20; an exhaust pipe 42, which is connected to a downstream-side merging portion of the exhaust manifold 41; a turbine 35b of the turbocharger 35 interposed in the exhaust pipe 42; and a diesel particulate filter (catalyst, hereinafter referred to as "DPNR") 43, which is interposed in the exhaust pipe 42. The exhaust manifold 41 and the exhaust pipe 42 constitute an exhaust passage.

[0049] The DPNR 43 is a filter unit which accommodates a filter 43a formed of a porous material such as cordierite and which collects, by means of a porous surface, the particulate matter contained in exhaust gas passing through the filter. In the DPNR 43, at least one metal element selected from alkaline metals such as potassium K, sodium Na, lithium Li, and cesium Cs; alkaline-earth metals such as barium Ba and calcium Ca; and rare-earth metals such as lanthanum La and yttrium Y is carried, together with platinum, on alumina serving as a carrier. Thus, the DPNR 43 also serves as a storage-reduction-type NOx catalyst unit which, after absorption of NOx, releases the absorbed NOx and reduces it.

[0050] The EGR apparatus 50 includes an exhaust circulation pipe 51, which forms a passage (EGR passage) for circulation of exhaust gas; an EGR control valve 52, which is interposed in the exhaust circulation pipe 51; and an EGR cooler 53. The exhaust circulation pipe 51 establishes communication between an exhaust passage (the exhaust manifold 41) located on the upstream side of the turbine 35b, and an intake passage (the intake manifold 31) located on the downstream side of the throttle valve 33. The EGR control valve 52 responds to a drive signal from the electronic control apparatus 60 so as to change the quantity of exhaust gas to be circulated (exhaust-gas circulation quantity, EGR-gas flow rate).

[0051] The electronic control apparatus 60 is a microcomputer which includes a CPU 61, ROM 62, RAM 63, backup RAM 64, an interface 65, etc., which are connected to one another by means of a bus. The ROM 62 stores a program to be executed by the CPU 61, tables (lookup tables, maps), constants, etc. The RAM 63 allows the CPU 61 to temporarily store data when necessary. The backup RAM 64 stores data in a state in which the power supply is on, and holds the stored data even after the power supply is shut off. The interface 65 contains A/D converters.

[0052] The interface 65 is connected to a hot-wire-type airflow meter 71, which serves as air flow rate (new air flow rate) measurement means, and is disposed in the intake pipe 32; an intake gas temperature sensor 72, which is provided in the intake passage to be located downstream of the throttle valve 33 and downstream of a point where the exhaust circulation pipe 51 is connected to the intake passage; an intake pipe pressure sensor 73, which is provided in the intake passage to be located downstream of the throttle valve 33 and downstream of the point where the exhaust circulation pipe 51 is connected to the intake passage; a crank position sensor 74; an accelerator opening sensor 75; an intake-gas oxygen concentration sensor 76 provided in the intake passage to be located downstream of the throttle valve 33 and downstream of the point where the exhaust circulation pipe 51 is connected to the intake passage; a fuel injection pressure sensor 77 provided in the fuel pipe 23 to be located in the vicinity of the discharge port of the fuel injection pump 22; a water temperature sensor 78; a catalyst upstream pressure sensor 79 provided in the exhaust passage on the upstream side of the DPNR 43; and a catalyst downstream pressure sensor 81 provided in the exhaust passage on the downstream side of the DPNR 43. The interface 65 receives respective signals from these sensors, and supplies the received signals to the CPU 61. Further, the interface 65 is connected to the fuel injection valves 21, the fuel injection pump 22, the throttle valve actuator 33a, the EGR control valve 52, and an unillustrated radiator flow rate control valve for controlling the flow rate of cooling water flowing through an unillustrated radiator; and outputs corresponding drive signals to these components in accordance with instructions from the CPU 61.

[0053] The hot-wire-type airflow meter 71 measures the mass flow rate of intake air (new air) passing through the intake passage (intake new air quantity per unit time), and generates a signal indicating the mass flow rate Ga (intake new air flow rate Ga). The intake gas temperature sensor 72 detects the temperature of intake gas, and generates a signal representing the intake gas temperature Tb. The intake pipe pressure sensor 73 measures the pressure of intake gas (i.e., intake pipe pressure), and generates a signal representing the intake pipe pressure Pb.

[0054] The crank position sensor 74 detects the absolute crank angle of each cylinder, and generates a signal representing the crank angle CA and engine speed NE; i.e., rotational speed of the engine 10. The accelerator opening sensor 75 detects an amount by which an accelerator pedal AP is operated, and generates a signal representing the accelerator pedal operated amount (opening) Accp. The intake-gas oxygen concentration sensor 76 detects the oxygen concentration of intake gas (i.e., intake-gas oxygen concentration), and a signal representing intake-gas oxygen concentration RO2in.

[0055] The fuel injection pressure sensor 77 detects the pressure of fuel within the fuel pipe 23 (fuel injection pressure), and generates a signal representing the fuel injection pressure Pcr. The water temperature sensor 78 detects the temperature of cooling water, and generates a signal representing the cooling water temperature THW. The catalyst upstream pressure sensor 79 detects the pressure of exhaust gas in the exhaust passage on the upstream side of the DPNR 43, and generates a signal representing the catalyst upstream exhaust pressure Pup. The catalyst downstream pressure sensor 81 detects the pressure of exhaust gas in the exhaust passage on the downstream side of the DPNR 43, and generates a signal representing the catalyst downstream exhaust pressure Pdown.

Outline of Control of Controlled Quantities

[0056] Next, there will be described an outline of control of controlled quantities performed by the engine control apparatus having the above-described configuration (hereinafter may be referred to as the "present apparatus"). In the present embodiment, the controlled quantities generated upon operation of the engine 10 include a NOx generation quantity, a PM generation quantity, and a CN quantity, which must be prevented from increasing with the operation of the engine 10. Accordingly, the present apparatus feedback-controls the NOx generation quantity, the PM generation quantity, and the CN quantity such that the NOx generation quantity actual value NOxa, the PM generation quantity actual value PMa, and the CN quantity actual value CNa approach an NOx generation quantity (final) target value NOxt, a PM generation quantity (final) target value PMt, and a CN quantity (final) target value CNt, respectively, which are set in a manner as described below. This feedback control will be described below in more detail. Notably, in the present embodiment, not only NOx and PM, but also CN may be called "emissions."

[0057] The NOx generation quantity, the PM generation quantity, and the CN quantity (hereinafter, these may be collectively referred to as the "emission generation quantities") are greatly influenced by various parameters which are necessary for control of the engine 10 (engine control parameters). That is, a certain correlation is present between the actual value of each emission generation quantity and the actual values of the engine control parameters. Therefore, in order to perform feedback control of the emission generation quantities, target values of the engine control parameters for causing the emission generation quantity actual values to approach the emission generation quantity target values are individually obtained in a manner as described below; and the engine control parameters are feedback-controlled such that the actual values of engine control parameters approach the corresponding target values.

[0058] In the present embodiment, the engine control parameters (actual values thereof) subjected to the above-described feedback control include pilot fuel injection start timing (crank angle) Aig, injection interval (crank angle) Aint between pilot fuel injection start timing and main fuel injection start timing, pilot injection quantity qfinp, the above-mentioned fuel injection pressure Pcr, the above-mentioned intake-gas oxygen concentration RO2in, intake air quantity per intake stroke Gcyl, and the above-mentioned cooling water temperature THW.

<Method of Obtaining Target Values of Engine Control Parameters>

[0059] Now, a method of obtaining target values Aigt, Aintt, qfinpt, Pcrt, RO2int, Gcylt, and THWt of the above-mentioned seven engine control parameters will be described. As described above, a certain correlation is present between the actual values of emission generation quantities and the actual values of the engine control parameters. Therefore, the actual values of the emission generation quantities can be represented by predetermined mathematical formulas (experimental formulas, predetermined functions) whose arguments are respective actual values of the engine control parameters; i.e., by the following Equations (1) to (3). In Equations (1) to (3), f, g, and h are functions which use the actual values of the engine control parameters as arguments so as to obtain the NOx generation quantity actual value NOxa, the PM generation quantity actual value PMa, and the CN quantity actual value CNa per unit quantity of injected fuel and per combustion cycle.

$$NOxa = f(Aig, Aint, qfinp, Pcr, RO2in, Gcyl, THW) \tag{1}$$

$$PMa = g(Aig, Aint, qfinp, Pcr, RO2in, Gcyl, THW) \tag{2}$$

$$CNa = h(Aig, Aint, qfinp, Pcr, RO2in, Gcyl, THW) \tag{3}$$

[0060] The present apparatus handles the above-mentioned seven engine control parameters while dividing them into five classes in terms of response speed (speed at which an actual value follows a target value in feedback control). Now, the response speeds of the seven engine control parameters will be considered. First, control of the pilot fuel injection start timing Aig, control of the injection interval Aint, and control of the pilot injection quantity qfinp are accomplished through control of the fuel injection valve 21, and their target values (i.e., instruction values) can be considered to be their actual values. Therefore, these three parameters have similar, considerably high response speeds.

[0061] Control of the fuel injection pressure Pcr is accomplished through control of the discharge pressure of the fuel injection pump 22. Control of the intake-gas oxygen concentration RO2in is accomplished through control of the EGR control valve 52. Control of the intake air quantity Gcyl is accomplished through control of the throttle valve actuator 33a. Control of the cooling water temperature THW is accomplished through control of the radiator flow rate control valve. The order of these four parameters from highest response speed to lowest response speed is generally such that the fuel injection pressure Pcr → the intake-gas oxygen concentration RO2in → the intake air quantity Gcyl → the cooling water temperature THW.

[0062] In view of the above, the engine control parameters belonging to the five classes will be called parameters Lv1 to Lv5, in descending order of response speed. The present apparatus selects the pilot fuel injection start timing Aig, the injection interval Aint, and the pilot injection quantity qfinp as parameters Lv1, and selects the fuel injection pressure Pcr, the intake-gas oxygen concentration RO2in, the intake air quantity Gcyl, and the cooling water temperature THW as parameters Lv2 to Lv5, respectively.

[0063] The pilot fuel injection start timing (actual value) Aig, the injection interval (actual value) Aint, and the pilot injection quantity (actual value) qfinp, which are the parameters Lv1, can be obtained from the combination of Equations (1) to (3), and can be represented by the following Equations (4) to (6) by use of functions p, q, and r, whose arguments are the NOx generation quantity actual value NOxa, the PM generation quantity actual value PMa, the CN quantity actual value CNa, and the actual values of the parameters Lv2 to Lv5.

$$Aig = p(NOxa, PMa, CNa, Pcr, RO2in, Gcyl, THW) \tag{4}$$

$$Aint = q(NOxa, PMa, CNa, Pcr, RO2in, Gcyl, THW) \tag{5}$$

$$qfinp = r(NOxa, PMa, CNa, Pcr, RO2in, Gcyl, THW) \tag{6}$$

[0064] The fuel injection pressure (actual value) Pcr, which is the parameter Lv2, can be obtained by solving Equation (1) for the fuel injection pressure Pcr, and can be represented by the following Equation (7) by use of a function s, whose arguments are the NOx generation quantity actual value NOxa and the actual values of the parameters Lv1, Lv3, Lv4, and Lv5.

$$Pcr = s(NOxa, Aig, Aint, qfinp, RO2in, Gcyl, THW) \tag{7}$$

[0065] The intake-gas oxygen concentration (actual value) RO2in, which is the parameter Lv3, can be obtained by solving Equation (1) for the intake-gas oxygen concentration RO2in, and can be represented by the following Equation (8) by use of a function t, whose arguments are the NOx generation quantity actual value NOxa and the actual values of the parameters Lv1, Lv2, Lv4, and Lv5.

$$RO2in = t(NOxa, Aig, Aint, qfinp, Pcr, Gcyl, THW) \tag{8}$$

[0066] The intake air quantity (actual value) Gcyl, which is the parameter Lv4, can be obtained by solving Equation (1) for the intake air quantity Gcyl, and can be represented by the following Equation (9) by use of a function u, whose arguments are the NOx generation quantity actual value NOxa and the actual values of the parameters Lv1, Lv2, Lv3, and Lv5.

$$Gcyl = u(NOxa, Aig, Aint, qfinp, Pcr, RO2in, THW) \tag{9}$$

[0067] The cooling water temperature (actual value) THW, which is the parameter Lv5, can be obtained by solving Equation (1) for the cooling water temperature THW, and can be represented by the following Equation (10) by use of a function v, whose arguments are the NOx generation quantity actual value NOxa and the actual values of the parameters Lv1, Lv2, Lv3, and Lv4.

$$THW = v(NOxa, Aig, Aint, qfinp, Pcr, RO2in, Gcyl) \quad (10)$$

[0068] When the NOx generation quantity actual value NOxa, the PM generation quantity actual value PMa, and the CN quantity actual value CNa in the above-described equations (4) to (10) are replaced with the NOx generation quantity target value NOxt, the PM generation quantity target value PMt, and the CN quantity target value CNt, the following Equations (11) to (17) can be obtained.

$$Aigc = p(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (11)$$

$$Aintc = q(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (12)$$

$$qfinpc = r(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (13)$$

$$Pcrc = s(NOxt, Aig, Aint, qfinp, RO2in, Gcyl, THW) \quad (14)$$

$$RO2inc = t(NOxt, Aig, Aint, qfinp, Pcr, Gcyl, THW) \quad (15)$$

$$Gcylc = u(NOxt, Aig, Aint, qfinp, Pcr, RO2in, THW) \quad (16)$$

$$THWc = v(NOxt, Aig, Aint, qfinp, Pcr, RO2in, Gcyl) \quad (17)$$

[0069] Each of the values Aigc, Aintc, qfinpc, Pcrc, RO2inc, Gcylc, and THWc calculated by Equations (11) to (17) is a value obtained from the emission generation quantity target value(s), and argument values regarding engine control parameters other than the engine control parameter(s) belonging to the class of interest, and serves as a value of the engine control parameter belonging to the class of interest for making the emission generation quantity actual value coincident with the emission generation quantity target value when the actual values of the engine control parameters other than the engine control parameter(s) belonging to the class of interest are equal to the argument values. That is, Equations (11) to (17) correspond to the class-by-class engine control parameter value calculation means.

[0070] Subsequently, the present apparatus successively obtains the target values Aigt, Aintt, qfinpt, Pert, RO2int, Gcylt, and THWt of the above-described seven engine control parameters in accordance with the following Equations (18) to (24), which are obtained from Equations (11) to (17) by using the actual values (Aig, Aint, qfinp,) Pcr, RO2in, Gcyl, and THW as they are as the argument values for the engine control parameters belonging to class(es) lower in response speed than a class of interest, and using steady-state adequate values AigTA, AintTA, qfinpTA, PcrTA, R02inTA, GcylTA (and THWTA) as the argument values regarding the engine control parameters belonging to class (es) higher in response speed than the class of interest. According, in particular, the target values Aigt, Aintt, and qfinpt of the parameters Lv1 can be obtained from the actual values of the parameters Lv2 to Lv5, as can be understood from Equations (18) to (20); and the target value THWt of the parameter Lv5 can be obtained from the steady-state adequate values of the parameters Lv1 to Lv4, as can be understood from Equation (24).

$$Aigt = p(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (18)$$

$$Aintt = q(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (19)$$

$$qfinpt = r(NOxt, PMt, CNt, Pcr, RO2in, Gcyl, THW) \quad (20)$$

$$Pcrt = s(NOxt, AigTA, AintTA, qfinpTA, RO2in, Gcyl, THW) \quad (21)$$

$$\mathrm{RO2int} = t(\mathrm{NOxt}, \mathrm{AigTA}, \mathrm{AintTA}, \mathrm{qfinpTA}, \mathrm{PcrTA}, \mathrm{Gcyl}, \mathrm{THW}) \qquad (22)$$

$$\mathrm{Gcylt} = u(\mathrm{NOxt}, \mathrm{AigTA}, \mathrm{AintTA}, \mathrm{qfinpTA}, \mathrm{PcrTA}, \mathrm{R02inTA}, \mathrm{THW}) \qquad (23)$$

$$\mathrm{THWt} = v(\mathrm{NOxt}, \mathrm{AigTA}, \mathrm{AintTA}, \mathrm{qfinpTA}, \mathrm{PcrTA}, \mathrm{RO2inTA}, \mathrm{GcylTA}) \qquad (24)$$

[0071] The engine control parameter steady-state adequate values can be obtained as follows. As described previously, a predetermined correlation exists between the actual value of each emission generation quantity and the actual values of the engine control parameters. Accordingly, there can be performed an experiment in which the operation state of the engine 10 is successively changed to and maintained in a plurality of steady states, and in each steady state, there are determined the optimal values (the optimal combination of values) of the engine control parameters required for making the emission generation quantity actual values NOxa, PMa, and CNa coincident with the above-mentioned target values NOxt, PMt, and CNt corresponding to the steady state are determined. Adequate values which are determined in accordance with the operation condition of the engine 10 through such an experiment or the like serve as engine control parameters steady-state adequate values.

[0072] Accordingly, through performance of the above-described experiment or the like, a table (map) which represents the correlation between the operation state of the engine 10 and the engine control parameters steady-state adequate values can be obtained. In the present apparatus, a previously formed table which defines the relation between a load index value LOAD of the engine 10, which is one operation state of the engine 10, and the above-described seven engine control parameters steady-state adequate values AigTA, AintTA, qfinpTA, PcrTA, R02inTA, GcylTA, and THWTA is stored in the ROM 62 for each engine control parameter. The load index value LOAD represents the degree of load of the engine 10, and can be determined on the basis of engine speed NE, accelerator opening Accp, etc.

[0073] Therefore, when the load index value LOAD of the engine 10 is iteratively obtained, the seven engine control parameters steady-state adequate values are successively obtained with reference to the respective tables. The means which obtains the seven engine control parameters steady-state adequate values in this manner corresponds to the engine control parameters steady-state adequate value obtaining means. Further, the means which obtains the load index value LOAD of the engine 10 corresponds to the operation state obtaining means.

[0074] As described above, among the actual values of the seven engine control parameters, the actual values of the pilot fuel injection start timing Aig, the injection interval Aint, and the pilot injection quantity qfinp are the same as the corresponding instruction values. Therefore, the actual values of these three engine control parameters can be obtained from the corresponding instruction values. The fuel injection pressure actual value Pcr, the intake-gas oxygen concentration actual value R02in, and the cooling water temperature actual value THW can be detected by means of the fuel injection pressure sensor 77, the intake-gas oxygen concentration sensor 76, and the water temperature sensor 78, respectively, as described above.

[0075] The intake air quantity actual value Gcyl can be obtained in accordance with Equation (25), which is based on the state equation of gas at the time when an unillustrated piston has reached compression bottom dead center (hereinafter referred to as "ATDC-180°").

$$\mathrm{Gcyl} = (\mathrm{Pa0}\cdot\mathrm{Va0})/(\mathrm{R}\cdot\mathrm{Ta0}) \qquad (25)$$

[0076] In Equation (25), Pa0 is bottom-dead-center cylinder interior gas pressure; i.e., cylinder interior gas pressure at ATDC-180°. At ATDC-180°, the cylinder interior gas pressure is considered to be substantially equal to the intake pipe pressure Pb. Therefore, the bottom-dead-center cylinder interior gas pressure Pa0 can be obtained from the intake pipe pressure Pb detected by means of the intake pipe pressure sensor 73 at ATDC-180°. Va0 is bottom-dead-center combustion chamber volume; i.e., combustion chamber volume at ATDC-180°. The combustion chamber volume Va can be represented as a function of the crank angle CA on the basis of the design specifications of the engine 10. Therefore, the bottom-dead-center combustion chamber volume Va0 can be obtained on the basis of the function. Ta0 is bottom-dead-center cylinder interior gas temperature; i.e., cylinder interior gas temperature at ATDC-180°. At ATDC-180°, the cylinder interior gas temperature is considered to be substantially equal to the intake gas temperature Tb. Therefore, the bottom-dead-center cylinder interior gas temperature Ta0 can be obtained from the intake gas temperature Tb detected by means of the intake gas temperature sensor 72 at ATDC-180°. R is the gas constant of the cylinder interior gas. In the above-described manner, the actual values of the seven engine control parameters can be obtained. The means which obtains the actual values of the seven engine control parameters corresponds to the engine control parameter actual value obtaining means.

[0077] By virtue of the above operation, steady-state adequate values and actual values can be successively obtained for all the seven engine control parameters. Accordingly, the present apparatus can successively obtain the target values Aigt, Aintt, qfinpt, Pcrt, RO2int, Gcylt, and THWt of the seven engine control parameters in accordance with the above-described Equations (18) to (24) by iteratively obtaining the load index value LOAD of the engine 10, and using the NOx generation quantity target value NOxt, the PM generation quantity target value PMt, and the CN quantity target value CNt, which are determined and obtained as described below. That is, the above-described Equations (18) to (24) correspond to the engine control parameter target value determination means.

[0078] Subsequently, the present apparatus controls the fuel injection valve 21, the fuel injection pump 22, the EGR control valve 52, the throttle valve actuator 33a, and the radiator flow rate control valve, respectively, such that the actual values Aig, Aint, qfinp, Pcr, RO2in, Gcyl, and THW of the seven engine control parameters approach (coincide with) the corresponding target values Aigt, Aintt, qfinpt, Pcrt, RO2int, Gcylt, and THWt. The means which controls the seven engine control parameters in this manner corresponds to the control means.

[0079] Next, operation for obtaining the target values of the seven engine control parameters according to the above-described Equations (18) to (24) will be described. In Equations (18) to (24), when all the argument values regarding the engine control parameters coincide with the corresponding steady-state adequate values, all the target values obtained from Equations (18) to (24) coincide with the corresponding steady-state adequate values. In other words, as can be understood from Equation (24), the target value THWt of the parameter Lv5 belonging to the class of the lowest response speed always coincides with the steady-state adequate value THWTA.
Also, as can be understood from Equations (18) to (23), each of the target values of the parameters Lv1 to Lv4 assumes a value which differs from the corresponding steady-state adequate value insofar as the actual value(s) of an engine control parameter(s) belonging to class(es) which is lower in response speed than the corresponding class differs from the corresponding steady-state adequate value.

[0080] The respective target values of the engine control parameters are set in this manner; therefore, in the case where the engine 10 returns from an excessive transition state to the steady state, when the actual value THW of the parameter Lv5 belonging to the class having the lowest response speed coincides with the steady-state adequate value THWTA, the target value Gcylt of the parameter Lv4 coincides with the corresponding steady-state adequate value GcylTA. Subsequently, when the actual value Gcyl of the parameter Lv4 coincides with the steady-state adequate value GcylTA, the target value RO2int of the parameter Lv3 coincides with the corresponding steady-state adequate value R02inTA. Subsequently, when the actual value R02in of the parameter Lv3 coincides with the steady-state adequate value RO2inTA, the target value Pcrt of the parameter Lv2 coincides with the corresponding steady-state adequate value PcrTA.
When the actual value Pcr of the parameter Lv2 coincides with the steady-state adequate value PcrTA, the target values Aigt, Aintt, qfinpt of the parameters Lv1 coincide with the corresponding steady-state adequate values AigTA, AintTA, qfinpTA, respectively. After that, when the actual values Aig, Aint, qfinp of the parameters Lv1 coincide with the steady-state adequate values AigTA, AintTA, qfinpTA, respectively, the transition state ends, and the engine 10 returns to the steady state.

[0081] Specifically, in this case, the target values (accordingly, actual values) of the engine control parameters successively coincide with the corresponding steady-state adequate values, from the parameter Lv5 to the parameters Lv1. Accordingly, when the engine 10 is returned from the transition state to the steady state, the target values of all the engine control parameters, excepting the parameter Lv5, are changed from moment to moment.

[0082] Moreover, under the assumption that the actual values of the parameters Lv2 to Lv5; i.e., all the engine control parameters, excepting the parameter Lv1, are maintained constant in the above-mentioned transition state, as can be understood from Equations (18) to (20), the actual values of the emission generation quantities accurately coincide with (follow) the corresponding target values, respectively, when the actual values of the parameters Lv1 have reached the corresponding target values. Further, the response speed of the parameters Lv1 is naturally higher than these of other parameters Lv2 to Lv5. Therefore, when the engine 10 is in a transition state (that is, the actual values of the engine control parameters differ from the steady-state adequate values), the emission generation quantity actual values NOxa, PMa, and CNa can follow the emission generation quantity target values NOxt, PMt, and CNt, respectively, at the response speed of the parameters Lv1 (or a response speed close to the response speed of the parameters Lv1).

[0083] In order to perform the control of causing the emission generation quantity actual values to follow the emission generation quantity target values at the response speed of the parameters Lv1, all the engine control parameters other than the parameter Lv5 function substantially. Therefore, the degree of freedom of control increases. The above is the outline of the method of obtaining the target values of the engine control parameters, and feedback control of the engine control parameters.

<Method for Obtaining Target Values of Emission Generation Quantities>

[0084] Next, a method for obtaining the emission generation quantity target values NOxt, PMt, and CNt will be described. As described previously, in principle, the emission generation quantity target values are determined in accordance with the operation state of the engine 10. In the present apparatus, a previously formed table which defines the relation between the above-mentioned load index value LOAD, representing the operation state of the engine 10, and the emission generation quantity base target values NOxtbase, PMtbase, and CNtbase, which are respective base values of the emission generation quantity target values, is stored in the ROM 62 for the individual emissions. The present apparatus iteratively obtains the load index value LOAD of the engine 10, and successively determines the emission generation quantity base target values NOxtbase, PMtbase, and CNtbase with reference to the corresponding tables.

[0085] As described previously, in order to suppress deterioration in drivability, which would otherwise be caused by deterioration in response of the engine 10, the emission generation quantity target values must be corrected in accordance with the degree of acceleration requested by the driver and the degree of transition in the operation state of the engine 10. Moreover, depending on the operation state of the engine 10, the degree of such correction must be changed on an emission-by-emission basis.

[0086] In view of the above, the present apparatus iteratively obtains deterioration ratios, each representing a degree of correction, (an NOx deterioration ratio KNOx, a PM deterioration ratio KPM, and a CN deterioration ratio KCN) for the individual emissions in a manner as described later, and successively determines emission generation quantity final target values NOxt, PMt, and CNt, which are the final values of the emission generation quantity target values. The means which corrects the emission generation quantity base target values in accordance with the following Equations (26) to (28) corresponds to the correction means, and the means which determines the emission generation quantity final target values in accordance with the following Equations (26) to (28) corresponds to the controlled quantity target value determination means.

$$\mathrm{NOxt} = \mathrm{NOxtbase}(1 + \mathrm{KNOx}) \qquad (26)$$

$$\mathrm{PMt} = \mathrm{PMtbase}(1 + \mathrm{KPM}) \qquad (27)$$

$$\mathrm{CNt} = \mathrm{CNtbase}(1 + \mathrm{KCN}) \qquad (28)$$

[0087] Now, a method for obtaining the NOx deterioration ratio KNOx, the PM deterioration ratio KPM, and the CN deterioration ratio KCN will be described with reference to FIG. 2, which is a functional block diagram of the present apparatus when it obtains the respective deterioration ratios. As shown in FIG. 2, the present apparatus obtains the emission deterioration ratios by use of means A1 to A13. These means will be described individually.

[0088] First, at computation intervals, accelerator opening change speed obtaining means A1 obtains the accelerator opening (current value) Accp from the accelerator opening sensor 75, and calculates an accelerator opening change speed dAccp/dt, which is the first derivative of the accelerator opening Accp with respect to time, in accordance with the following Equation (29). In Equation (29), Accpb represents the accelerator opening (previous value) obtained at the previous computation time, and Δt represents the computation intervals.

$$\mathrm{dAccp/dt} = (\mathrm{Accp} - \mathrm{Accpb})/\Delta t \qquad (29)$$

[0089] Response coefficient obtaining means A2 obtains, at the computation intervals, a response coefficient (current value) Res, which serves as a requested acceleration degree index value representing the degree of acceleration requested by the driver, from the accelerator opening Accp and the latest accelerator opening change speed dAccp/dt obtained by means of the accelerator opening change speed obtaining means A1. Specifically, the response coefficient obtaining means A2 calculates the response coefficient Res in accordance with the following Equation (30).

$$\mathrm{Res} = \mathrm{Resbase} + \mathrm{Reshis} \qquad (30)$$

[0090] In Equation (30), Resbase represents a response coefficient base quantity, and Reshis represents a response coefficient historical quantity. In principle, the response coefficient base quantity Resbase is calculated in accordance with the following Equation (31). In Equation (31), Kres represents a positive proportionality constant. Therefore, in principle, the response coefficient base quantity Resbase is calculated as a value which is in proportion to the accelerator opening change speed absolute value |dAccp/dt|.

$$\text{Resbase} = \text{Kres} \cdot |\text{dAccp/dt}| \tag{31}$$

[0091] In principle, the response coefficient historical quantity Reshis is calculated in accordance with the following Equation (32) on the basis of a response coefficient previous value Resb calculated in the previous computation time in accordance with Equation (30). In Equation (32), grad represents a monotonously increasing function for obtaining a historical gradient, and the greater the value of the response coefficient previous value Resb, the greater the value of the function grad(Resb).

$$\text{Reshis} = \text{Resb} - \text{grad(Resb)} \cdot \Delta t \tag{32}$$

[0092] FIG. 3 shows time charts showing example changes in the accelerator opening Accp, the accelerator opening change speed absolute value |dAccp/dt|, and the response coefficient Res calculated in accordance with Equations (30) to (32). As shown in FIG. 3, every time the accelerator opening change speed absolute value |dAccp/dt| assumes a value other than zero (i.e., positive value) because of a change in the accelerator opening Accp, the response coefficient Res increases, because the response coefficient base quantity Resbase assumes a value other than zero (i.e., positive value) (see times t3, t5, and t10).

[0093] Meanwhile, once the response coefficient Res assumes a value other than zero (i.e., positive value), the response coefficient historical quantity Reshis assumes a value which gradually decreases to zero from a value other than zero, even when the accelerator opening Accp becomes constant, and thus the value of the response coefficient base quantity Resbase becomes zero (see times t4, t6, t7, t8, t9, t11, and t12). Accordingly, the value of the response coefficient Res is prevented from becoming zero immediately after the accelerator opening Accp becomes constant.

[0094] Moreover, as described above, the historical gradient grad, which determines the decreasing gradient of the response coefficient historical quantity Reshis, increases with the response coefficient previous value Resb. Therefore, for example, even when the response coefficient base quantity Resbase repeatedly assumes a (positive) value other than zero because of repetitive, stepwise increase of the accelerator opening Accp, the response coefficient Res is reliably prevented from diverging to a large value. The response coefficient obtaining means A2 corresponds to the requested acceleration degree index value obtaining means.

[0095] Load index value obtaining means A3 obtains, at the computation intervals, the above-described load index value LOAD, representing the degree of load of the engine 10, on the basis of the engine speed NE, the accelerator opening Accp, etc., as previously described. Specifically, the load index value obtaining means A3 includes a table (map) which defines the relation between the load index value LOAD and the engine speed NE, the accelerator opening Accp, etc. and which is stored in the ROM 62, and obtains the load index value LOAD from the engine speed NE, the accelerator opening Accp, etc. and the table.

[0096] Intake air quantity steady-state adequate value obtaining means A4 obtains, at the computation intervals, an intake air quantity steady-state adequate value GcylTA from the latest load index value LOAD obtained by means of the load index value obtaining means A3 and the table which defines the relation between the load index value LOAD and the intake air quantity steady-state adequate value GcylTA.

[0097] Intake air quantity actual value obtaining means A5 obtains, every time the crank angle CA of the fuel injection cylinder reaches ATDC-180°, the intake air quantity actual value Gcyl from the bottom-dead-center cylinder interior gas pressure Pa0 and the bottom-dead-center cylinder interior gas temperature Ta0, and in accordance with the above-described Equation (25). As described above, the bottom-dead-center cylinder interior gas pressure Pa0 can be obtained from the intake pipe pressure Pb detected by means of the intake pipe pressure sensor 73, and the bottom-dead-center cylinder interior gas temperature Ta0 can be obtained from the intake gas temperature Tb detected by means of the intake gas temperature sensor 72.

[0098] Emission total deterioration ratio obtaining means A6 obtains, at the computation intervals, an emission total deterioration ratio Kall, which is a transition degree index value representing the degree of transition in the operation state of the engine 10, from the latest intake air quantity steady-state adequate value GcylTA obtained by means of the intake air quantity steady-state adequate value obtaining means A4 and the latest intake air quantity actual value Gcyl obtained by means of the intake air quantity actual value obtaining means A5. Specifically, the emission total deterioration ratio obtaining means A6 calculates the emission total deterioration ratio Kall in accordance with the following Equation (33). Therefore, the emission total deterioration ratio Kall assumes a value corresponding to the difference between the intake air quantity steady-state adequate value GcylTA and the intake air quantity actual value Gcyl, and can serve as a proper value which represents the degree of transition in the operation state of the engine 10. The emission total deterioration ratio obtaining means A6 corresponds to the transition degree index value obtaining means.

$$\mathrm{Kall} = (\mathrm{GcylTA} - \mathrm{Gcyl})/\mathrm{GcylTA} \tag{33}$$

[0099] Final emission deterioration ratio obtaining means A7 obtains, at the computation intervals, a final emission deterioration ratio Kallfin from the latest response coefficient Res obtained by means of the response coefficient obtaining means A2 and the latest emission total deterioration ratio Kall obtained by means of the emission total deterioration ratio obtaining means A6, and in accordance with the following Equation (34). The final emission deterioration ratio Kallfin represents a degree of the correction for the case where the degree of correction is uniformly set among the emission generation quantity target values.

$$\mathrm{Kallfin} = \mathrm{Res} \cdot \mathrm{Kall} \tag{34}$$

[0100] Engine state obtaining means A8 obtains, at the computation intervals, the state of the engine 10 (engine state) from the cooling water temperature THW detected by the water temperature sensor 78 or the like. Catalyst state obtaining means A9 obtains, at the computation intervals, the state of the DPNR 43 (catalyst state), including the quantity of PM accumulated in the DPNR 43, from the catalyst upstream exhaust pressure Pup detected by the catalyst upstream pressure sensor 79, the catalyst downstream exhaust pressure Pdown detected by the catalyst downstream pressure sensor 81, etc.

[0101] Deterioration ratio distribution means A10 calculates, at the computation intervals, deterioration ratio distribution coefficients RatioNOx, RatioPM, and RatioCN (RatioNOx + RatioPM + RatioCN = 1) for the individual emissions so as to change, for the individual emissions, the degree of the above-mentioned correction corresponding to the final emission deterioration ratio Kallfin. Specifically, the deterioration ratio distribution means A10 calculates the deterioration ratio distribution coefficients RatioNOx, RatioPM, and RatioCN from the engine state obtained by means of the engine state obtaining means A8, the catalyst state obtained by means of the catalyst state obtaining means A9, and the latest value of the response coefficient Res. More specifically, the deterioration ratio distribution means A10 includes tables for the individual emissions, each of which defines the relation between the corresponding deterioration ratio distribution coefficient and the engine state, the catalyst state, and the response coefficient Res, and is stored in the ROM 62. The deterioration ratio distribution means A10 obtains the respective deterioration ratio distribution coefficients from the engine state, the catalyst state, the response coefficient Res, and the respective tables.

[0102] With this operation, for example, when the amount of PM accumulated in the DPNR 43 is equal to or greater than a predetermined value, the value of RatioPM is set to a smallish value. As a result, the degree of correction of the PM generation quantity target value PMt (i.e., the degree of increase of the target value) is set to a smallish value, so that the PM generation quantity actual value PMa is controlled to a smallish value to thereby protect the DPNR 43. Also, when the response coefficient Res is equal to or greater than a predetermined value, the value of RatioPM is set to a smallish value. As a result, the quantity of PM which becomes more likely to be generated during abrupt acceleration can be reduced. The deterioration ratio distribution means A10 corresponds to the correction ratio determination means.

[0103] A multiplier A11 outputs, at the computation intervals, an NOx deterioration ratio KNOx, which is obtained by multiplying the latest final emission deterioration ratio Kallfin obtained by means of the final emission deterioration ratio obtaining means A7 by the latest deterioration ratio distribution coefficient RatioNOx for NOx obtained by means of the deterioration ratio distribution means A10. Similarly, a multiplier A12 outputs, at the computation intervals, a PM deterioration ratio KPM, which is obtained by multiplying the latest final emission deterioration ratio Kallfin by the latest deterioration ratio distribution coefficient RatioPM for PM. A multiplier A13 outputs, at the computation intervals, a CN deterioration ratio KCN, which is obtained by multiplying the latest final emission deterioration ratio Kallfin by the latest deterioration ratio distribution coefficient RatioCN for CN.

[0104] In the above-described manner, the emission deterioration ratios KNOx, KPM, and KCN are obtained by means of the multipliers A11 to A13 at the computation intervals. Subsequently, the emission generation quantity final target values NOxt, PMt, and CNt are successively determined by use of the above-described Equations (26) to (28). Above is the outline of the method for obtaining the emission generation quantity target values.

Actual Operation

[0105] Next, actual operation of the engine control apparatus having the above-described configuration will be described. The CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 4 and adapted to obtain engine control parameter actual value, steady-state adequate values, etc. Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 400, and then proceeds to step 405 so as to obtain the engine speed actual value NE, the accelerator opening actual value Accp, the fuel injection pressure actual value Pcr, the intake-gas oxygen concentration actual value RO2in, and the cooling water temperature actual value THW.

[0106] Next, the CPU 61 proceeds to step 410 so as to determine whether the crank angle CA of the fuel injection cylinder coincides with ATDC-180°. When the CPU 61 makes a "No" determination in step 410, it proceeds directly to step 425. Meanwhile, when the CPU 61 makes a "Yes" determination in step 410, it proceeds to step 415 so as to obtain, as bottom-dead-center (BDC) cylinder interior gas temperature Ta0, the intake gas temperature Tb detected by means of the intake gas temperature sensor 72, and obtain, as bottom-dead-center (BDC) cylinder interior gas pressure Pa0, the intake pipe pressure Pb detected by means of the intake pipe pressure sensor 73. Subsequently, the CPU 61 obtains the intake air quantity actual value Gcyl in accordance with the above-described Equation (25) in step 420, and then proceeds to step 425.

[0107] In step 425, the CPU 61 obtains the above-mentioned load index value LOAD from the engine speed NE, the accelerator opening Accp, etc. at the present point in time, and through searching of predetermined tables. Subsequently, the CPU 61 proceeds to step 430 so as to determine steady-state adequate values AigTA, AintTA, qfinpTA, PcrTA, RO2inTA, GcylTA of the engine control parameters on the basis of the obtained load index value LOAD and through searching of predetermined tables, and then proceeds to step 495 so as to end the current execution of the present routine. Through repeated execution of the present routine, the actual values (excepting the intake air quantity actual value Gcyl) of the engine control parameters, the steady-state adequate values, and the load index value LOAD are obtained at the computation intervals.

[0108] Further, the CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 5 and adapted to calculate a response coefficient. Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 500, and then proceeds to step 505 so as to determine whether the accelerator opening current value Accp obtained in the previously described step 405 and the accelerator opening previous value Accpb updated in step 550, which will be described later, during the previous execution of the present routine are both not greater than a predetermined value Accpref.

[0109] When the CPU 61 makes a "No" determination in step 505, it proceeds to step 510 so as to obtain the accelerator opening change speed dAccp/dt in accordance with the above-described Equation (29). In this step, the latest value obtained in the previously described step 405 is used as the accelerator opening current value Accp, and the latest value obtained in step 550, which will be described later, is used as the accelerator opening previous value Accpb. Subsequently, the CPU 61 proceeds to step 515 so as to calculate the response coefficient base quantity Resbase in accordance with the above-described Equation (31). In this step, the latest value obtained in step 510 is used as the accelerator opening change speed dAccp/dt

[0110] Meanwhile, when the CPU 61 makes a "Yes" determination in step 505, the CPU 61 proceeds to step 520 so as to set the value of the response coefficient base quantity Resbase to zero. By virtue of this setting, when the accelerator opening Accp changes under the predetermined value Accpref, the driver is considered not to request acceleration.

[0111] Subsequently, the CPU 61 proceeds to step 525 so as to calculates the historical gradient grad on the basis of the function grad and the response coefficient previous value Resb updated in step 555, which will be described later, during the previous execution of the present routine. Subsequently, the CPU 61 proceeds to step 530 so as to calculate the response coefficient historical quantity Reshis in accordance with the above-described Equation (32).

[0112] Next, the CPU 61 proceeds to step 535 so as to determine whether the calculated response coefficient historical quantity Reshis is negative. When the CPU 61 makes a "No" determination in step 535, it proceeds directly to step 545. Meanwhile, when the CPU 61 makes a "Yes" determination in step 535, it proceeds to step 540 so as to set the value of the response coefficient historical quantity Reshis to zero, and then proceeds to step 545. With this setting, the response coefficient historical quantity Reshis is always set to a value equal to or greater than 0.

[0113] In step 545, the CPU 61 calculates the response coefficient (current value) Res from the response coefficient base quantity Resbase obtained in step 515 (or step 520), the response coefficient historical quantity Reshis obtained in step 530 (or step 540), and the above-described Equation (30). The CPU 61 then proceeds to step 550 so as to store, as the accelerator opening previous value Accpb, the accelerator opening current value Accp (obtained in step 405), and proceeds to step 555 so as to store, as the response coefficient previous value Resb, the response coefficient current value Res obtained in step 545. After that, the CPU 61 proceeds to step 595 so as to end the current execution of the present routine. Through repeated execution of the present routine, the response coefficient Res is obtained at the computation intervals.

[0114] Further, the CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 6 and adapted to calculate respective deterioration ratios of the emission generation quantities. Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 600, and then proceeds to step 605 so as to calculate the emission total deterioration ratio Kall from the intake air quantity steady-state adequate value GcylTA obtained in the previously described step 430, the latest intake air quantity actual value Gcyl obtained in the previously described step 420, and the above-mentioned Equation (33).

[0115] Next, the CPU 61 proceeds to step 610 so as to calculate the final emission deterioration ratio Kallfin from the response coefficient Res obtained in the previously described step 545, the emission total deterioration ratio Kall obtained in the previously described step 605, and the above-mentioned Equation (34).

[0116] Subsequently, the CPU 61 proceeds to step 615 so as to determine the respective deterioration ratio distribution coefficients RatioNOx, RatioPM, and RatioCN of the above-described emissions from the engine state based on the cooling water temperature THW, etc. at the present point in time, the catalyst state based on the catalyst upstream exhaust pressure Pup and the catalyst downstream exhaust pressure Pdown, etc. at the present point in time, and the latest response coefficient Res obtained in the previously described step 545.

[0117] Subsequently, the CPU 61 proceeds to step 620 so as to determine the respective deterioration ratios KNOx, KPM, and KCN of the emissions from the determined deterioration ratio distribution coefficients RatioNOx, RatioPM, and RatioCN, the final emission deterioration ratio Kallfin calculated in the previously described step 610, and the above-described Equations (26) to (28). After that, the CPU 61 proceeds to step 695 so as to end the current execution of the present routine. Through repeated execution of the present routine, the respective deterioration ratios KNOx, KPM, and KCN of the emissions are obtained at the computation intervals.

[0118] Further, the CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 7 and adapted to calculate respective target values of the engine control parameters. Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 700, and then proceeds to step 705 so as to determine the emission generation quantity base target values NOxtbase, PMtbase, and CNtbase on the basis of the load index value LOAD obtained in the previously described step 425 and through searching of the predetermined tables.

[0119] Next, the CPU 61 proceeds to step 710 so as to calculate the emission generation quantity final target values NOxt, PMt, and CNt from the determined emission generation quantity base target values NOxtbase, PMtbase, and CNtbase, the emission deterioration ratios KNOx, KPM, and KCN calculated in the previously described step 620, and the above-described Equations (26) to (28).

[0120] Subsequently, the CPU 61 proceeds to step 715 so as to calculate target values Aigt, Aintt, qfinpt, Pcrt, RO2int, Gcylt, and THWt of the engine control parameters from the emission generation quantity final target values NOxt, PMt, and CNt calculated in step 710, the latest engine control parameter actual values Pcr, RO2in, Gcyl, and THW obtained in the previously described steps 405 and 420, and the latest engine control parameter steady-state adequate values AigTA, AintTA, qfinpTA, PcrTA, R02inTA, and GcylTA obtained in the previously described step 430, and the above-described Equations (18) to (24). After that, the CPU 61 proceeds to step 795 so as to end the current execution of the present routine. Through repeated execution of the present routine, the engine control parameter target values are obtained at the computation intervals.

[0121] Further, the CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 8 and adapted to control the fuel injection manner (injection quantity and injection timing). Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 800, and then proceeds to step 805 so as to obtain the fuel injection quantity instruction value qfint from the accelerator opening Accp, the engine speed NE, and a table (map) Mapqfint shown in FIG. 9. The table Mapqfint defines the relation between the fuel injection quantity instruction value qfint and the accelerator opening Accp and the engine speed NE, and is stored in the ROM 62. The fuel injection quantity instruction value qfint is the total of a pilot injection quantity instruction value and a main injection quantity instruction value.

[0122] Next, the CPU 61 proceeds to step 810 so as to determine whether the value of a pilot injection execution flag PILOT is 0. The pilot injection execution flag PILOT indicates that the pilot injection has been performed when it value is 1, and that the pilot injection has not yet been performed when it value is 0.

[0123] Here, it is assumed that the pilot injection has not yet been performed and the pilot injection start timing has not come yet. In this case, since the value of the pilot injection execution flag PILOT is 0, the CPU 61 makes a "Yes" determination in step 810, and then proceeds to step 815 so as to monitor and determine whether the crank angle CA of the fuel injection cylinder coincides with the latest pilot injection start timing target value (instruction value) Aigt calculated in the previously described step 715.

[0124] At the present point in time, the crank angle CA of the fuel injection cylinder does not coincide with the latest pilot injection start timing target value (instruction value) Aigt. Therefore, the CPU 61 makes a "No" determination in step 815, and then proceeds to step 895 so as to end the current execution of the present routine. After that, the CPU 61 repeatedly executes the processing of steps 800, 805, 810, 815, and 895 until the pilot injection start timing comes.

[0125] When the crank angle CA of the fuel injection cylinder has reached the latest pilot injection start timing target value (instruction value) Aigt, the CPU 61 makes a "Yes" determination when its proceeds to step 815, and then proceeds to step 820 so as to instruct the fuel injection valve 21 of the fuel injection cylinder to inject fuel in an amount corresponding to the latest pilot injection quantity target value (instruction value) qfinpt calculated in the previously described step 715.

[0126] Subsequently, the CPU 61 proceeds to step 825, and stores, as a main injection quantity target value (instruction value) qfinmt, a value obtained through subtraction of the latest pilot injection quantity target value (instruction value) qfinpt from the fuel injection quantity instruction value qfint determined in the previously described step 805. Next, the CPU 61 proceeds to step 830 so as to store, as an injection interval control value Ainttc, the latest value of the injection interval target value (instruction value) Aintt calculated in the previously described step 715. The CPU 61 then proceeds to step 835 so as to store, as an injection timing control value Aigtc, the latest value of the pilot injection start timing target value (instruction value) Aigt. Subsequently, the CPU 61 proceeds to step 840 so as to set the value of the pilot injection execution flag PILOT to 1, and then proceeds to step 895 so as to end the current execution of the present routine.

[0127] After this point in time, since the value of the pilot injection execution flag PILOT has been set to 1, the CPU 61 makes a "No" determination when it proceeds to step 810, and then proceeds to step 845. In step 845, the CPU 61 monitors and determines whether the crank angle CA of the fuel injection cylinder coincides with a value obtained through addition of the above-mentioned injection interval control value Ainttc to the above-mentioned injection timing control value Aigtc (i.e., whether the main injection start timing has come). When the CPU 61 makes a "No" determination in step 845, it proceeds directly to step 895. After that, the CPU 61 repeatedly executes the processing of steps 800, 805, 810, 845, and 895 until the main injection start timing comes.

[0128] When the main injection start timing has come, the CPU 61 makes a "Yes" determination when it proceeds to step 845, and then proceeds to step 850. In step 850, the CPU 61 instructs the fuel injection valve 21 of the fuel injection cylinder (i.e., the fuel injection valve 21 which has performed the pilot injection at step 820) to inject fuel in an amount corresponding to the main injection quantity target value (instruction value) qfinmt calculated in the previously described step 825.

[0129] Subsequently, the CPU 61 proceeds to step 855 so as to set the value of the pilot injection execution flag PILOT to 0, and then proceeds to step 895 so as to end the current execution of the present routine. After this point in time, since the value of the pilot injection execution flag PILOT has been set to 0, the CPU 61 again makes a "Yes" determination when it proceeds to step 810, and monitors the pilot injection start timing for the next fuel injection cylinder. Through repeated execution of this routine, the fuel injection manner (injection quantity and injection timing) for the fuel injection cylinder, which is a portion of the engine control parameters, is controlled.

[0130] Further, the CPU 61 repeatedly executes, at predetermined intervals, a routine shown by the flowchart of FIG. 10 and adapted to control the engine control parameters (excluding the pilot injection start timing, the injection interval, and the pilot injection quantity). Therefore, when a predetermined timing has been reached, the CPU 61 starts the processing from step 1000, and then proceeds to step 1005 so as to feedback-control the discharge pressure of the fuel injection pump 22 such that the latest fuel injection pressure actual value Pcr obtained in the previously described step 405 coincides with the latest fuel injection pressure target value Pcrt calculated in the previously described step 715.

[0131] Next, the CPU 61 proceeds to step 1010 so as to feedback-control the EGR control valve 52 such that the latest intake-gas oxygen concentration actual value RO2in obtained in the previously described step 405 coincides with the latest intake-gas oxygen concentration target value RO2int calculated in the previously described step 715. Subsequently, the CPU 61 proceeds to step 1015 so as to feedback-control the throttle valve 33 such that the latest intake air quantity actual value Gcyl obtained in the previously described step 420 coincides with the latest intake air quantity target value Gcylt calculated in the previously described step 715.

[0132] Subsequently, the CPU 61 proceeds to step 1020 so as to feedback-control the unillustrated radiator flow rate control valve such that the latest cooling water temperature actual value THW obtained in the previously described step 405 coincides with the latest cooling water temperature target value THWt calculated in the previously described step 715. After that, the CPU 61 proceeds to step 1095 so as to end the current execution of the present routine. Through repeated execution of the present routine, the fuel injection pressure, the intake-gas oxygen concentration, the intake air quantity, and the cooling water temperature, which are a portion of the engine control parameters, are feedback-controlled.

[0133] As described above, in the control apparatus for an internal combustion engine according to the embodiment of the present invention, in order to perform feedback control such that the emission generation quantity actual values NOxa, PMa, and CNa which are controlled quantities, approach the emission generation quantity target values NOxt, PMt, and CNt, the plurality of (seven) engine control parameters which influence the emission generation quantities are classified into five classes (Lv1 to Lv5) in terms of response speed, and the respective target values of the engine control parameters are obtained in accordance with the above-described Equations (18) to (24), respectively (see step 715). The engine control parameters are then feedback-controlled such that the actual values of the engine control parameters approach the corresponding target values. By virtue of this operation, when the engine 10 is in a transition state, the emission generation quantity actual values NOxa, PMa, and CNa can always follow the emission generation quantity target values NOxt, PMt, and CNt at the response speed of the parameter Lv1 belonging to the class having the highest response speed, irrespective of the response speed of the parameter Lv5 belonging to the class having the lowest response speed. Accordingly, when the engine 10 is in a transition state, the emission generation quantity actual values can be caused to accurately follow the emission generation quantity target values.

[0134] Moreover, when the emission generation quantity (final) target values NOxt, PMt, and CNt are obtained, the degree of acceleration requested by the driver (i.e., the response coefficient Res) and the degree of transition in the operation state of the engine 10 (i.e., the emission total deterioration ratio Kall) are taken into consideration. Therefore, a decrease in drivability, which would be caused by a decrease in the response of the engine 10, can be suppressed properly.

[0135] The present invention is not limited to the above-described embodiment, and may be modified in various manners within the scope of the present invention. For example, the following modifications may be employed. In the above-described embodiment, the target values of the plurality of engine control parameters (parameters Lv1 to Lv5) are obtained in accordance with the above-described Equations (18) to (24), respectively. However, the control apparatus may be configured such that only the target values Aigt, Aintt, qfinpt of the parameters Lv1 are obtained in accordance with the above-described Equations (18) to (20), respectively, and the target values of the parameters Lv2 to Lv5 are always set to the corresponding steady-state adequate values. In this configuration as well, when the engine 10 is in a transition state, the emission generation quantity actual values NOxa, PMa, and CNa can always follow the emission generation quantity target values NOxt, PMt, and CNt at the response speed of the parameter Lv1 belonging to the class having the highest response speed.

[0136] In the above-described embodiment, Equations (21) to (24) for calculating the target values of the parameters Lv2 to Lv5 employ the NOx generation quantity target value NOxt as an argument. However, these equations may employ any one of the PM generation quantity target value PMt and the CN generation quantity target value CNt, as an argument.

[0137] In the above-described embodiment, the plurality of engine control parameters are divided such that one class include a plurality of (three) parameters Lv1, and each of the remaining classes includes a single parameter Lv2, Lv3, Lv4, or Lv5. However, the plurality of engine control parameters may be divided such that each of the classes includes a plurality of engine control parameters, or divided such that each of the classes includes a single engine control parameter.

[0138] In the above-described embodiment, the catalyst state which is obtained by the catalyst state obtaining means A9 and is used by the deterioration ratio distribution means A10 so as to obtain deterioration ratio distribution coefficients, includes the quantity of PM accumulated in the DPNR 43. However, in place of, or in addition to the quantity of accumulated PM, the quantity of NOx accumulated in the DPNR 43 may be used as the catalyst state. In this case, when the quantity of NOx accumulated in the DPNR 43 exceeds a predetermined value, the value of RatioNOx is preferably set to a smallish value. As a result, the NOx generation quantity actual value NOxa is controlled to a smallish value, whereby the DPNR 43 is protected. Notably, in this case, an NOx concentration sensor must be disposed, for example, in the exhaust passage on the upstream side of the DPNR 43 so as to obtain the quantity of NOx accumulated in the DPNR 43.

[0139] In the above-described embodiment, feedback control of the intake air quantity Gcyl is accomplished through control of the throttle valve actuator 33a. However, in place of, or in addition to the throttle valve actuator 33a, a boosted pressure control valve for adjusting the boosted pressure of the turbocharger 35 may be controlled.

[0140] In the above-described embodiment, the response coefficient Res obtained by the response coefficient obtaining means A2 is calculated on the basis of only the accelerator opening Accp and the accelerator opening change speed dAccp/dt. However, the calculated response coefficient Res may be corrected in accordance with the state (e.g., the cooling water temperature THW, the engine speed NE, etc.) of the engine. For example, in the case where the response coefficient Res is corrected in accordance with the cooling water temperature THW, the response coefficient Res is preferably corrected to a decreasing direction when the cooling water temperature THW is lower than a predetermined value. Further, in the case where the response coefficient Res is corrected in accordance with the engine speed NE, the response coefficient Res is preferably corrected in an increasing direction when the engine speed NE is lower than a predetermined value, and corrected in a decreasing direction when the engine speed NE is higher than the predetermined value.

[0141] A control apparatus for an internal combustion engine handles a plurality of engine control parameters which influence the emission generation quantity, while dividing them into a plurality of classes in terms of response speed. An empirical formula which obtains the emission generation quantity by use of the plurality of parameters as arguments is solved for each parameter, whereby an equation for obtaining the value of a parameter of a class of interest while using parameters of the remaining classes and the emission generation quantity as arguments is obtained for each parameter. In each of the obtained equations, a target value is used as an argument value of the emission generation quantity, an actual value is used as an argument value of a parameter of a class which is lower in response speed than the class of interest, and a steady-state adequate values is used as an argument value of a parameter of a class which is higher in response speed than the class of interest. The values calculated by these equations are used as target values of the parameters.

Claims

1. A control apparatus for an internal combustion engine, comprising:

   operation state obtaining means for obtaining operation state of the engine;
   controlled quantity target value determination means for determining a target value of a predetermined controlled quantity, which is generated upon operation of the engine, on the basis of the obtained operation state;
   engine control parameter actual value obtaining means for obtaining actual values of a plurality of engine control parameters which influence an actual value of the controlled quantity;
   engine control parameter steady-state adequate value obtaining means for obtaining, as engine control parameter steady-state adequate values, respective values of the engine control parameters on the basis of the obtained operation state, the values being necessary for rendering the actual value of the controlled quantity coincident with the controlled quantity target value when the engine is in a steady state in the obtained operation state;
   engine control parameter target value determination means for determining target values of the engine control parameters which cause the actual value of the controlled quantity to approach the controlled quantity target value; and
   control means for individually controlling the engine control parameters such that the actual values of the engine control parameters approach the corresponding engine control parameter target values, whereby the controlled quantity is controlled such that the actual value of the controlled quantity approaches the controlled quantity target value, wherein
   the engine control parameter target value determination means is configured to handle the engine control parameters while dividing them into a plurality of classes in accordance with response speed at the time when the engine control parameters are controlled by means of the control means;
   the engine control parameter target value determination means comprises class-by-class engine control parameter value calculation means for calculating, from the controlled quantity target value and argument values regarding the engine control parameters other than an engine control parameter belonging to a class having the highest response speed, at least a value of the engine control parameter belonging to the class having the highest response speed, the value rendering the actual value of the controlled quantity coincident with the controlled quantity target value when the actual values of the engine control parameters other than the engine control parameter belonging to the class having the highest response speed are equal to the argument values;
   the engine control parameter target value determination means uses, as the target value of the engine control parameter belonging to the class having the highest response, a value of the engine control parameter belonging to the class having the highest response, the value being calculated by means of the class-by-class engine control parameter value calculation means by making use of corresponding engine control parameter actual values as the argument values regarding the engine control parameters other than the engine control parameter belonging to the class having the highest response; and
   the engine control parameter target value determination means uses, as the target values of the engine control parameters other than the engine control parameter belonging to the class having the highest response, values which are at least based on the plurality of the engine control parameter steady-state adequate values.

2. A control apparatus for an internal combustion engine according to claim 1, wherein
   the class-by-class engine control parameter value calculation means is configured to calculate, for each class of interest, a value of the engine control parameter belonging to the class of interest on the basis of the controlled quantity target value and the argument values regarding the engine control parameters other than the engine control parameter belonging to the class of interest, the value making the actual value of the controlled quantity coincident with the controlled quantity target value when the actual values of the engine control parameters other than the engine control parameter belonging to the class of interest are equal to the argument values; and
   the engine control parameter target value determination means is configured to use, for each class of interest, as the target value of the engine control parameter belonging to the class of interest, a value of the engine control parameter belonging to the class of interest calculated by means of the class-by-class engine control parameter value calculation means which uses, as an argument value regarding the engine control parameter belonging to a class having a lower response speed than the class of interest, the corresponding engine control parameter actual value, and uses, as an argument value regarding the engine control parameter belonging to a class having a higher response speed than the class of interest, the corresponding engine control parameter steady-state adequate value.

3. A control apparatus for an internal combustion engine according to claim 1 or 2, wherein the controlled quantity

comprises at least generation quantity of an emission.

4. A control apparatus for an internal combustion engine according to claim 3, wherein the controlled quantity target value determination means comprises:

requested acceleration degree index value obtaining means for obtaining a requested acceleration degree index value representing the degree of acceleration requested by a driver of the vehicle on which the engine is mounted; and
correction means for correcting the determined controlled quantity target value in accordance with the requested acceleration degree index value to thereby determine a final controlled quantity target value to be used in place of the controlled quantity target value.

5. A control apparatus for an internal combustion engine according to claim 4, wherein
the requested acceleration degree index value is change speed of accelerator operation amount.

6. A control apparatus for an internal combustion engine according to claim 4 or 5, wherein
the controlled quantity target value determination means comprises transition degree index value obtaining means for obtaining a transition degree index value representing the degree of transition in the operation state of the engine; and
the correction means is configured to correct the determined controlled quantity target value in accordance with the transition degree index value to thereby determine the final controlled quantity target value.

7. A control apparatus for an internal combustion engine according to claim 6, wherein
the transition degree index value is a value based on the deviation of the actual value from the steady-state adequate value of an intake air quantity taken into a cylinder per intake stroke.

8. A control apparatus for an internal combustion engine according to any one of claims 4 to 7, wherein
the control apparatus is configured to control a plurality of controlled quantities so that actual values of the controlled quantities approach corresponding controlled quantity target values; and
the correction means comprises correction ratio determination means for determining, for each of the controlled quantity target values, a ratio of degree of the correction in accordance with the operation state of the engine, and determines, for each controlled quantity, the degree of correction of the corresponding controlled quantity target value on the basis of the determined ratio.

9. A control apparatus for an internal combustion engine according to claim 8, wherein
the correction ratio determination means determines the ratio of degree of the correction in accordance with at least one of temperature of cooling water of the engine, a state of a catalyst interposed in an exhaust passage of the engine and the requested acceleration degree index value.

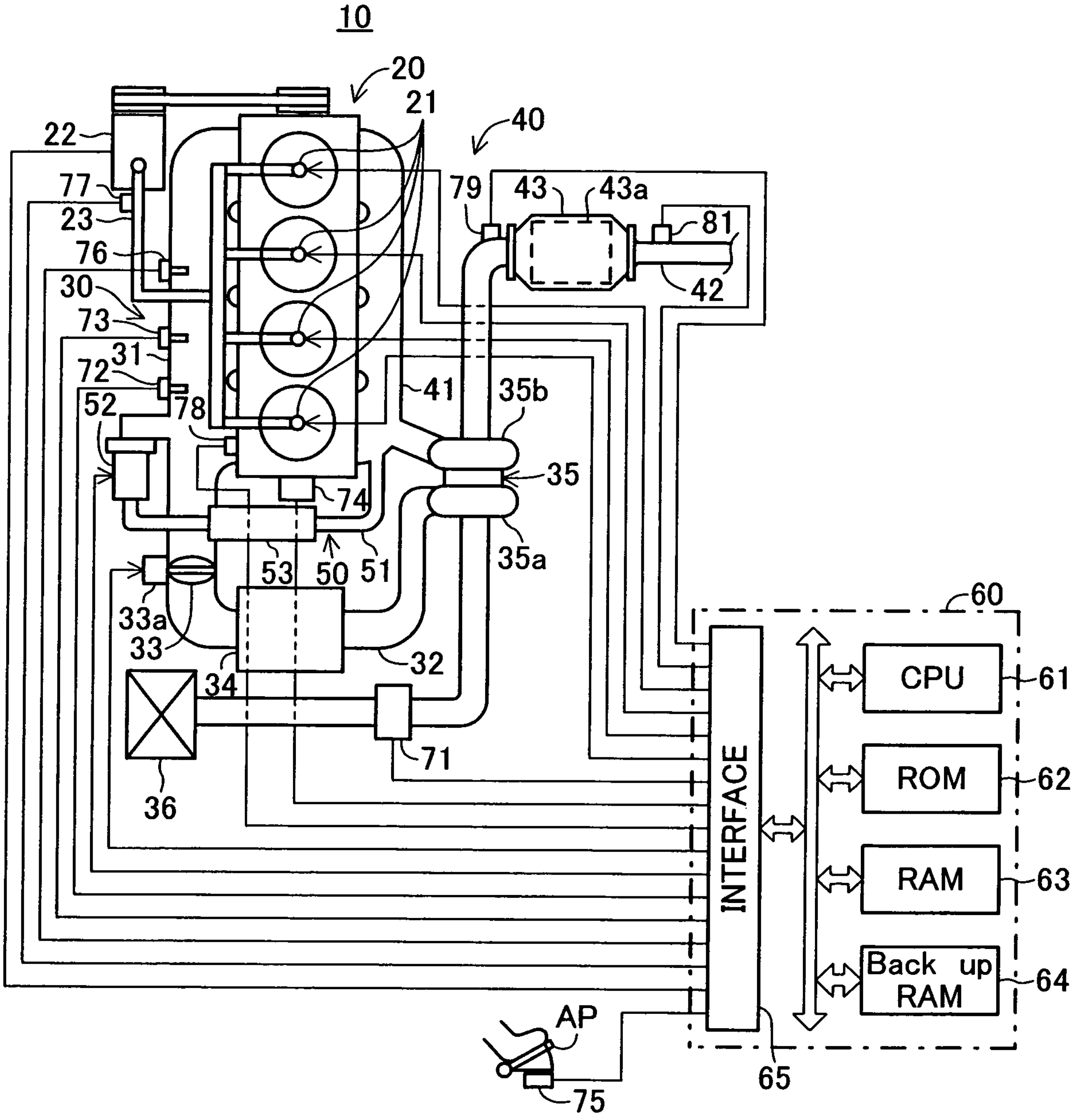
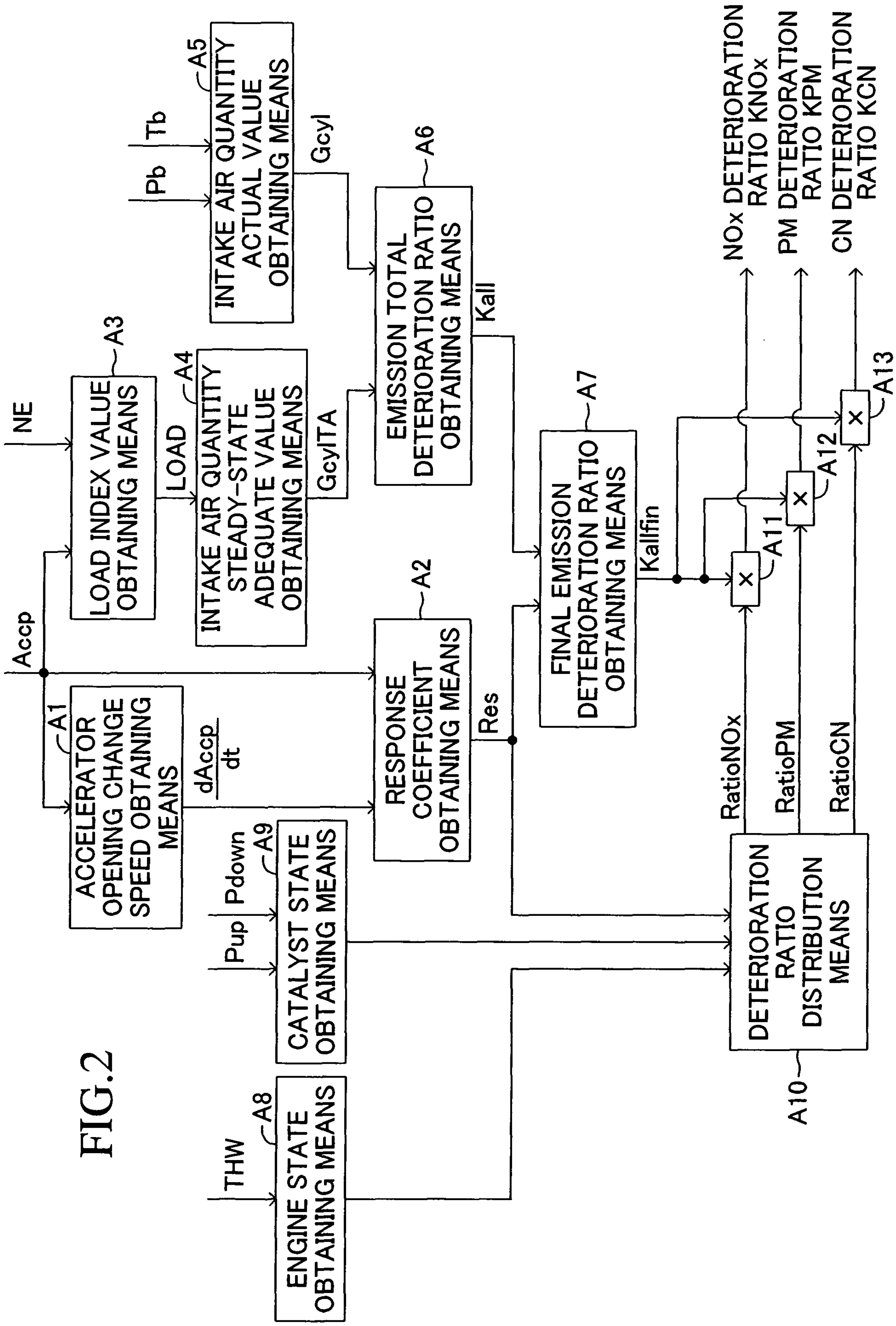

10
20
21
40
22
77
23
76
30
73
31
72
52
78
79
43
43a
81
42
41
35b
35
35a
74
53
50
51
33a
33
34
32
36
71
60
CPU
61
ROM
62
RAM
63
Back up RAM
64
INTERFACE
65
AP
75

FIG.1

FIG.2


Accp
NE
Pb
Tb
THW
Pup
Pdown
A1
ACCELERATOR OPENING CHANGE SPEED OBTAINING MEANS
dAccp/dt
A2
RESPONSE COEFFICIENT OBTAINING MEANS
Res
A3
LOAD INDEX VALUE OBTAINING MEANS
LOAD
A4
INTAKE AIR QUANTITY STEADY-STATE ADEQUATE VALUE OBTAINING MEANS
GcylTA
A5
INTAKE AIR QUANTITY ACTUAL VALUE OBTAINING MEANS
Gcyl
A6
EMISSION TOTAL DETERIORATION RATIO OBTAINING MEANS
Kall
A7
FINAL EMISSION DETERIORATION RATIO OBTAINING MEANS
Kallfin
A8
ENGINE STATE OBTAINING MEANS
A9
CATALYST STATE OBTAINING MEANS
A10
DETERIORATION RATIO DISTRIBUTION MEANS
RatioNOx
RatioPM
RatioCN
A11
×
A12
×
A13
×
NOx DETERIORATION RATIO KNOx
PM DETERIORATION RATIO KPM
CN DETERIORATION RATIO KCN

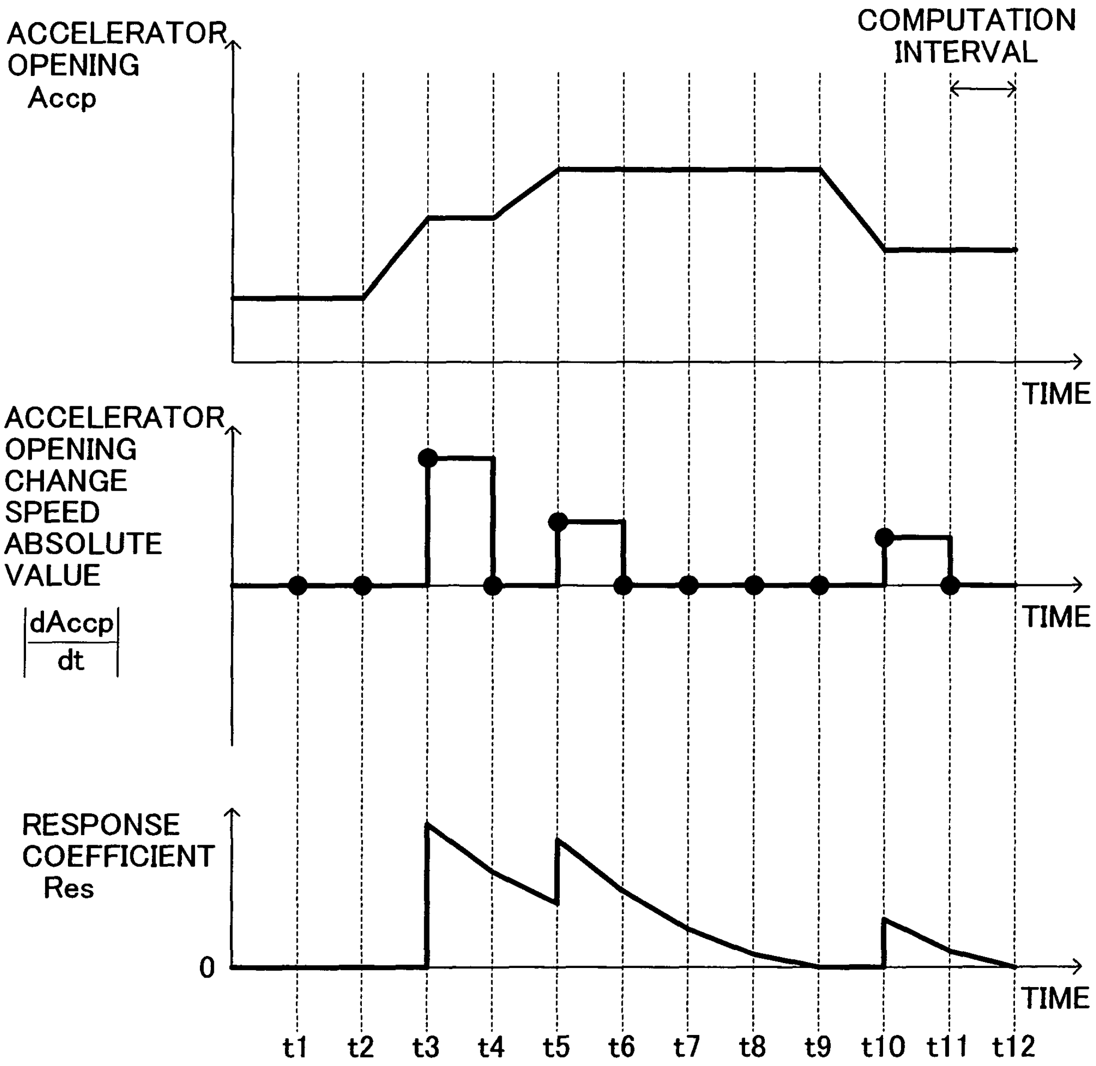

ACCELERATOR OPENING Accp
COMPUTATION INTERVAL
TIME
ACCELERATOR OPENING CHANGE SPEED ABSOLUTE VALUE
$\left|\frac{dAccp}{dt}\right|$
TIME
RESPONSE COEFFICIENT Res
0
TIME
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
t11
t12

FIG.3

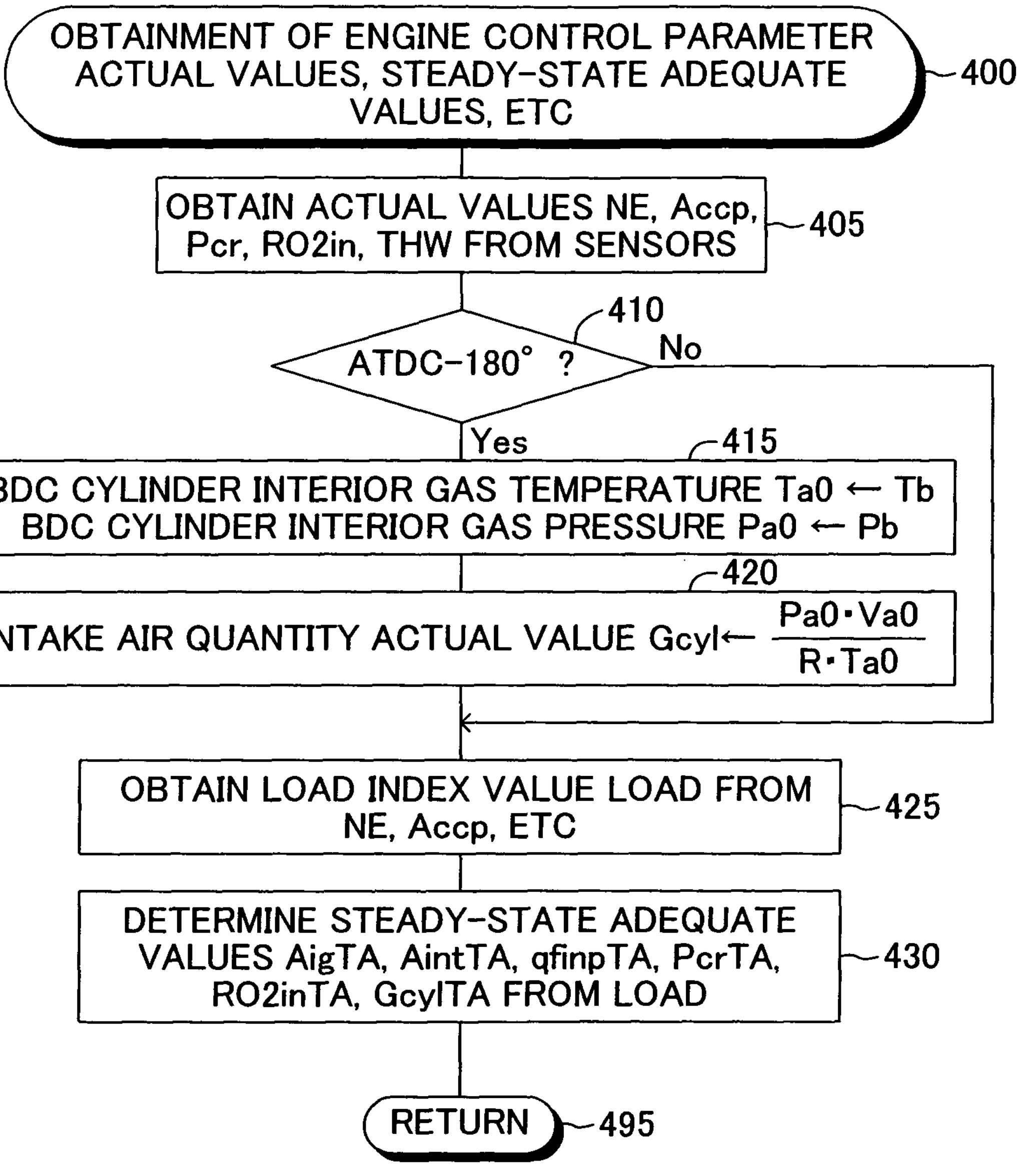

OBTAINMENT OF ENGINE CONTROL PARAMETER ACTUAL VALUES, STEADY-STATE ADEQUATE VALUES, ETC
400
OBTAIN ACTUAL VALUES NE, Accp, Pcr, RO2in, THW FROM SENSORS
405
410
ATDC-180° ?
No
Yes
415
BDC CYLINDER INTERIOR GAS TEMPERATURE Ta0 ← Tb
BDC CYLINDER INTERIOR GAS PRESSURE Pa0 ← Pb
420
INTAKE AIR QUANTITY ACTUAL VALUE Gcyl← Pa0•Va0 / R•Ta0
OBTAIN LOAD INDEX VALUE LOAD FROM NE, Accp, ETC
425
DETERMINE STEADY-STATE ADEQUATE VALUES AigTA, AintTA, qfinpTA, PcrTA, RO2inTA, GcylTA FROM LOAD
430
RETURN
495

FIG.4

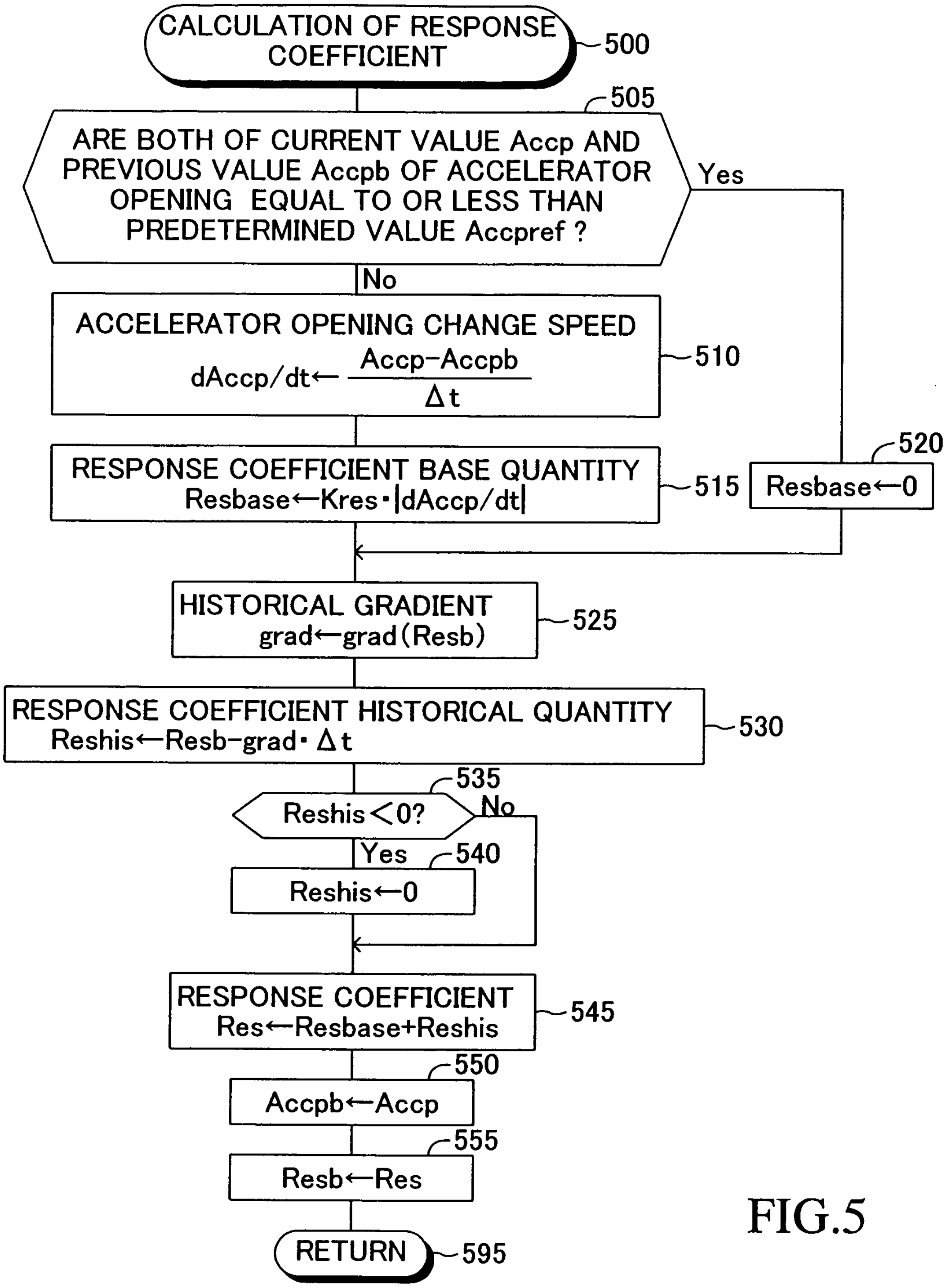

CALCULATION OF RESPONSE COEFFICIENT
500
505
ARE BOTH OF CURRENT VALUE Accp AND PREVIOUS VALUE Accpb OF ACCELERATOR OPENING EQUAL TO OR LESS THAN PREDETERMINED VALUE Accpref ?
Yes
No
ACCELERATOR OPENING CHANGE SPEED
dAccp/dt← (Accp−Accpb)/Δt
510
520
RESPONSE COEFFICIENT BASE QUANTITY
Resbase←Kres·|dAccp/dt|
515
Resbase←0
HISTORICAL GRADIENT
grad←grad(Resb)
525
RESPONSE COEFFICIENT HISTORICAL QUANTITY
Reshis←Resb−grad·Δt
530
535
Reshis<0?
No
Yes
540
Reshis←0
RESPONSE COEFFICIENT
Res←Resbase+Reshis
545
550
Accpb←Accp
555
Resb←Res
RETURN
595

FIG.5

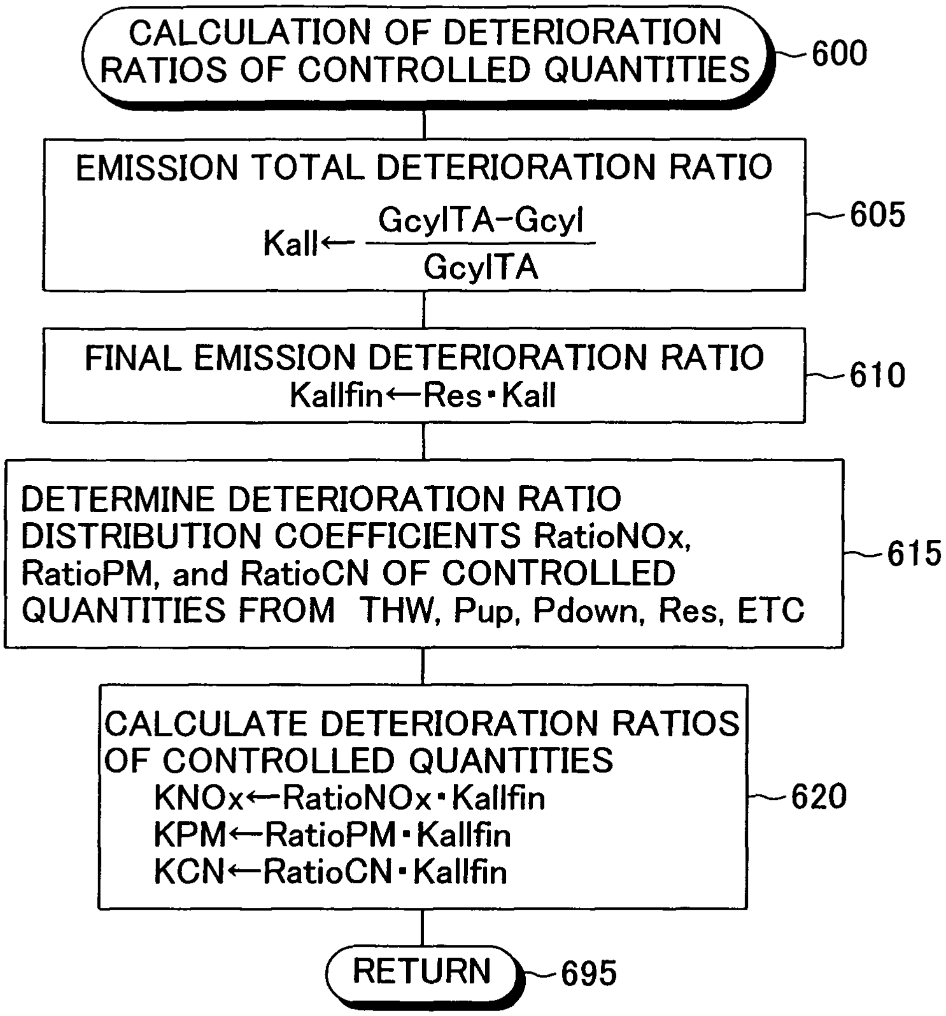

CALCULATION OF DETERIORATION RATIOS OF CONTROLLED QUANTITIES
600
EMISSION TOTAL DETERIORATION RATIO
Kall← (GcylTA−Gcyl)/GcylTA
605
FINAL EMISSION DETERIORATION RATIO
Kallfin←Res•Kall
610
DETERMINE DETERIORATION RATIO DISTRIBUTION COEFFICIENTS RatioNOx, RatioPM, and RatioCN OF CONTROLLED QUANTITIES FROM THW, Pup, Pdown, Res, ETC
615
CALCULATE DETERIORATION RATIOS OF CONTROLLED QUANTITIES
KNOx←RatioNOx•Kallfin
KPM←RatioPM•Kallfin
KCN←RatioCN•Kallfin
620
RETURN
695

FIG.6

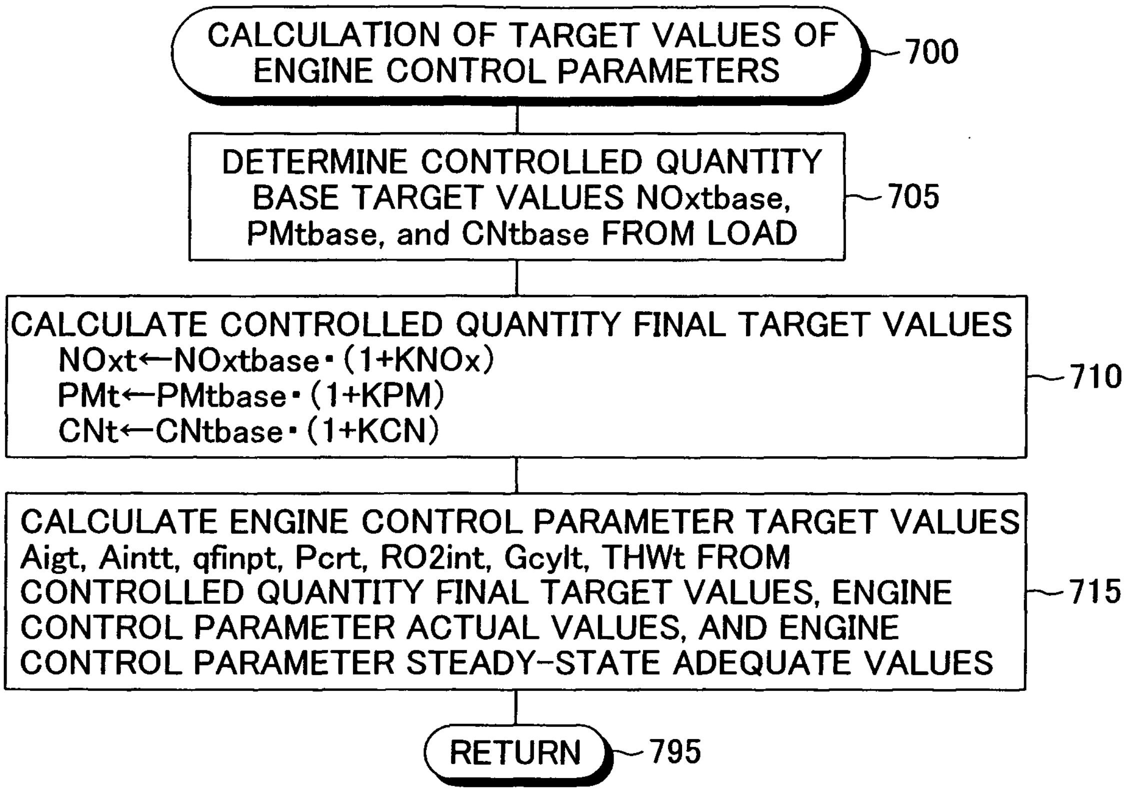

CALCULATION OF TARGET VALUES OF ENGINE CONTROL PARAMETERS
700
DETERMINE CONTROLLED QUANTITY BASE TARGET VALUES NOxtbase, PMtbase, and CNtbase FROM LOAD
705
CALCULATE CONTROLLED QUANTITY FINAL TARGET VALUES
NOxt←NOxtbase・(1+KNOx)
PMt←PMtbase・(1+KPM)
CNt←CNtbase・(1+KCN)
710
CALCULATE ENGINE CONTROL PARAMETER TARGET VALUES Aigt, Aintt, qfinpt, Pcrt, RO2int, Gcylt, THWt FROM CONTROLLED QUANTITY FINAL TARGET VALUES, ENGINE CONTROL PARAMETER ACTUAL VALUES, AND ENGINE CONTROL PARAMETER STEADY-STATE ADEQUATE VALUES
715
RETURN
795

FIG.7

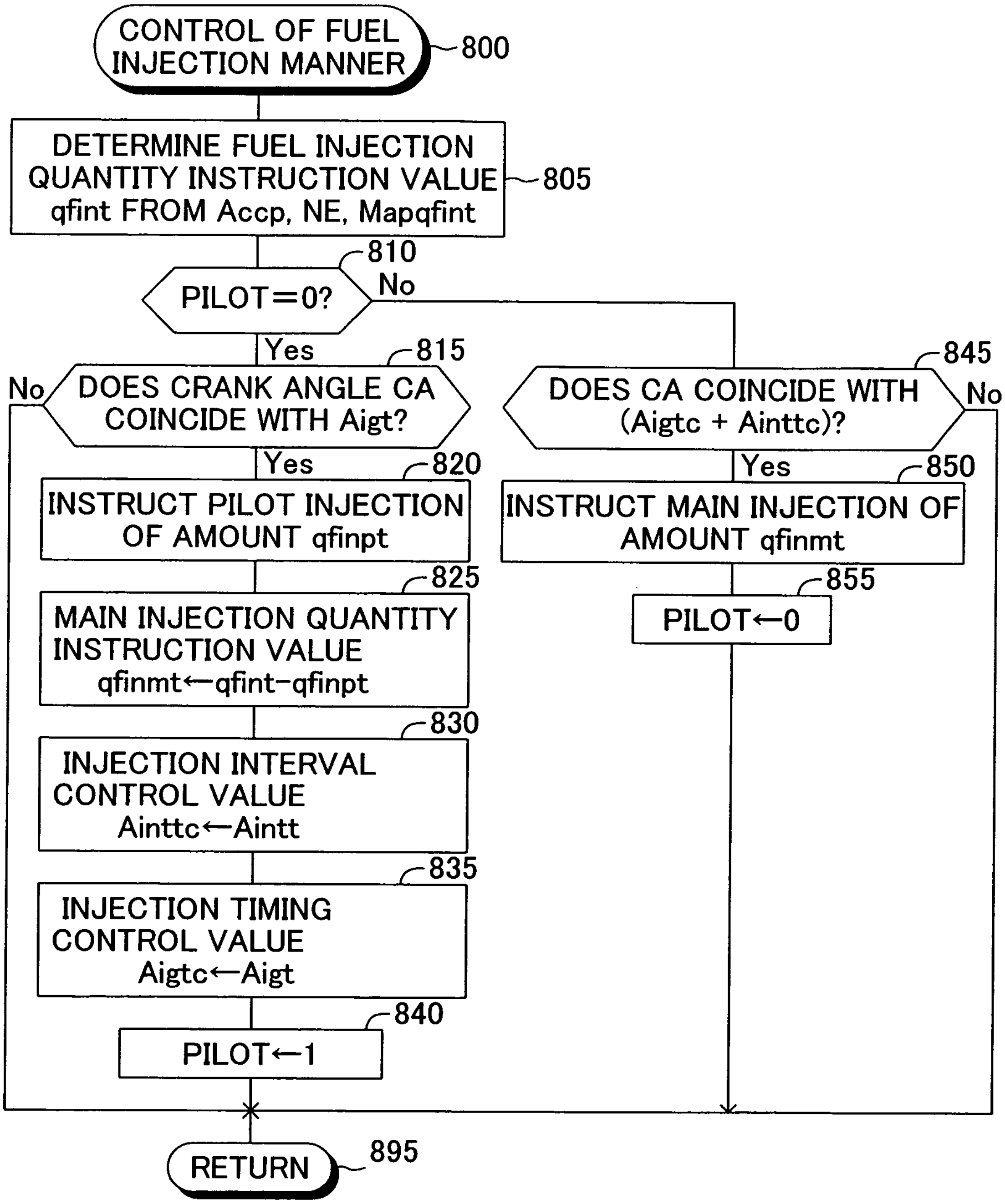

CONTROL OF FUEL INJECTION MANNER
800
DETERMINE FUEL INJECTION QUANTITY INSTRUCTION VALUE qfint FROM Accp, NE, Mapqfint
805
PILOT=0?
810
No
Yes
815
No
DOES CRANK ANGLE CA COINCIDE WITH Aigt?
Yes
820
INSTRUCT PILOT INJECTION OF AMOUNT qfinpt
825
MAIN INJECTION QUANTITY INSTRUCTION VALUE qfinmt←qfint−qfinpt
830
INJECTION INTERVAL CONTROL VALUE Ainttc←Aintt
835
INJECTION TIMING CONTROL VALUE Aigtc←Aigt
840
PILOT←1
845
DOES CA COINCIDE WITH (Aigtc + Ainttc)?
No
Yes
850
INSTRUCT MAIN INJECTION OF AMOUNT qfinmt
855
PILOT←0
RETURN
895

FIG.8

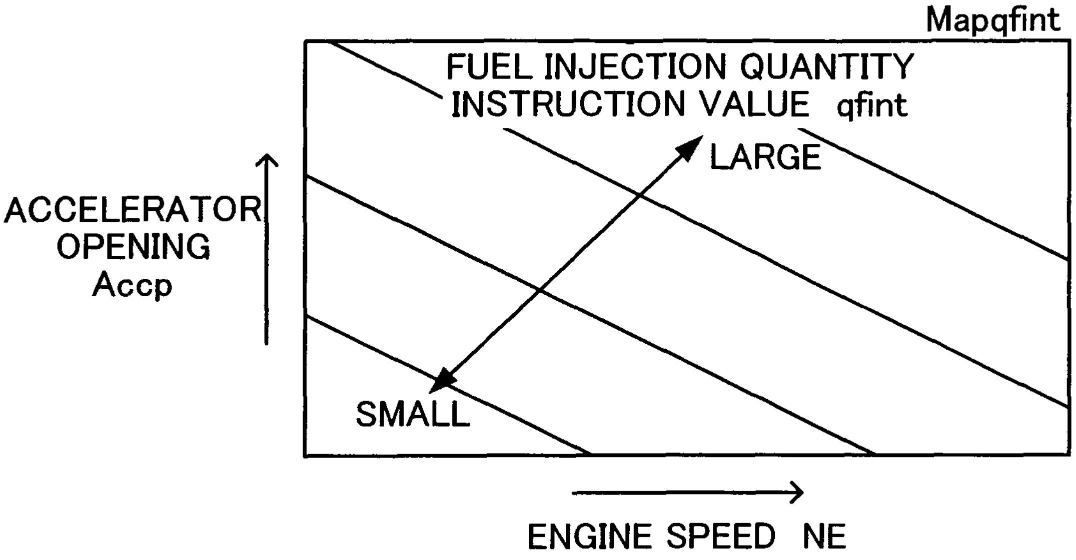

Mapqfint
FUEL INJECTION QUANTITY INSTRUCTION VALUE qfint
LARGE
SMALL
ACCELERATOR OPENING Accp
ENGINE SPEED NE

FIG.9

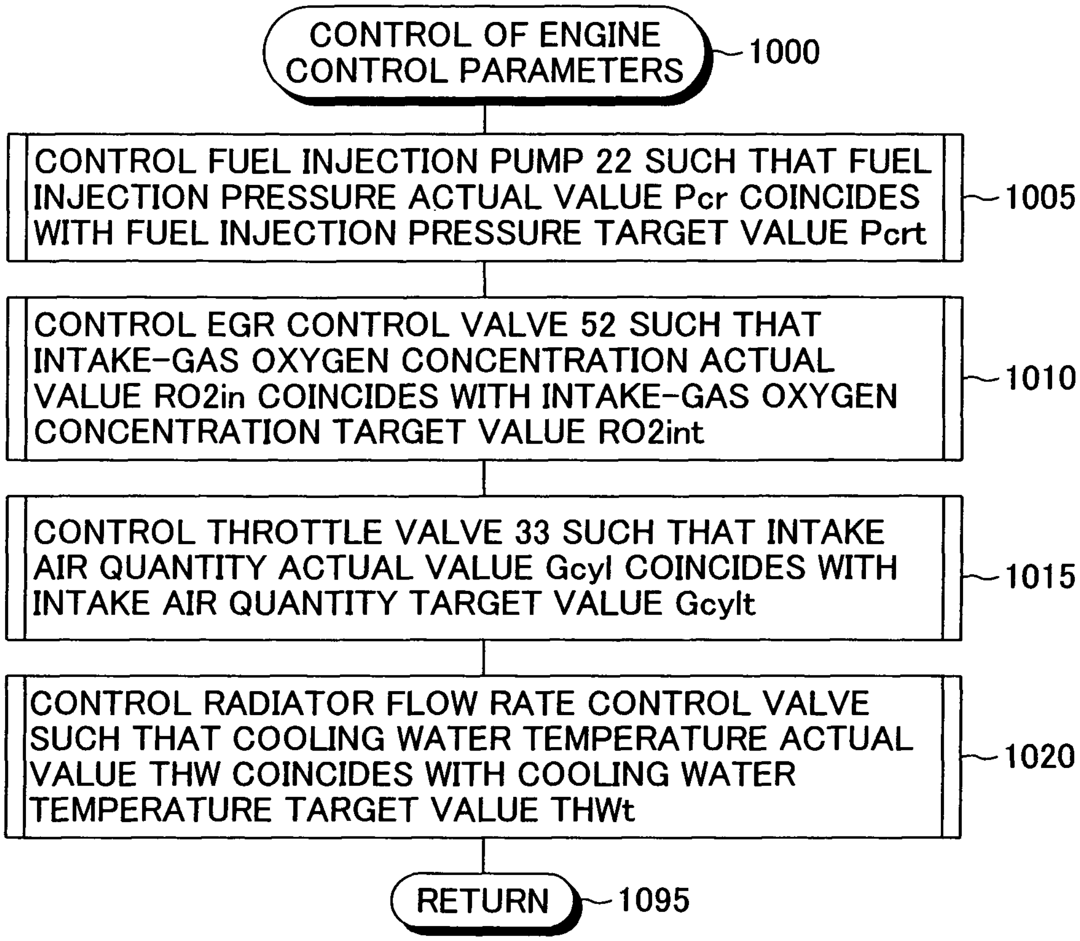

CONTROL OF ENGINE CONTROL PARAMETERS
1000
CONTROL FUEL INJECTION PUMP 22 SUCH THAT FUEL INJECTION PRESSURE ACTUAL VALUE Pcr COINCIDES WITH FUEL INJECTION PRESSURE TARGET VALUE Pcrt
1005
CONTROL EGR CONTROL VALVE 52 SUCH THAT INTAKE-GAS OXYGEN CONCENTRATION ACTUAL VALUE RO2in COINCIDES WITH INTAKE-GAS OXYGEN CONCENTRATION TARGET VALUE RO2int
1010
CONTROL THROTTLE VALVE 33 SUCH THAT INTAKE AIR QUANTITY ACTUAL VALUE Gcyl COINCIDES WITH INTAKE AIR QUANTITY TARGET VALUE Gcylt
1015
CONTROL RADIATOR FLOW RATE CONTROL VALVE SUCH THAT COOLING WATER TEMPERATURE ACTUAL VALUE THW COINCIDES WITH COOLING WATER TEMPERATURE TARGET VALUE THWt
1020
RETURN
1095

FIG.10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 00 3317

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 208 930 B1 (UEMATSU YOSHITAKA) 27 March 2001 (2001-03-27) * abstract *	1-9	F02D41/26
X	EP 1 111 223 A (FORD GLOBAL TECHNOLOGIES, INC) 27 June 2001 (2001-06-27) * abstract *	1-9	
X	US 2003/101963 A1 (ESTEGHLAL GHOLAMABAS ET AL) 5 June 2003 (2003-06-05) * abstract *	1-9	
X	US 5 964 811 A (ISHII ET AL) 12 October 1999 (1999-10-12) * abstract *	1-9	
X	US 2002/123828 A1 (BELLMANN HOLGER ET AL) 5 September 2002 (2002-09-05) * abstract *	1-9	
X	EP 0 608 456 A (SIEMENS AKTIENGESELLSCHAFT) 3 August 1994 (1994-08-03) * abstract *	1-9	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F02D
X	US 6 240 358 B1 (KAWAI MITSUHIRO) 29 May 2001 (2001-05-29) * abstract *	1-9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	17 May 2005	Jackson, S

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

2

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 00 3317

17-05-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6208930 B1	27-03-2001	JP 2000199450 A	18-07-2000
EP 1111223 A	27-06-2001	US 6275766 B1	14-08-2001
		EP 1111223 A2	27-06-2001
US 2003101963 A1	05-06-2003	DE 10043072 A1	14-03-2002
		CN 1388859 A	01-01-2003
		WO 0218768 A1	07-03-2002
		EP 1315895 A1	04-06-2003
		JP 2004507657 T	11-03-2004
US 5964811 A	12-10-1999	JP 3321837 B2	09-09-2002
		JP 6058197 A	01-03-1994
		DE 4326498 A1	24-03-1994
		US 6085132 A	04-07-2000
US 2002123828 A1	05-09-2002	DE 19744230 A1	08-04-1999
		FR 2771193 A1	21-05-1999
		IT 1302575 B1	29-09-2000
		JP 11191002 A	13-07-1999
EP 0608456 A	03-08-1994	EP 0608456 A1	03-08-1994
		DE 59302747 D1	04-07-1996
US 6240358 B1	29-05-2001	JP 2000047883 A	18-02-2000
		DE 19935878 A1	02-03-2000
		FR 2781897 A1	04-02-2000