A diagnostic apparatus for a catalyst in a fuel-property reforming system includes an inlet-side temperature sensor disposed upstream of the fuel-reforming catalyst and an outlet-side temperature sensor disposed downstream of the fuel-reforming catalyst. In a reforming driving mode, while the EGR valve is opened to recirculate a part of exhaust gas into the intake pipe, a reforming-fuel injector injects a reforming fuel into the EGR gas. A fuel-reforming catalyst reforms the fuel into a fuel having high-combustibility. A differential temperature between a temperature detected by the inlet-side temperature sensor and a temperature detected by the outlet-side temperature sensor is compared with a deterioration-determination threshold, whereby a computer determines whether the fuel-reforming catalyst is deteriorated.
FIG. 2

REFORMING-FUEL INJECTION

TEMPERATURE

Tin  Tout (NORMAL)  Tout (DETERIORATED)  Tout (FULLY DETERIORATED)

Tdif  Tth

FULLY DETERIORATED  DETERIORATED  NORMAL

TIME

FIG. 3

REFORMING-FUEL INJECTION

TEMPERATURE

Tin  Tout (FULLY DETERIORATED)  Tout (DETERIORATED)  Tout (NORMAL)

Tdif  Tth

FULLY DETERIORATED  DETERIORATED  NORMAL

TIME
FIG. 4

START

NO

REFORMING DRIVING MODE?

YES

OPEN EGR VALVE

INJECT REFORMING-FUEL

READ “Tin” & “Tout”

COMPUTE “Tth”

Tdiff ≥ Tth?

YES

NOT DETERIORATED

RETURN

NO

DETERIORATED

FAIL-SAFE PROCESSING

RETURN
FIG. 5

![Graph showing Tth vs. EGR-GAS QUANTITY.]

FIG. 6

![Graph showing Tth vs. REFORMING-FUEL INJECTION QUANTITY.]
FIG. 7

START

NO

REFORMING DRIVING MODE?

YES

OPEN EGR VALVE

INJECT REFORMING-FUEL

READ “Tin” & “Tout”

COMPUTE “Tth”

Tdif ≤ Tth?

NO

YES

NOT DETERIORATED

DETERIORATED

FAIL-SAFE PROCESSING

RETURN
FIG. 9

- Reforming Mode
- Normal Mode
- Temperature
  - $T_{in}$
  - $T_{out}$
- Torque
- Reforming-Fuel Injection Quantity
- Main Fuel Injection Quantity
- Opening Degree of EGR Valve
- Determination
  - Deteriorated
  - OK

DIAGNOSIS

TIME
FIG. 11

COMBUSTION PARAMETER

THRESHOLD

REFORMING-FUEL INJECTION

DETERIORATED CATALYST

NORMAL CATALYST

FIG. 12

START

REFORMING DRIVING MODE?

YES

OPEN EGR VALVE

INJECT REFORMING-FUEL

COMPUTE COMBUSTION PARAMETER

COMPUTE THRESHOLD

COMBUSTION PARAMETER IS IN NORMAL RANGE?

YES

NOT DETERIORATED

NO

DETERIORATED

FAIL-SAFE PROCESSING

RETURN
FIG. 13

- Reforming Mode
- Normal Mode
- Torque
- Combustion Parameter: COV
- Ignition Delay
- Main Combustion Period
- Combustion Parameter: Combustion Center
- Maximum Pressure
- Reforming-Fuel Injection Quantity
- Main Fuel Injection Quantity
- Opening Degree of EGR Valve
- Determination
- Deteriorated
- OK

Time

Diagnosis
FIG. 15

REFORMING-FUEL INJECTION

NORMAL CATALYST

DETERIORATED CATALYST

THRESHOLD

TIME

FIG. 16

START

NO

REFORMING DRIVING MODE?

YES

OPEN EGR VALVE

INJECT REFORMING-FUEL

READ REFORMING DEGREE

COMPUTE THRESHOLD

REFORMING DEGREE ≥ THRESHOLD?

YES

NOT DETERIORATED

NO

DETERIORATED

FAIL-SAFE PROCESSING

RETURN
FIG. 17

- Reforming Mode
- Normal Mode
- Torque
- Reforming Degree
- Reforming-Fuel Injection Quantity
- Main Fuel Injection Quantity
- Opening Degree of EGR Valve
- Determination
- Deteriorated
- OK

Time
DIAGNOSTIC APPARATUS FOR CATALYST IN FUEL-PROPERTY REFORMING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based on Japanese Patent Application No. 2011-112142 filed on May 19, 2011, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a diagnostic apparatus for a catalyst in a fuel-property reforming system. The fuel-property reforming apparatus reforms a property of fuel supplied to an internal combustion engine. The property of fuel is referred to as fuel property, hereinafter.

BACKGROUND

[0003] JP-2004-218548A shows a fuel-property reforming apparatus which is provided with a heater and a catalyst for reforming fuel property in a fuel supply passage through which fuel flows from a fuel tank to a fuel injector.
[0004] If a malfunction occurs in the fuel-property reforming apparatus, it is likely that a combustion condition of the engine may be deteriorated. Thus, such a malfunction should be detected as early as possible.
[0005] If a reforming condition of fuel (e.g., a containing ratio of high boiling point component) is varied due to a malfunction of the fuel-property reforming apparatus, the fuel property (relative density and vapor pressure) is varied. In view of this, the apparatus shown in JP-2004-218548A is provided with a tank for storing the fuel flowing out from a fuel-property reforming apparatus, and a property sensor for detecting the fuel-property (relative density and vapor pressure) in the tank. By comparing the detected fuel-property with a reference value, it is determined whether a malfunction occurs in a fuel-property reforming apparatus.
[0006] However, in the fuel-property reforming apparatus shown in JP-2004-218548A, the tank and the property sensor are necessary, which increases a product cost thereof.

SUMMARY

[0007] It is an object of the present disclosure to provide a diagnostic apparatus for a catalyst in a fuel-property reforming system with low product cost.
[0008] According to the present disclosure, a diagnostic apparatus for a catalyst in a fuel-property reforming system includes: a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid; a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reaction-heat information.
[0009] Since no fuel tank for reforming fuel and no property sensor are necessary, the apparatus can be configured with low cost.
[0010] According to another aspect, a diagnostic apparatus includes: a combustion condition detecting portion which detects a combustion condition information of the internal combustion engine; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition information.
[0011] According to the other aspect, a diagnostic apparatus includes: a reforming-degree detecting portion which detects a reforming degree of the fuel at an outlet of the fuel-reforming catalyst; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming degree of the fuel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:
[0013] FIG. 1 is a schematic view of an engine control system according to a first embodiment of the present invention;
[0014] FIG. 2 is a time chart for explaining a diagnosis method of an exothermic-reaction catalyst, according to a first embodiment;
[0015] FIG. 3 is a time chart for explaining a diagnosis method of an endothermic-reaction catalyst, according to the first embodiment;
[0016] FIG. 4 is a flow chart showing a processing of a diagnosis of an exothermic-reaction catalyst according to the first embodiment;
[0017] FIG. 5 is a chart for explaining a relationship between a reforming-fuel injection quantity and a deterioration-determination threshold;
[0018] FIG. 6 is a chart for explaining a relationship between an EGR-gas quantity and a deterioration-determination threshold;
[0019] FIG. 7 is a flow chart showing a processing of a diagnosis of an endothermic-reaction catalyst according to the first embodiment;
[0020] FIG. 8 is a time chart for explaining a diagnosis method of an exothermic-reaction catalyst, according to a first embodiment;
[0021] FIG. 9 is a time chart for explaining a diagnosis method of an endothermic-reaction catalyst, according to a first embodiment;
[0022] FIG. 10 is a schematic view of an engine control system according to a second embodiment of the present invention;
[0023] FIG. 11 is a time chart for explaining a diagnosis method according to the second embodiment;
[0024] FIG. 12 is a flow chart showing a processing of a diagnosis method according to the second embodiment;
[0025] FIG. 13 is a time chart for explaining a diagnosis method according to the second embodiment;
[0026] FIG. 14 is a schematic view of an engine control system according to a third embodiment of the present invention;
[0027] FIG. 15 is a time chart for explaining a diagnosis method according to the third embodiment;
[0028] FIG. 16 is a flow chart showing a processing of a diagnosis method according to the third embodiment; and
FIG. 17 is a time chart for explaining a diagnosis method according to the third embodiment.

DETAILED DESCRIPTION

Embodiments of the present invention will be described, hereinafter.

First Embodiment

Referring to FIGS. 1 to 9, a first embodiment will be described hereinafter.

First, referring to FIG. 1, an engine control system is explained. An air cleaner 13 is arranged upstream of an intake pipe 12 of an internal combustion engine 11. A throttle valve 14 is arranged downstream of the air cleaner 13. An opening degree of the throttle valve 14 is adjusted by a motor (not shown).

A surge tank 15 is provided downstream of the throttle valve 14. An intake manifold 16 introducing air into each cylinder of the engine 11 is provided downstream of the surge tank 15, and the fuel injector 17 injecting the fuel is provided at a vicinity of an intake port (not shown) connected to the intake manifold 20 of each cylinder. A spark plug 18 is mounted on a cylinder head of the engine 11 corresponding to each cylinder to ignite air-fuel mixture in each cylinder.

An exhaust pipe 19 of the engine 11 is provided with a three-way catalyst 20 purifying CO, HC, NOx in the exhaust gas. Exhaust gas sensors 21 and 22, such as an air-fuel ratio sensor and an oxygen sensor, are disposed upstream and downstream of the three-way catalyst 20 to detect air-fuel ratio and rich/lean of the exhaust gas.

The engine 11 is provided with an exhaust gas recirculation (EGR) apparatus 23 for recirculating a part of exhaust gas into the intake pipe 12. The EGR apparatus 23 has an EGR pipe 24 connecting the exhaust pipe 19 upstream of the catalyst 20 and the intake pipe 12 downstream of the throttle valve 14. An EGR valve 25 is provided in the EGR pipe 24 to adjust an exhaust gas recirculation quantity (external EGR quantity).

The EGR pipe 24 has a reforming-fuel injection apparatus 27 which is provided with a fuel injector 26 injecting reforming-fuel into the EGR gas. This fuel injector 26 injecting the reforming-fuel is referred to as a reforming-fuel injector 26, hereinafter. Further, the EGR pipe 24 has a fuel-property reforming apparatus 29 which is provided with a fuel-reforming catalyst 28. An inlet-side temperature sensor 30 is disposed upstream of the fuel-reforming catalyst 28 in order to detect temperature of EGR gas upstream of the fuel-reforming catalyst 28. An outlet-side temperature sensor 31 is disposed downstream of the fuel-reforming catalyst 28 in order to detect temperature of EGR gas downstream of the fuel-reforming catalyst 28. These temperature sensors 30 and 31 function as a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst 28. The fuel injector 17 and the reforming-fuel injector 26 receive the fuel from a common fuel tank (not shown).

An airflow meter 32 detecting intake air flow rate and a crank angle sensor 33 are disposed at outer circumference of a crank shaft (not shown) to output a pulse signal every when the crank shaft rotates a specified crank angle. Based on the output signal of the crank angle sensor 33, a crank angle and an engine speed are detected.

The outputs of the above sensors are transmitted to an electronic control unit (ECU) 34. The ECU 34 includes a microcomputer which executes an engine control program stored in a Read Only Memory (ROM) to control a fuel injection quantity, an ignition timing, a throttle position (intake air flow rate) and the like.

When the driving condition of the engine 11 is a specified reforming-condition, for example, when the engine speed is low and the engine load is low, the ECU 34 switches an engine driving mode from a normal driving mode to a reforming driving mode. In the reforming driving mode, while the EGR valve 25 is opened to recirculate a part of exhaust gas into the intake pipe 12, the reforming-fuel injector 26 injects the reforming fuel into the EGR pipe 24. The injected reforming fuel is vaporized, whereby combustibility of the fuel in the EGR gas improved by the fuel-reforming catalyst 28. For example, hydrogen concentration of the EGR gas becomes higher. This reform fuel is supplied to the intake pipe 12 of the engine 11.

In a case that the fuel-reforming catalyst 28 is an exothermal-reaction catalyst, the ECU 34 executes a diagnosis shown in FIG. 4. In this diagnosis, a differential temperature "Tdif" between the temperature detected by the inlet-side temperature sensor 30 (Tin) and the temperature detected by the outlet-side temperature sensor 31 (Tout) during a fuel-reforming control is compared with a deterioration-determination threshold "Tth", whereby the computer determines whether the fuel-reforming catalyst 28 is deteriorated.

In a case that the fuel-reforming catalyst 28 is an exothermal-reaction catalyst, the fuel-reforming catalyst 28 is deteriorated, the calorific value of the fuel-reforming catalyst 28 is decreased and variation rate of the temperature "Tout" relative to the temperature "Tin" is also varied, as shown in FIG. 2. Thus, by comparing the differential temperature "Tdif" with the threshold "Tth", it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

Referring to FIG. 4, a processing of the diagnosis will be described hereinafter. The ECU 34 executes this diagnosis in a case that the fuel-reforming catalyst 28 is an exothermal-reaction catalyst.

The diagnosis routine shown in FIG. 4 is executed at a specified cycle while the ECU 34 is ON. This diagnosis routine corresponds to a catalyst diagnosis portion. In step 101, the computer determines whether the engine driving mode is the reforming driving mode. When the answer is NO, the procedure ends.

When the answer is YES in step 101, the procedure proceeds to step 102. In step 102, the EGR valve 25 is opened to recirculate a part of the exhaust gas into an intake pipe 12. Then, in step 103, the reforming-fuel injector 26 injects the reforming-fuel into the exhaust gas flowing through the EGR pipe 24. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst 28. The fuel-reforming catalyst 28 reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe 12. The reforming fuel quantity and the EGR gas quantity are computed according to the engine driving condition (engine speed and engine load) in view of a map. The above control is referred to as a fuel-reforming control.

Then, in step 104, the computer reads the temperature "Tin" and the temperature "Tout". In step 105, the computer computes the threshold "Tth" in view of a map which defines the threshold "Tth" according to the reforming-fuel injection quantity and the EGR gas quantity. In a case that the fuel-reforming catalyst 28 is an exothermal-reaction catalyst,
as the reforming-fuel injection quantity becomes larger, the threshold “Tth” becomes higher, as shown in FIG. 5. Further, as the reforming-fuel injection quantity becomes larger, the threshold “Tth” becomes higher, as shown in FIG. 6. Besides, the threshold “Tth” may be corrected based on the temperature “Tin”.

[0046] Then, the procedure proceeds to step 106 in which the computer determines whether the differential temperature “Tdif” is greater than or equal to the threshold “Tth”. When the answer is YES in step 106, the procedure proceeds to step 107 in which the computer determines that the fuel-reforming catalyst 28 is not deteriorated.

[0047] When the answer is NO in step 106, the procedure proceeds to step 108 in which the computer determines that the fuel-reforming catalyst 28 is deteriorated. Then, the procedure proceeds to step 109 in which the fail-safe processing is conducted. In this fail-safe processing, an opening degree of the EGR valve 25 is decreased to reduce the EGR gas quantity and the reforming-fuel injector 26 stops the reforming-fuel injection, whereby the fuel reforming is prohibited.

[0048] Meanwhile, in a case that the fuel-reforming catalyst 28 is an endothermal-reaction catalyst, the ECU 34 executes a diagnosis routine shown in FIG. 7. In this diagnosis, a differential temperature between the temperature detected by the inlet-side temperature sensor 30 and the temperature detected by the outlet-side temperature sensor 31 is compared with a deterioration-determination threshold, whereby the computer determines whether the fuel-reforming catalyst 28 is deteriorated.

[0049] In a case that the fuel-reforming catalyst 28 is an endothermal-reaction catalyst, if the fuel-reforming catalyst 28 is deteriorated, the endothermic value of the fuel-reforming catalyst 28 is decreased and variation rate of the temperature “Tout” relative to the temperature “Tin” is also varied, as shown in FIG. 3. Thus, by comparing the differential temperature “Tdif” with the threshold “Tth”, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

[0050] Referring to FIG. 7, a processing of the diagnosis will be described hereinafter. The ECU 34 executes this diagnosis in a case that the fuel-reforming catalyst 28 is an endothermal-reaction catalyst.

[0051] In step 101, the computer determines whether the engine driving mode is the reforming driving mode. When the answer is YES in step 101, the procedure proceeds to step 102 in which the EGR valve 25 is opened to recirculate a part of the exhaust gas into an intake pipe 12. Then, in step 103, the reforming-fuel injector 26 injects the reforming-fuel into the exhaust gas flowing through the EGR pipe 24. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst 28. The fuel-reforming catalyst 28 reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe 12.

[0052] Then, in step 104, the computer reads the temperature “Tin” and the temperature “Tout”. In step 105, the computer computes the threshold “Tth” in view of a map which defines the threshold “Tth” according to the reforming-fuel injection quantity and the EGR gas quantity. In a case that the fuel-reforming catalyst 28 is an endothermal-reaction catalyst, as the reforming-fuel injection quantity becomes larger, the threshold “Tth” becomes lower. Further, as the EGR gas quantity becomes larger, the threshold “Tth” becomes lower. Besides, the threshold “Tth” may be corrected based on the temperature “Tin”.

[0053] Then, the procedure proceeds to step 106a in which the computer determines whether the differential temperature “Tdif” is less than or equal to the threshold “Tth”. When the answer is YES in step 106a, the procedure proceeds to step 107 in which the computer determines that the fuel-reforming catalyst 28 is not deteriorated.

[0054] When the answer is NO in step 106a, the procedure proceeds to step 108 in which the computer determines that the fuel-reforming catalyst 28 is deteriorated. Then, the procedure proceeds to step 109 in which the fail-safe processing is conducted.

[0055] Referring to time charts shown in FIGS. 8 and 9, a catalyst diagnosis will be described hereinafter. FIG. 8 shows a case of an exothermal-reaction catalyst, and FIG. 9 shows a case of endothermal-reaction catalyst.

[0056] When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve 25 is opened to recirculate a part of the exhaust gas into an intake pipe 12. Then, the reforming-fuel injector 26 injects the reforming-fuel into the exhaust gas flowing through the EGR pipe 24. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst 28. The fuel-reforming catalyst 28 reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe 12.

[0057] According to the first embodiment, while the reforming control is executed, the differential temperature “Tdif” between the temperature “Tout” and the temperature “Tin” is computed, and then the differential temperature “Tdif” is compared with the threshold “Tth” in order to determine whether the fuel-reforming catalyst 28 is deteriorated. Thus, it can be accurately determines whether the fuel-reforming catalyst 28 is deteriorated. Furthermore, since no fuel tank for reforming-fuel and no property sensor are necessary, the apparatus can be configured with low cost.

[0058] In a system having no catalyst diagnosis function, as shown by dashed lines in FIGS. 8 and 9, even if the fuel-reforming catalyst 28 is deteriorated, this deterioration can not be detected and no fail-safe processing can be conducted. Thus, it is likely that a combustion condition of the engine 11 is deteriorated and variation in torque occurs, which may deteriorate drivability.

[0059] According to the first embodiment, by comparing the differential temperature “Tdif” with the threshold “Tth”, it is determined whether the fuel-reforming catalyst 28 is deteriorated. When it is determined that the fuel-reforming catalyst 28 is deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

[0060] In the first embodiment, by comparing the differential temperature “Tdif” with the threshold “Tth”, it is determined whether the fuel-reforming catalyst 28 is deteriorated. The diagnosis method is not limited to this. For example, a ratio between the temperature “Tout” and the temperature “Tin” is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst 28 is deteriorated.

[0061] Alternatively, a differential temperature or a ratio between the temperature “Tout” detected before the fuel-reforming control is started and the temperature “Tout” detected after the fuel-reforming control is started may be compared with a deterioration-determination threshold, whereby the computer determines whether the fuel-reforming catalyst 28 is deteriorated. Alternatively, a catalyst tem-
perature sensor is provided in the fuel-reforming catalyst 28. A catalyst temperature detected before the fuel-reforming control is started and a catalyst temperature detected after the fuel-reforming control is started are compared with each other. Based on this differential temperature or its ratio, it can be determined whether the fuel-reforming catalyst 28 is deteriorated. When the fuel-reforming catalyst 28 is deteriorated, a reaction heat quantity of the fuel-reforming catalyst 28 is decreased. The catalyst temperature or the temperature “Tout” detected before the fuel-reforming control is started becomes different from the catalyst temperature or the temperature “Tout” detected after the fuel-reforming control is started. Thus, based on these temperatures, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

Alternatively, by comparing a catalyst temperature or the temperature “Tout” detected after the fuel-reforming control is started with a deterioration-determination threshold, it may be determined whether the fuel-reforming catalyst 28 is deteriorated.

Second Embodiment

Referring to FIGS. 10 to 13, a second embodiment will be described hereinafter. In the second embodiment, the same parts and components as those in the first embodiment are indicated with the same reference numerals and the same descriptions will not be reiterated.

As shown in FIG. 10, a combustion pressure sensor 35 is provided in the cylinder head 11 with respect to each cylinder. The combustion pressure sensor 35 detects combustion pressure a cylinder. The combustion pressure sensor 35 may be integrated with a spark plug 18. The temperature sensors 30 and 31 may not be provided.

According to the second embodiment, the ECU 34 executes a diagnosis routine shown in FIG. 12. During a fuel-reforming control, the computer computes a combustion parameter indicative of a combustion condition of the engine, based on an output signal of the combustion pressure sensor 35. This combustion parameter is compared with a deterioration-determination threshold, whereby it is determined whether the fuel-reforming catalyst 28 is deteriorated. As the combustion parameter, the coefficient of variation (COV), an ignition delay period, main combustion period, combustion center, and maximum value of combustion pressure is computed.

As shown in FIG. 11, when the catalyst 28 is deteriorated, the reforming degree of the fuel by the catalyst 28 is deteriorated and the combustion condition is varied, so that the combustion parameter is also varied. Thus, by comparing the combustion parameter detected during the fuel-reforming control with the threshold, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

Referring to FIG. 12, a processing of the diagnosis routine will be described hereinafter.

This diagnosis routine is executed at specified intervals while the ECU 34 is ON. In step S201, the computer determines whether the engine driving mode is the reforming-driving mode. When the answer is YES, the procedure proceeds to step S202 in which the EGR valve 25 is opened. Then, the procedure proceeds to step S203 in which the reforming-fuel injector 26 injects the reforming-fuel into the EGR gas. The fuel is reformed in the fuel-reforming catalyst 28.

Then, the procedure proceeds to step S204 in which the combustion parameter is computed based on the output signal of the combustion pressure sensor 35. The process in step S204 corresponds to a combustion-condition-information detecting portion.

Then, the procedure proceeds to step S205 in which a deterioration-determination threshold is computed according to the reforming fuel injection quantity and the EGR gas quantity in view of a map. Besides, the deterioration-determination threshold may be corrected based on the combustion parameter detected before the fuel-reforming control is started.

Then, the procedure proceeds to step S206 in which the computer determines whether the combustion parameter is within a normal range. In a case that the combustion parameter is the combustion stability index, the ignition delay time or the main combustion period, if the combustion parameter is less than the deterioration-determination threshold, the computer determines that the combustion parameter is within the normal range. In a case that the combustion parameter is the combustion center or the maximum combustion pressure, if the combustion parameter is greater than the deterioration-determination threshold, the computer determines that the combustion parameter is within the normal range.

When the answer is YES in step S206, the procedure proceeds to step S207 in which the computer determines that the fuel-reforming catalyst 28 is not deteriorated.

When the answer is NO in step S206, the procedure proceeds to step S208 in which the computer determines that the fuel-reforming catalyst 28 is deteriorated. Then, the procedure proceeds to step S209 in which the fail-safe processing is conducted.

Referring to a time chart shown in FIG. 13, a catalyst diagnosis according to the second embodiment will be described hereinafter.

When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve 25 is opened to recirculate a part of the exhaust gas into an intake pipe 12. Then, the reforming-fuel injector 26 injects the reforming-fuel into the exhaust gas flowing through the EGR pipe 24. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst 28. The fuel-reforming catalyst 28 reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe 12.

According to the second embodiment, the computer computes the combustion parameter based on the output of the combustion pressure sensor 35 while the fuel-reforming control is performed. This combustion parameter is compared with the threshold in order to determine whether the fuel-reforming catalyst 28 is deteriorated. Thus, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

In a system having no catalyst diagnosis function, as shown by dashed lines in FIG. 13, even if the fuel-reforming catalyst 28 is deteriorated, this deterioration cannot be detected and no fail-safe processing can be conducted. Thus, it is likely that the combustion condition of the engine 11 is deteriorated and variation in torque occurs, which may deteriorate drivability.

According to the second embodiment, by comparing the combustion parameter with the threshold, it is determined whether the fuel-reforming catalyst 28 is deteriorated. When it is determined that the fuel-reforming catalyst 28 is
deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

[0080] In the second embodiment, by comparing the combustion parameter with the threshold, it is determined whether the fuel-reforming catalyst 28 is deteriorated. The diagnosis method is not limited to this. For example, a difference or a ratio between the combustion parameter detected before the fuel-reforming control is started and the combustion parameter detected after the fuel-reforming control is started is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst 28 is deteriorated.

[0081] As shown in FIG. 11, when the catalyst 28 is deteriorated, the reforming degree of the fuel by the catalyst 28 is deteriorated and the combustion condition is varied before and after the fuel-reforming control. Thus, based on these combustion parameters, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

[0082] As the combustion parameter, an EGR limit, combustion speed, a variation in engine speed, or variation in engine torque may be detected.

[0083] Instead of the combustion pressure sensor 35, a current sensor detecting ion current flowing through the spark plug 18 may be applied.

Third Embodiment

[0084] Referring to FIGS. 14 to 17, a third embodiment will be described hereinafter. In the third embodiment, the same parts and components as those in the first and the second embodiment are indicated with the same reference numerals and the same descriptions will not be reiterated.

[0085] As shown in FIG. 14, a reforming-degree sensor 36 is provided downstream of the fuel-reforming catalyst 28 for detecting a reforming degree of the fuel. The reforming-degree sensor 36 is, for example, a hydrogen sensor which detects hydrogen concentration of the exhaust gas flowing through the EGR pipe 24. Besides, the temperature sensors 30 and 31 may not be provided.

[0086] According to the third embodiment, the ECU 34 executes a diagnosis routine shown in FIG. 16. In this diagnosis, while the fuel-reforming control is performed, a reforming degree of the fuel is compared with a threshold, whereby the computer determines whether the fuel-reforming catalyst 28 is deteriorated.

[0087] As shown in FIG. 15, when the catalyst 28 is deteriorated, the reforming degree of the fuel by the catalyst 28 is deteriorated. Thus, by comparing the reforming degree of the fuel with the threshold, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

[0088] Referring to FIG. 16, a processing of the diagnosis routine will be described hereinafter.

[0089] This diagnosis routine is executed at specified intervals while the ECU 34 is ON. In step S301, the computer determines whether the engine driving mode is the reforming-driving mode. When the answer is YES, the procedure proceeds to step S302 in which the EGR valve 25 is opened. Then, the procedure proceeds to step S303 in which the reforming-fuel injector 26 injects the reforming-fuel into the EGR gas. The fuel is reformed in the fuel-reforming catalyst 28.

[0090] Then, in step S304, the computer reads the reforming degree detected by the sensor 36. In step S305, the computer computes the threshold in view of a map which defines the threshold according to the reforming-fuel injection quantity and the EGR gas quantity. Besides, the deterioration-determination threshold may be corrected based on a reforming degree which is detected before the fuel-reforming control is started.

[0091] In step S306, the computer determines whether the reforming degree is greater than or equal to a deterioration-determination threshold. When the answer is YES in step S306, the procedure proceeds to step S307 in which the computer determines that the fuel-reforming catalyst 28 is not deteriorated.

[0092] When the answer is NO in step S306, the procedure proceeds to step S308 in which it is determined that the fuel-reforming catalyst 28 is deteriorated. Then, in step S309, the fail-safe processing is conducted.

[0093] Referring to a time chart shown in FIG. 17, a catalyst diagnosis according to the third embodiment will be described hereinafter.

[0094] When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve 25 is opened to recirculate a part of the exhaust gas into an intake pipe 12. Then, the reforming-fuel injector 26 injects the reforming-fuel into the exhaust gas flowing through the EGR pipe 24. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst 28. The fuel-reforming catalyst 28 reform the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe 12.

[0095] According to the third embodiment, while the fuel-reforming control is performed, the reforming-degree sensor 36 detects the reforming degree of the fuel (for example, hydrogen concentration) and then the reforming degree of the fuel is compared with the threshold to determine whether the fuel-reforming catalyst 28 is deteriorated. Thus, it is accurately whether the fuel-reforming catalyst 28 is deteriorated.

[0096] In a system having no catalyst diagnosis function, as shown by dashed lines in FIG. 17, even if the fuel-reforming catalyst 28 is deteriorated, this deterioration cannot be detected and no fail-safe processing can be conducted. Thus, it is likely that the combustion condition of the engine 11 is deteriorated and variation in torque occurs, which may deteriorate drivability.

[0097] According to the third embodiment, by comparing the reforming degree with the threshold, it is determined whether the fuel-reforming catalyst 28 is deteriorated. When it is determined that the fuel-reforming catalyst 28 is deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

[0098] In the third embodiment, the reforming degree is detected while the fuel-reforming control is performed. Then, the reforming degree is compared with the threshold, whereby it is determined whether the fuel-reforming catalyst 28 is deteriorated. The diagnosis method is not limited to this. For example, a difference or a ratio between the reforming degree detected before the fuel-reforming control is started and the reforming degree detected after the fuel-reforming control started is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst 28 is deteriorated.

[0099] When the catalyst 28 is deteriorated, the reforming degree of the fuel by the catalyst 28 is deteriorated and the reforming degree is varied before and after the fuel-reforming
control. Thus, based on these reforming degrees, it can be accurately determined whether the fuel-reforming catalyst 28 is deteriorated.

[0100] The reforming-fuel injector and the fuel-reforming catalyst may be arranged downstream of a supercharger in the intake pipe.

[0101] The present invention is not limited to an intake port injection engine. The present invention can be applied to a direct injection engine or a dual injection engine.

What is claimed is:

1. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:
   a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine;
   a fuel-reforming catalyst for reforming the fuel in the medium fluid;
   a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst; and
   a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reaction-heat information.

2. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 1, wherein:
   the reaction-heat detection portion includes an inlet-side temperature sensor disposed upstream of the fuel-reforming catalyst and an outlet-side temperature sensor disposed downstream of the fuel-reforming catalyst; the catalyst-inlet temperature and the catalyst-outlet temperature are detected while a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is executed; and
   the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on a catalyst-inlet temperature detected by the inlet-side temperature sensor and a catalyst-outlet temperature detected by the outlet-side temperature sensor.

3. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 1, wherein:
   the reaction-heat detection portion includes a temperature detecting portion which detects a temperature at a temperature at an outlet of the fuel-reforming catalyst;
   the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the temperatures of fuel-reforming catalyst or a temperature at an outlet of the fuel-reforming catalyst which are detected before and after the fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

4. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:
   a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid; a combustion-condition detecting portion which detects a combustion-condition information of the internal combustion engine; a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition information.

5. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 4, wherein:
   the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition informations which are detected before and after a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

6. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 4, wherein:
   the combustion-condition detecting portion detects, as the combustion-condition information, at least one of a combustion stability index, an ignition delay period, a main combustion period, a combustion center, a maximum combustion pressure, an EGR limit, and a combustion speed.

7. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:
   a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid; a reforming-degree detecting portion which detects an reforming degree of the fuel at an outlet of the fuel-reforming catalyst; and
   a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming degree of the fuel.

8. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 7, wherein:
   the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming-degrees of the fuel which are detected before and after a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

9. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim 7, wherein:
   the reforming-degree detecting portion is a hydrogen sensor which detects hydrogen concentration in the fuel as the reforming-degree of the fuel.