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(54) **INTERNAL COMBUSTION ENGINE CONTROL DEVICE**

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(52) **U.S. Cl.**
CPC ***F02D 41/0255*** (2013.01); *F01N 2430/06* (2013.01); *F01N 2900/1402* (2013.01)

(58) **Field of Classification Search**
CPC F02D 41/0255; F01N 2900/1402
See application file for complete search history.

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* cited by examiner

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(57) **ABSTRACT**

The internal combustion engine includes a fuel injection valve, a cylinder into which the fuel injected by the fuel injection valve is introduced, an exhaust passage through which the exhaust generated by the combustion of the fuel in the cylinder flows, a catalyst installed in the exhaust passage, an upstream air-fuel ratio sensor disposed upstream of the catalyst in the exhaust passage, and a downstream air-fuel ratio sensor disposed downstream of the catalyst in the exhaust passage. The processing circuit calculates a detection value difference which is a difference between detection values of the two air-fuel ratio sensors when the warm-up of the catalyst is completed. When the detection value difference is in the predetermined detection value difference range, the processing circuit lowers the warm-up completion temperature as compared with a case where the detection value difference is not in the detection value difference range.

5 Claims, 5 Drawing Sheets

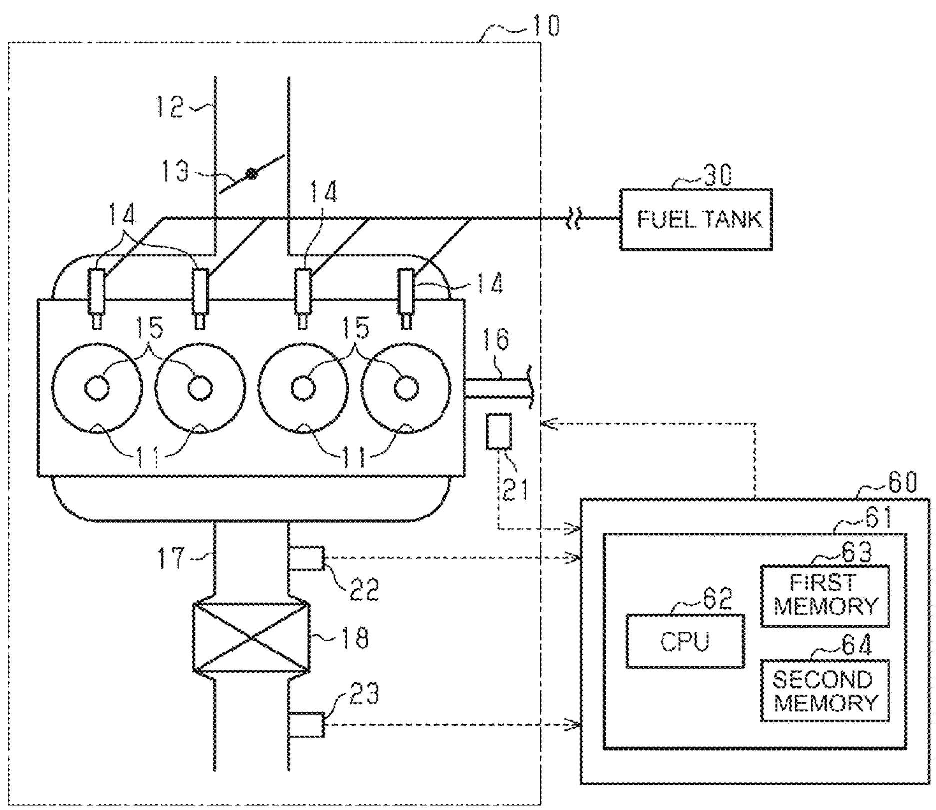


FIG. 1

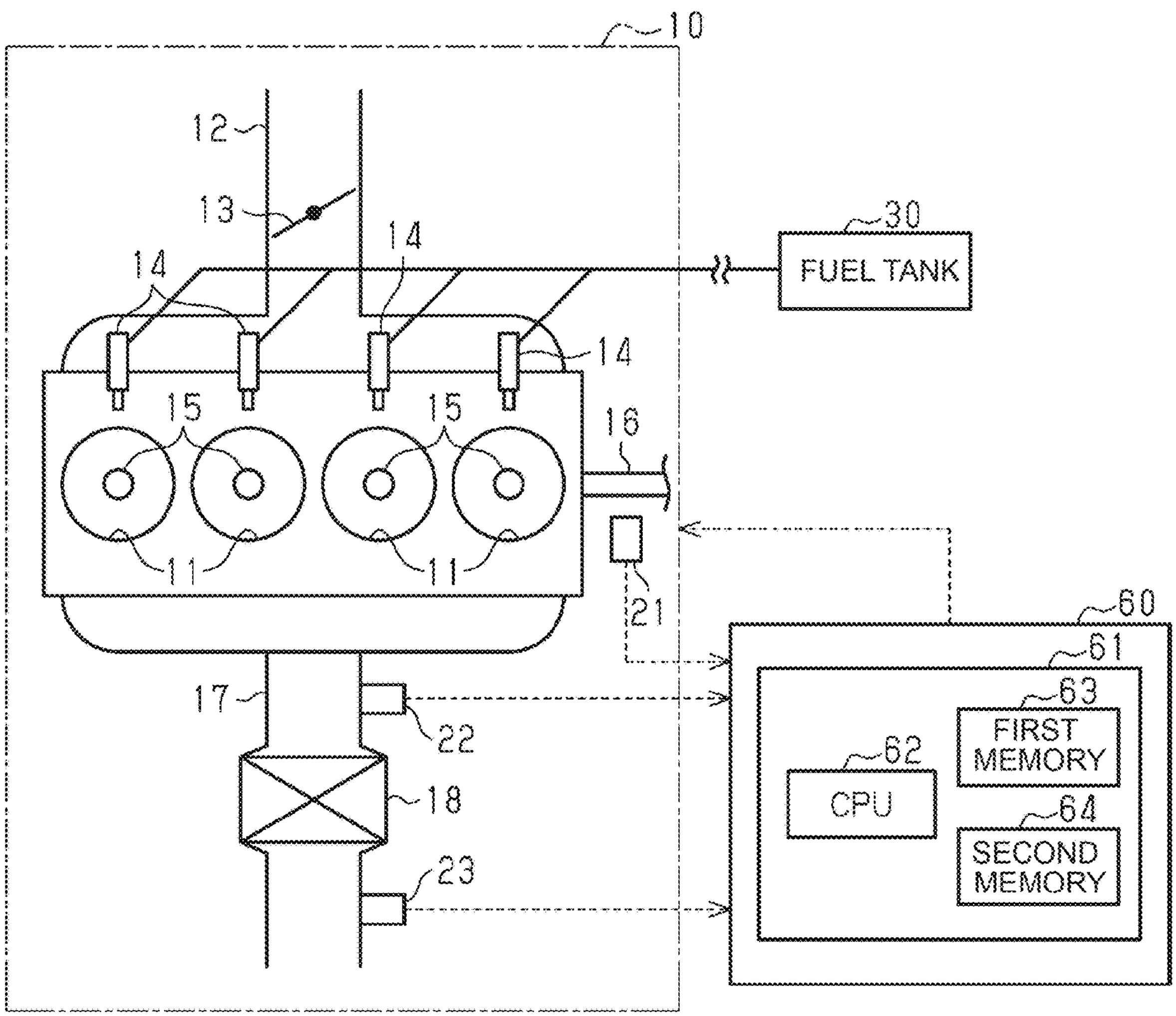

10
12
13
14
14
14
30
FUEL TANK
15
15
16
11
11
21
60
61
63
FIRST MEMORY
62
CPU
64
SECOND MEMORY
17
22
18
23

FIG. 2

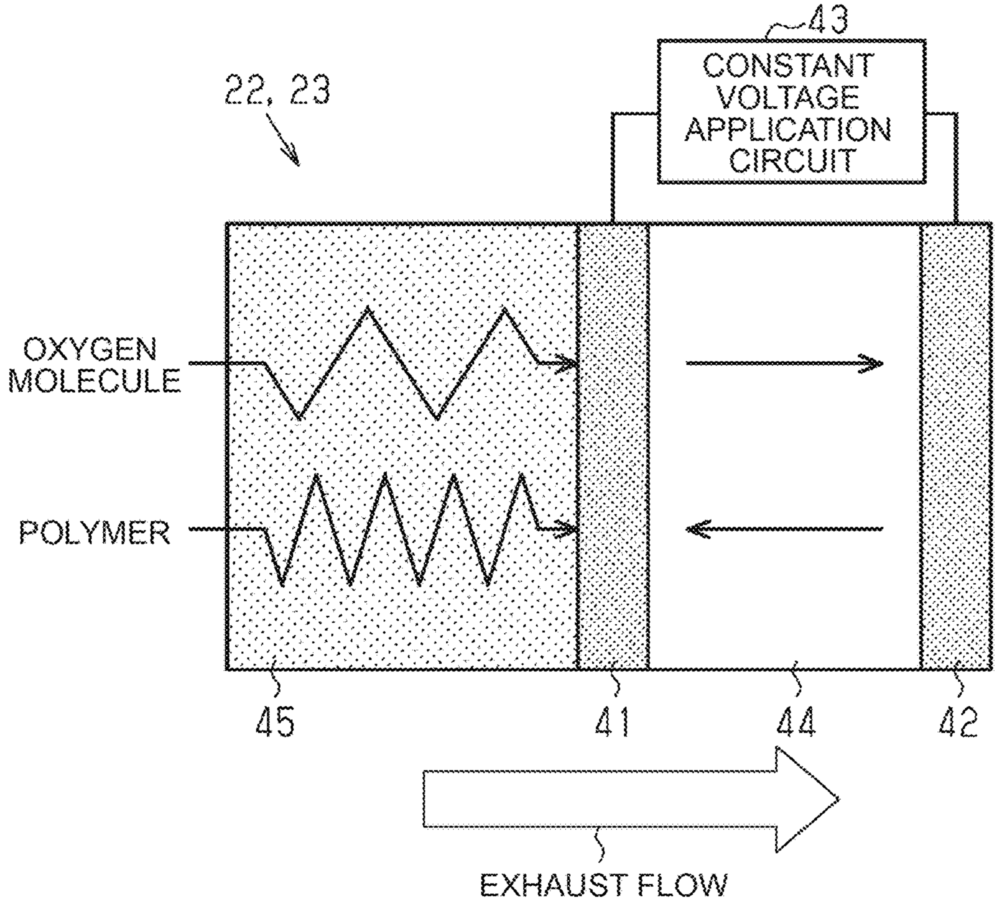

43
CONSTANT VOLTAGE APPLICATION CIRCUIT
22, 23
OXYGEN MOLECULE
POLYMER
45
41
44
42
EXHAUST FLOW

FIG. 3

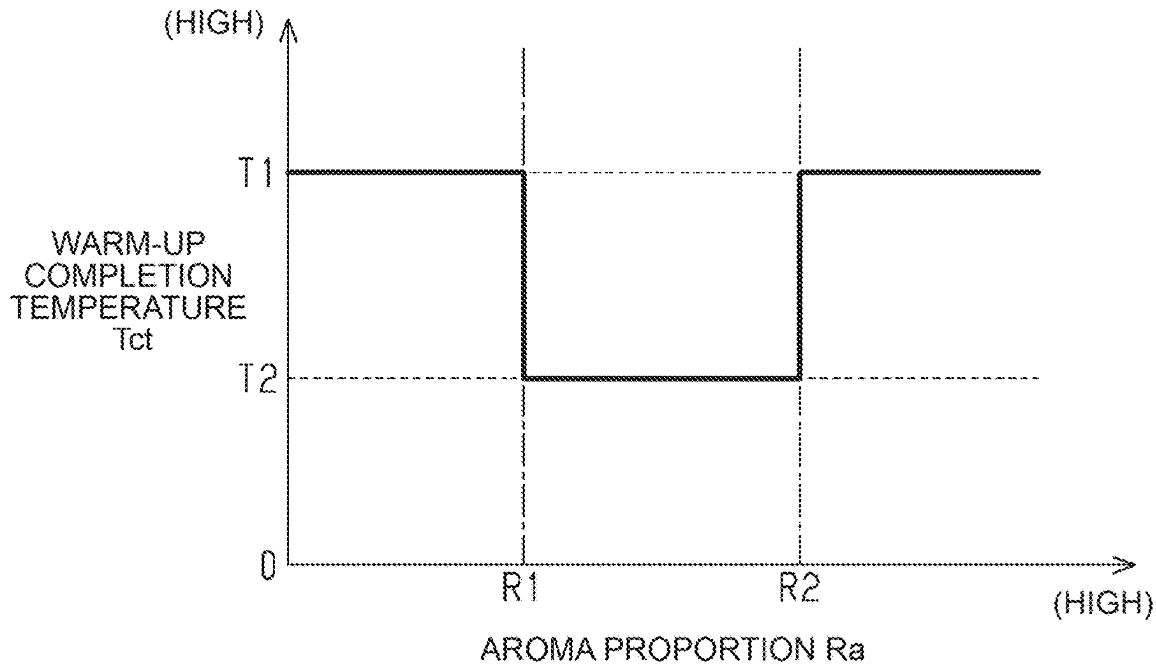

(HIGH)
T1
WARM-UP COMPLETION TEMPERATURE Tct
T2
0
R1
R2
(HIGH)
AROMA PROPORTION Ra

FIG. 4A

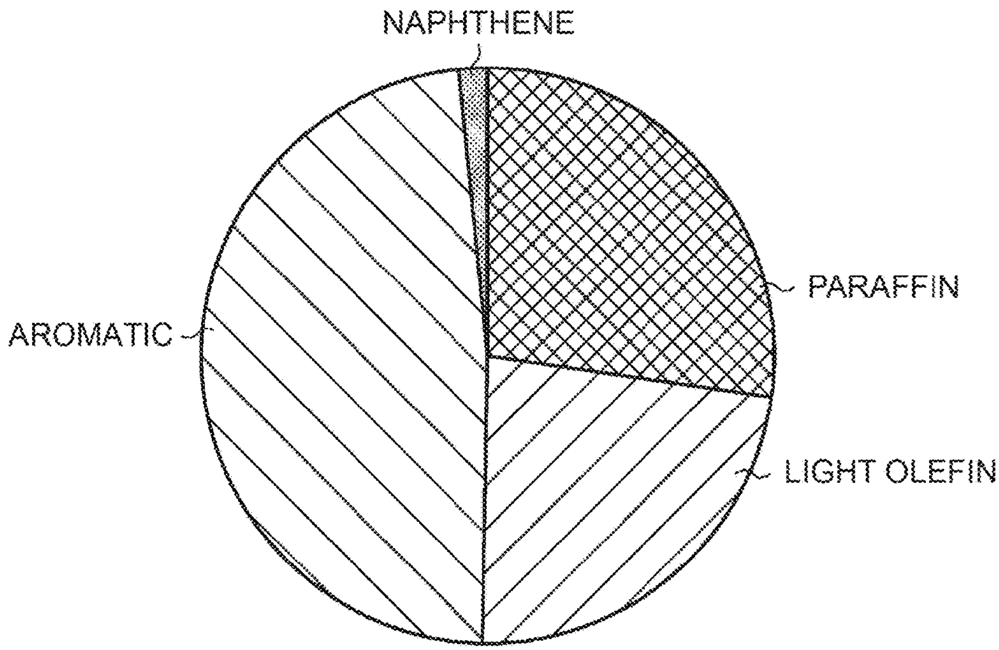

NAPHTHENE
PARAFFIN
AROMATIC
LIGHT OLEFIN

FIG. 4B

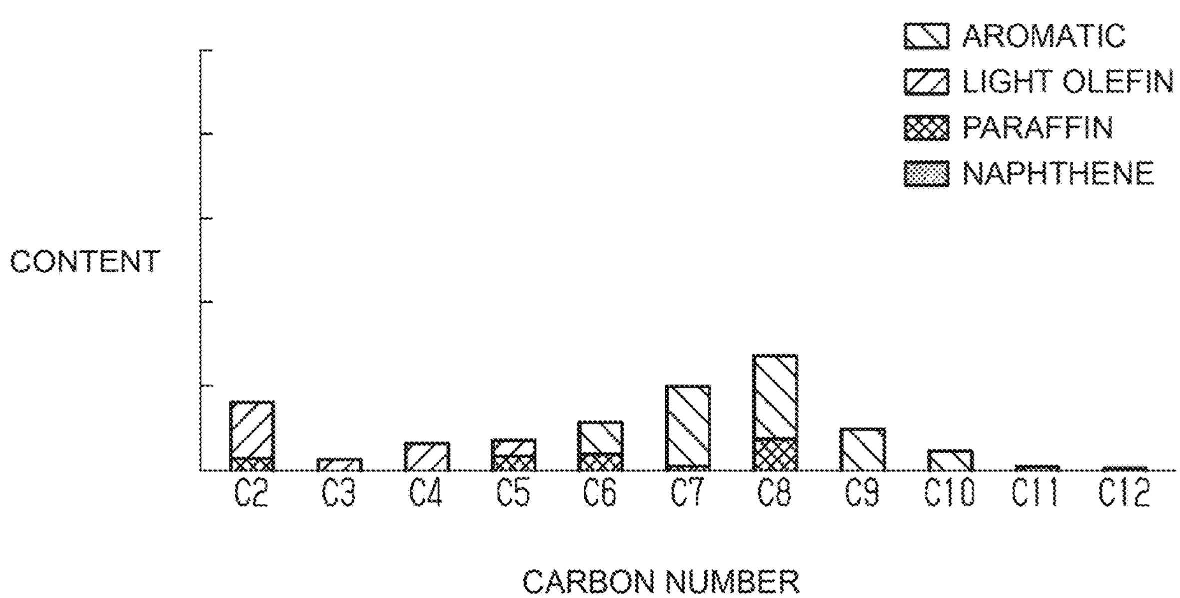

AROMATIC
LIGHT OLEFIN
PARAFFIN
NAPHTHENE
CONTENT
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
CARBON NUMBER

FIG. 5

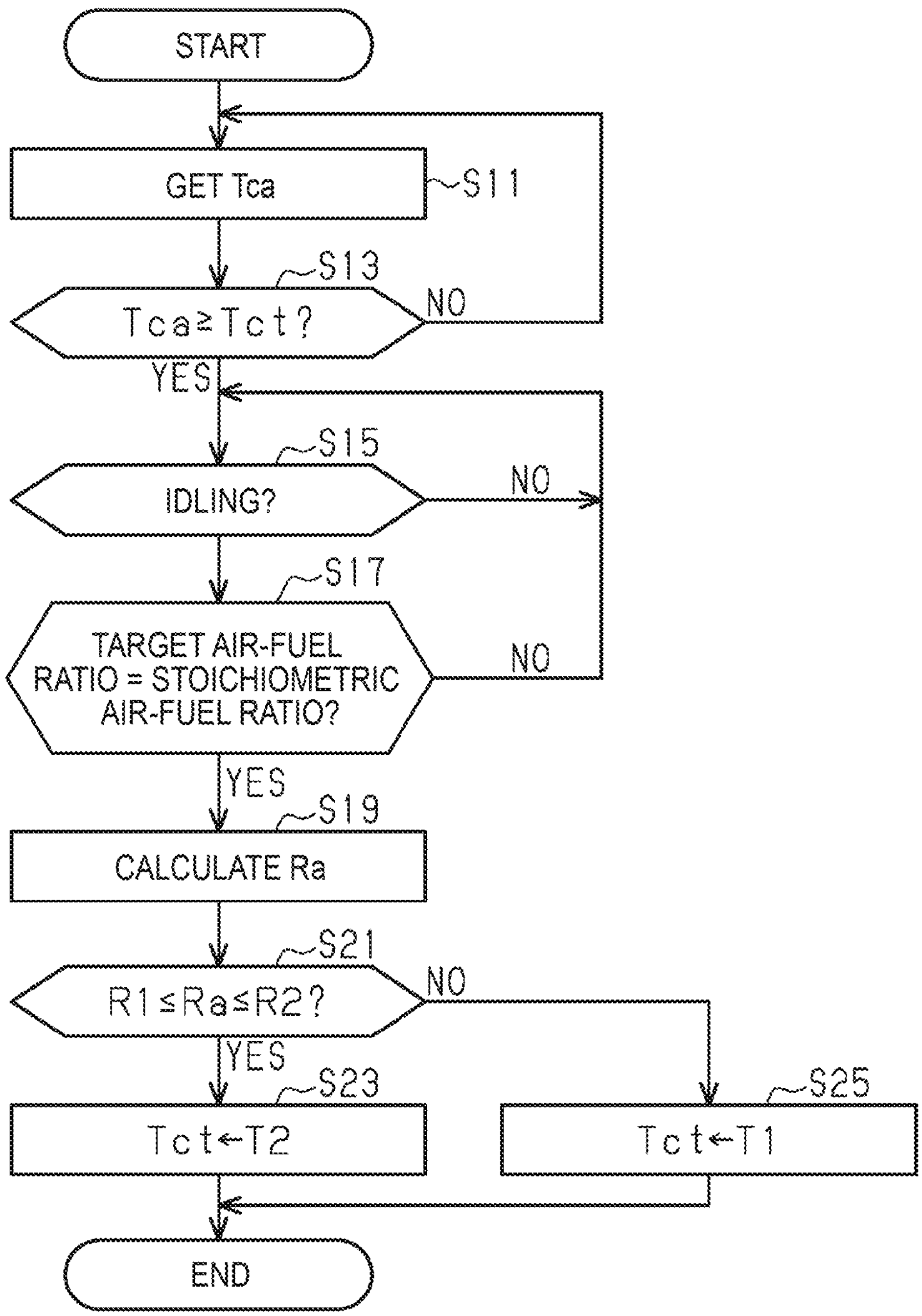
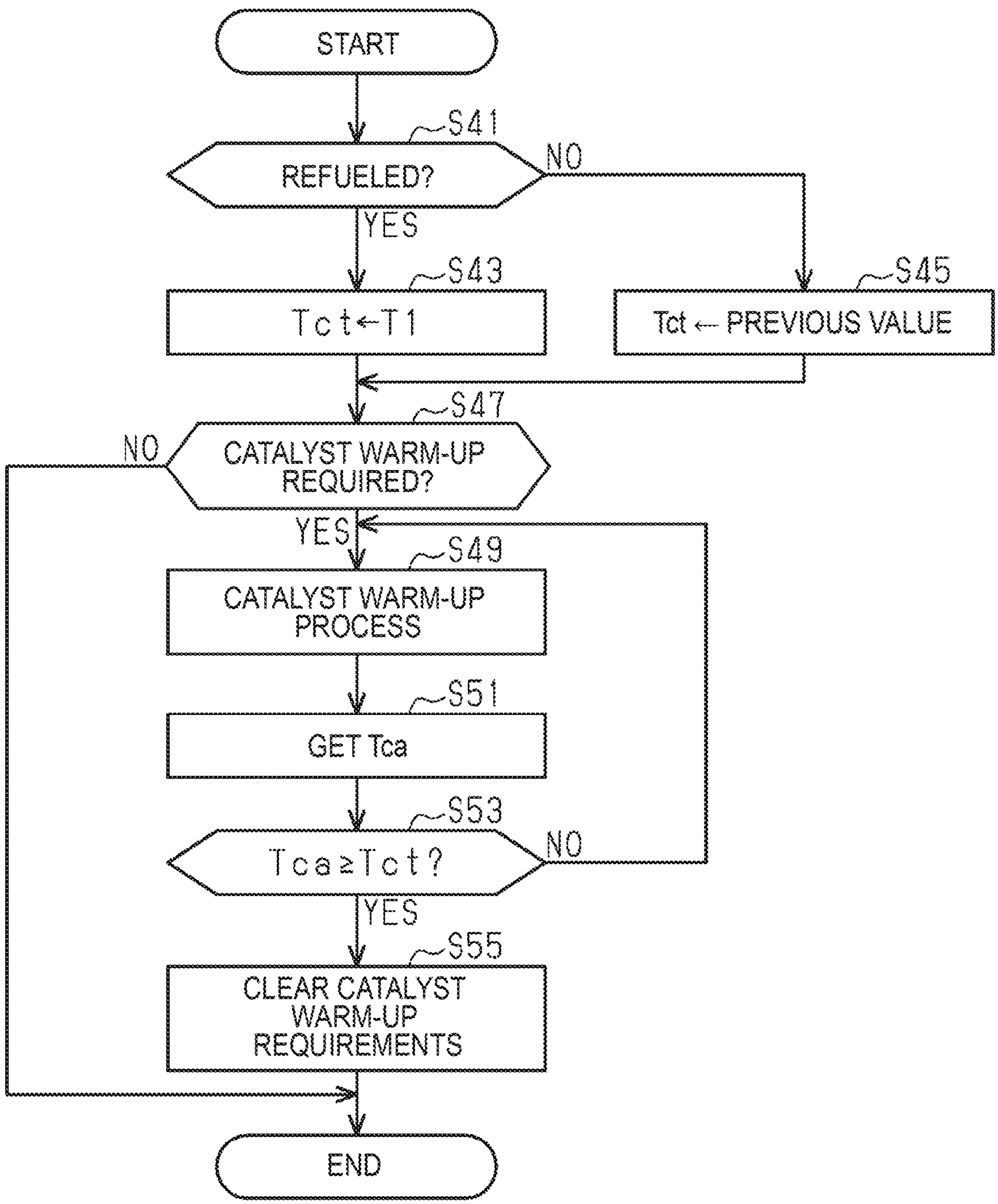

START
GET Tca
S11
S13
Tca≥Tct?
NO
YES
S15
IDLING?
NO
S17
TARGET AIR-FUEL RATIO = STOICHIOMETRIC AIR-FUEL RATIO?
NO
YES
S19
CALCULATE Ra
S21
R1≤Ra≤R2?
NO
YES
S23
Tct←T2
S25
Tct←T1
END

FIG. 6


START
S41
REFUELED?
NO
YES
S43
Tct←T1
S45
Tct ← PREVIOUS VALUE
S47
CATALYST WARM-UP REQUIRED?
NO
YES
S49
CATALYST WARM-UP PROCESS
S51
GET Tca
S53
Tca≥Tct?
NO
YES
S55
CLEAR CATALYST WARM-UP REQUIREMENTS
END

INTERNAL COMBUSTION ENGINE CONTROL DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2024-015626 filed on Feb. 5, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to internal combustion engine control devices that are applied to spark ignition internal combustion engines.

2. Description of Related Art

Japanese Unexamined Patent Application Publication No. 2013-72313 (JP 2013-72313 A) discloses a control device that is applied to a spark ignition internal combustion engine. This internal combustion engine includes a catalyst installed in an exhaust passage, an upstream oxygen sensor disposed upstream of the catalyst in the exhaust passage, and a downstream oxygen sensor disposed downstream of the catalyst in the exhaust passage. The control device performs rich/lean control when warming up the catalyst by retarding the ignition timing. The control device determines the degree of activity of the catalyst based on the difference between the rich/lean cycles that can be acquired from detection values from the two oxygen sensors at this time.

SUMMARY

When the rich/lean control is performed, the proportion of unburned HC components in exhaust flowing into the catalytic increases. However, if the catalyst is not activated, the catalyst cannot control the exhaust. Therefore, if the rich/lean control is performed before the catalyst is activated, the properties of the exhaust flowing downstream of the catalyst in the exhaust passage deteriorate.

A first aspect of an internal combustion engine control device for solving the above issue is applied to a spark ignition internal combustion engine including a fuel injection valve that injects fuel containing gasoline, a cylinder into which the fuel injected from the fuel injection valve is introduced, an exhaust passage through which exhaust generated by combustion of the fuel in the cylinder flows, a catalyst installed in the exhaust passage, an upstream air-fuel ratio sensor disposed upstream of the catalyst in the exhaust passage, and a downstream air-fuel ratio sensor disposed downstream of the catalyst in the exhaust passage.

The internal combustion engine control device includes a processing circuit configured to perform a catalyst warm-up process when a temperature of the catalyst is lower than a warm-up completion temperature. The catalyst warm-up process is a process of increasing the temperature of the catalyst.

The processing circuit is configured to, when a proportion of a heavy component in the exhaust discharged from the cylinder to the exhaust passage is in a predetermined proportion range, set the warm-up completion temperature to a lower value than when the proportion is not in the proportion range.

A second aspect of an internal combustion engine control device for solving the above issue is applied to a spark ignition internal combustion engine including a fuel injection valve that injects fuel containing gasoline, a cylinder into which the fuel injected from the fuel injection valve is introduced, an exhaust passage through which exhaust generated by combustion of the fuel in the cylinder flows, a catalyst installed in the exhaust passage, an upstream air-fuel ratio sensor disposed upstream of the catalyst in the exhaust passage, and a downstream air-fuel ratio sensor disposed downstream of the catalyst in the exhaust passage.

The internal combustion engine control device includes a processing circuit configured to perform a catalyst warm-up process when a temperature of the catalyst is lower than a warm-up completion temperature. The catalyst warm-up process is a process of increasing the temperature of the catalyst.

The processing circuit is configured to calculate a detection value difference that is a difference between detection values from the two air-fuel ratio sensors when warm-up of the catalyst is completed, and when the detection value difference is in a predetermined detection value difference range, set the warm-up completion temperature to a lower value than when the detection value difference is not in the detection value difference range.

The above internal combustion engine control device is advantageous in that it can activate the catalyst at an early stage while reducing deterioration in properties of the exhaust.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

FIG. **1** is a schematic configuration diagram illustrating an embodiment of an internal combustion engine control device and an internal combustion engine to which the internal combustion engine control device is applied;

FIG. **2** is a schematic diagram illustrating an air-fuel ratio sensor in an internal combustion engine;

FIG. **3** is a diagram illustrating a relationship between an aromatics proportion and a warm-up completion temperature;

FIG. **4**A is a diagrammatic representation of the proportions of various components of unburned HC components in exhaust air;

FIG. **4**B is a graph showing the relation between the carbon-number and the content of various components;

FIG. **5** is a flow chart showing a series of processes for setting a warm-up completion temperature; and

FIG. **6** is a flowchart showing a series of processes when the catalyst warm-up process is executed at the time of starting the internal combustion engine.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment of an internal combustion engine control device will be described with reference to FIG. **1** to FIG. **6**.

FIG. **1** illustrates a spark ignition type internal combustion engine **10** and a control device **60** applied to the internal combustion engine **10**. The control device **60** corresponds to an “internal combustion engine control device”. The fuel used in the internal combustion engine **10** includes gasoline. That is, the fuel is a fuel containing at least gasoline among gasoline and alcohol.

Configuration of Internal Combustion Engine

The internal combustion engine **10** includes a plurality of cylinders **11**, an intake passage **12**, a plurality of fuel injection valves **14**, a plurality of ignition devices **15**, a crankshaft **16**, and an exhaust passage **17**.

The intake passage **12** is a passage through which air to be introduced into the plurality of cylinders **11** flows. A throttle valve **13** is installed in the intake passage **12**. By adjusting the opening degree of the throttle valve **13**, the intake air amount, which is the amount of air flowing through the intake passage **12**, is adjusted.

The plurality of fuel injection valves **14** inject the fuel supplied from the fuel tank **30**. The fuel injection valve **14** may be a port injection valve that injects fuel into the intake passage **12**, or may be an in-cylinder injection valve that injects fuel into the cylinder **11**. In the plurality of cylinders **11**, an air-fuel mixture containing air and fuel is burned by the discharge of the ignition devices **15**. The power obtained by the combustion of the air-fuel mixture is transmitted to the crankshaft **16**, so that the crankshaft **16** rotates. In the plurality of cylinders **11**, exhaust is generated by combustion of the air-fuel mixture. Such exhaust is discharged from the inside of the plurality of cylinders **11** to the exhaust passage **17**.

In the exhaust passage **17**, the exhaust discharged from the plurality of cylinders **11** flows. A catalyst **18** is installed in the exhaust passage **17**. An example of the catalyst **18** is a three-way catalyst that reduces the exhaust flowing through the exhaust passage **17**.

The internal combustion engine **10** includes a plurality of sensors. The plurality of sensors includes a crank angle sensor **21**, an upstream air-fuel ratio sensor **22**, and a downstream air-fuel ratio sensor **23**. The crank angle sensor **21** outputs a signal corresponding to the rotational speed of the crankshaft **16**. The upstream air-fuel ratio sensor **22** is disposed upstream of the catalyst **18** in the exhaust passage **17**. The upstream air-fuel ratio sensor **22** detects the air-fuel ratio of the exhaust flowing toward the catalyst **18** as a detection value. The downstream air-fuel ratio sensor **23** is disposed downstream of the catalyst **18** in the exhaust passage **17**. The downstream air-fuel ratio sensor **23** detects the air-fuel ratio of the exhaust that has passed through the catalyst **18** as a detection value.

Hereinafter, the rotational speed of the crankshaft **16** according to the output signal of the crank angle sensor **21** is referred to as an "engine rotational speed NE". The detection value from the upstream air-fuel ratio sensor **22** may be referred to as "upstream air-fuel ratio AF**1**", and the detection value from the downstream air-fuel ratio sensor **23** may be referred to as "downstream detection value AF**2**".

The air-fuel ratio sensors **22** and **23** will be described with reference to FIG. **2**.

The air-fuel ratio sensors **22** and **23** are configured to be able to detect a deviation width of the air-fuel ratio of the exhaust from the stoichiometric air-fuel ratio. For example, the air-fuel ratio sensors **22** and **23** include a first electrode **41**, a second electrode **42**, and a constant voltage application circuit **43**. The second electrode **42** is positioned downstream of the first electrode **41** in the direction in which the exhaust flows. A solid electrolyte layer **44** is provided between the first electrode **41** and the second electrode **42**. The constant voltage application circuit **43** is operated so that a potential difference is generated between the first electrode **41** and the second electrode **42**. Therefore, in the solid electrolyte layer **44**, charge **15** transfer occurs between the first electrode **41** and the second electrode **42**.

Further, a diffusion layer **45** is provided upstream of the first electrode **41** in the direction in which the exhaust flows. Therefore, the molecules contained in the exhaust pass through the diffusion layer **45** and reach the first electrode **41**. The diffusion layer **45** is configured as a multiple network. Therefore, the passage time, which is the time required for the molecules to reach the first electrode **41** through the diffusion layer **45**, varies depending on the size of the molecules. Specifically, when the passage time of the oxygen molecule is set as the "reference time TMb", the passage time TMh of the polymer larger than the oxygen molecule becomes longer than the reference time TMb. Therefore, the higher the proportion of the polymer in the exhaust, the smaller the molecular weight that reaches the first electrode **41** within the unit time. As a result, as the proportion of the polymer in the exhaust increases, the detection values of the air-fuel ratio sensors **22** and **23** are shifted to the lean side from the actual air-fuel ratio.

Control Device

As shown in FIG. **1**, the control device **60** includes a processing circuit **61**. An example of the processing circuit **61** is an electronic control unit. The processing circuit **61** includes a CPU **62**, a first memory **63**, and a second memory **64**. The first memory **63** stores control programs executed by CPU **62**. The second memory **64** stores CPU **62** computations. When CPU **62** executes the control program of the first memory **63**, the processing circuit **61** controls the operation of the internal combustion engine **10**.

Catalyst Warm-Up Process

When the catalyst **18** is not activated because the temperature of the catalyst **18** is low, the exhaust control capability of the catalyst **18** is not sufficiently exhibited. Therefore, the processing circuit **61** executes the catalyst warm-up processing when the catalytic temperature Tca, which is the temperature of the catalyst **18**, is less than the warm-up completion temperature Tct. In the catalyst warm-up process, the processing circuit **61** increases the temperature of the exhaust discharged from the inside of the plurality of cylinders **11** to the exhaust passage **17** by retarding the ignition timing. Accordingly, the processing circuit **61** can increase the rate of increase of the catalytic temperature Tca.

The longer the execution time of the catalyst warm-up process, the worse the fuel efficiency of the internal combustion engine **10**. Therefore, in order to suppress deterioration in fuel efficiency, it is preferable to shorten the execution time of the catalyst warm-up process. Therefore, the processing circuit **61** changes the warm-up completion temperature Tct in accordance with the properties of the fuel that is burned in the plurality of cylinders **11**. For example, the processing circuit **61** determines whether the proportion of the heavy component in the exhaust is in a predetermined proportion range. When it is determined that the proportion of the heavy component is in the proportion range, the processing circuit **61** lowers the warm-up completion temperature Tct as compared with the case where it is determined that the proportion is not in the proportion component. For example, when determining that the proportion is not in the proportion range, the processing circuit **61** sets the reference temperature T**1** to the warm-up completion temperature Tct. On the other hand, if it is determined that the proportion is in the proportion range, the processing circuit **61** sets the specified temperature T**2** lower than the reference temperature T**1** to the warm-up completion temperature Tct.

Here, referring to FIGS. **4**A and **4**B, the reason for changing the warm-up completion temperature Tct according to the proportion of the heavy component in the exhaust will be described.

As shown in FIG. **4**A, the majority of unburned HC (hydrocarbons) components in the exhaust are paraffins, light olefins and aromatics. Although the unburned HC components comprise naphthenes, the naphthenes are very small. The proportion of paraffins is comparable to the proportion of light olefins. Here, a component having 7 or more carbon atoms is defined as a heavy component. As shown in FIG. **4**B, the content of the light olefin is relatively high in the low-carbon components. However, in the case of heavy components, the aromatic content is high. Thus, the heavy component can be considered to be an aromatic.

When the catalytic temperature Tca is less than the warm-up completion temperature Tct, the unburned HC components contained in the exhaust are adsorbed on the surface of the catalyst **18**. The unburned HC components adsorbed to the catalyst **18** have a poisoning effect. The degree of poisoning depends on the type of unburned HC components. For example, while light olefins and aromatics have no poisoning effects, paraffins have poisoning effects.

The activation temperature, which is the temperature of the catalyst **18** serving as a criterion for determining whether or not the catalyst **18** has been activated, varies depending on the unburned HC components. Specifically, among paraffins, light olefins, and aromatics, the activation temperature required by the light olefin is the lowest. The aromatic require a second lowest activation temperature. Paraffin requires the highest activation temperature. Therefore, the warm-up completion temperature Tct may be appropriately set depending on the unburned HC components. That is, the more components that require a lower activation temperature, the lower the appropriate warm-up completion temperature Tct.

As shown in FIG. **4**A, the proportions of paraffins and light olefins in the unburned HC components are comparable. Therefore, when the proportion of aromatics is known, an appropriate value of the warm-up completion temperature Tct is known.

As mentioned above, the heavy component of the exhaust can be regarded as an aromatic. Heavy components of the exhaust, such as aromatics, are molecules of larger size than oxygen molecules, i.e., the polymeric components described above. Therefore, the higher the proportion of the aromatics in the exhaust discharged from the plurality of cylinders **11** to the exhaust passage **17**, the first air-fuel ratio AF**1**, which is the detection value from the upstream air-fuel ratio sensor **22**, is shifted to a leaner value than the actual air-fuel ratio.

When the catalyst **18** is activated, the exhaust that has passed through the catalyst **18** contains few aromatics because the catalyst **18** can control the exhaust. Therefore, the second air-fuel ratio AF**2**, which is the detection value from the downstream air-fuel ratio sensor **23**, does not deviate from the actual air-fuel ratio to the lean-side value. Therefore, it can be inferred that the larger the detection value difference, which is the difference between the first air-fuel ratio AF**1** and the second air-fuel ratio AF**2**, is, the higher the proportion of aromatics in the exhaust discharged from the plurality of cylinders **11** to the exhaust passage **17** is. When the proportion of the aromatics in the exhaust discharged from the plurality of cylinders **11** to the exhaust passage **17** is defined as "aromatics proportion Ra", the warm-up completion temperature Tct can be set based on the aromatics proportion Ra.

Warm-Up Completion Temperature Setting Process

Referring to FIGS. **3** and **5**, a series of processing executed by the processing circuit **61** to set the warm-up completion temperature Tct will be described. The processing circuit **61** executes a series of processing illustrated in FIG. **5** on condition that both of the two air-fuel ratio sensors **22** and **23** are activated.

In S**11**, the processing circuit **61** obtains the catalytic temperature Tca. When the internal combustion engine **10** includes a sensor for detecting the temperature of the catalyst **18**, the processing circuit **61** acquires the temperature corresponding to the detection signal of the sensor as the catalytic temperature Tca. In the subsequent S**13**, the processing circuit **61** determines whether the catalytic temperature Tca is greater than or equal to the warm-up completion temperature Tct. When the catalytic temperature Tca is equal to or higher than the warm-up completion temperature Tct, it is assumed that the catalyst **18** is activated. On the other hand, when the catalytic temperature Tca is less than the warm-up completion temperature Tct, it is considered that the catalyst **18** is not yet activated. When the catalytic temperature Tca is equal to or higher than the warm-up completion temperature Tct (S**13**: YES), the processing circuit **61** shifts the processing to S**15**. On the other hand, when the catalytic temperature Tca is less than the warm-up completion temperature Tct (S**13**: NO), the processing circuit **61** shifts the processing to S**11**.

In S**15**, the processing circuit **61** determines whether the internal combustion engine **10** is idling. For example, if the engine speed NE is substantially equal to the idle speed, the processing circuit **61** may determine that the internal combustion engine **10** is idling. The idle speed is a target of the engine speed during idling. When the processing circuit **61** determines that the internal combustion engine **10** is idling (S**15**: YES), the processing proceeds to S**17**. On the other hand, when it is determined that the internal combustion engine **10** is not idling (S**15**: NO), the processing circuit **61** repeats the determination of S**15** until it can be determined that the internal combustion engine **10** is idling.

In S**17**, the processing circuit **61** determines whether the target air-fuel ratio is set to the stoichiometric air-fuel ratio. When the target air-fuel ratio is set to the stoichiometric air-fuel ratio (S**17**: YES), the processing circuit **61** shifts the processing to S**19**. On the other hand, when the target air-fuel ratio is set to an air-fuel ratio that differs from the stoichiometric air-fuel ratio (S**17**: NO), the processing circuit **61** shifts the processing to S**15**.

In S**19**, the processing circuit **61** calculates the aromatics proportion Ra. The processing circuit **61** calculates, as the aromatics proportion Ra, a detection value difference that is a difference between the first air-fuel ratio AF**1**, which is a detection value from the upstream air-fuel ratio sensor **22**, and the second air-fuel ratio AF**2**, which is a detection value from the downstream air-fuel ratio sensor **23**. In the following S**21**, the processing circuit **61** determines whether the aromatics proportion Ra is in a predetermined detection value difference range.

As shown in FIG. **3**, the lower limit of the detection value difference range is the aromatics proportion lower limit value R**1**, and the upper limit of the detection value difference range is the aromatics proportion upper limit value R**2**. The detection value difference range corresponds to the above-described proportion range. Therefore, when the aromatics proportion Ra is in the detection value difference range, it can be determined that the proportion of the heavy component in the exhaust is in the predetermined proportion range. On the other hand, when the aromatics proportion Ra is not in the detection value difference range, it can be determined that the proportion of the heavy component in the exhaust is not in the predetermined proportion range.

The paraffins contained in the unburned HC components are less flammable than light olefins and aromatics. The smaller the aromatics proportion Ra, the higher the proportion of paraffin in the unburned HC components occupied. Since the unburned HC components adsorbed to the catalyst **18** are less likely to burn, the catalyst **18** is less likely to be activated if the proportion of the unburned HC components to paraffin is large. Therefore, the aromatics proportion lower limit value R**1** is set as a criterion for determining whether the proportion of paraffin in the unburned HC components is high.

Light olefins, on the other hand, are more flammable than aromatics. The larger the aromatics proportion Ra, the smaller the proportion of light olefins among the unburned HC components. Therefore, as the aromatics proportion Ra increases, the unburned HC components adsorbed to the catalyst **18** are less likely to burn, and thus the catalyst **18** is less likely to be activated. Therefore, the aromatics proportion upper limit value R**2** is set as a criterion for determining whether the proportion of light olefins in the unburned HC components is small.

Returning to FIG. **5**, in S**21**, when the aromatics proportion Ra is in the detection value difference range (S**21**: YES), the processing circuit **61** shifts the processing to S**23**. In S**23**, the processing circuit **61** sets the specified temperature T**2** to the warm-up completion temperature Tct. Then, the processing circuit **61** ends the series of processing.

On the other hand, when the aromatics proportion Ra is not in the detection value difference range (S**21**: NO), the processing circuit **61** shifts the processing to S**25**. In S**25**, the processing circuit **61** sets the reference temperature T**1** to the warm-up completion temperature Tct. Then, the processing circuit **61** ends the series of processing.

Processing at Start of Internal Combustion Engine

A series of processes executed by the processing circuit **61** when the internal combustion engine **10** is started will be described with reference to FIG. **6**.

In S**41**, the processing circuit **61** determines whether or not the lubrication has been performed from the time when the operation of the internal combustion engine **10** was stopped last time to the time of the current start. When the processing circuit **61** determines that the refueling has been performed (S**41**: YES), the processing proceeds to S**43**. On the other hand, when the processing circuit **61** determines that the refueling is not performed (S**41**: NO), the processing proceeds to S**45**.

In S**43**, the processing circuit **61** sets the reference temperature T**1** to the warm-up completion temperature Tct. Then, the processing circuit **61** shifts the processing to S**47**.

In S**45**, the processing circuit **61** sets the previous value to the warm-up completion temperature Tct. The previous value is the warm-up completion temperature Tct at the time when the operation of the internal combustion engine **10** is stopped last time. Then, the processing circuit **61** shifts the processing to S**47**.

In S**47**, the processing circuit **61** determines whether there is a warm-up demand for the catalyst **18**. When both of the fact that the catalytic temperature Tca is less than the warm-up completion temperature Tct and the fact that there is no request to rapidly increase the engine speed NE are satisfied, it can be determined that there is a warm-up request. On the other hand, when the catalytic temperature Tca is equal to or higher than the warm-up completion temperature Tct or there is a request to rapidly increase the engine speed NE, it can be determined that there is no warm-up request. If it is determined that there is a warm-up request (S**47**: YES), the processing circuit **61** shifts the processing to S**49**. On the other hand, if it is determined that there is no warm-up request (S**47**: NO), the processing circuit **61** ends the series of processing.

In S**49**, the processing circuit **61** executes the catalyst warm-up process. In the following S**51**, the processing circuit **61** obtains the catalytic temperature Tca in the same manner as in the above S**11**. In the subsequent S**53**, the processing circuit **61** determines whether the catalytic temperature Tca is greater than or equal to the warm-up completion temperature Tct. When the catalytic temperature Tca is equal to or higher than the warm-up completion temperature Tct (S**53**: YES), it can be considered that the warm-up of the catalyst **18** is completed, and therefore, the processing circuit **61** shifts the processing to S**55**. On the other hand, when the catalytic temperature Tca is less than the warm-up completion temperature Tct (S**53**: NO), it is considered that the warm-up of the catalyst **18** is not completed, and therefore, the processing circuit **61** shifts the processing to S**49**. That is, the processing circuit **61** continues the catalyst warm-up processing.

In S**55**, the processing circuit **61** clears the warm-up requirement of the catalyst **18**. When the catalyst warm-up process is terminated as described above, the processing circuit **61** terminates the series of processes.

Operation and Effect of Present Embodiment (1) When warm-up of the catalyst **18** is completed while the internal combustion engine **10** is in operation, the processing circuit **61** calculates the detection value difference as the aromatics proportion Ra. When the aromatics proportion Ra is in the detection value difference range, the processing circuit **61** lowers the warm-up completion temperature Tct as compared with the case where the aromatics proportion Ra is not in the detection value difference range.

When the aromatics proportion Ra is in the detection value difference range, it can be determined that the proportion of the heavy component in the exhaust discharged from the plurality of cylinders **11** to the exhaust passage **17** is in the predetermined proportion range. Therefore, in such a case, the processing circuit **61** sets a lower temperature to the warm-up completion temperature Tct than in a case where it can be determined that the proportion of the heavy component is not in the predetermined proportion range. Thus, in a case where the catalyst warm-up process is executed at the next start of the internal combustion engine **10**, the processing circuit **61** can complete the catalyst warm-up process at an early stage. Moreover, as compared with the case where the lean/rich control is performed in a state where the catalyst **18** is not yet activated, the properties of the exhaust flowing downstream of the catalyst **18** in the exhaust passage **17** do not deteriorate.

Therefore, the control device **60** can activate the catalyst **18** at an early stage while suppressing deterioration in the properties of the exhaust discharged from the exhaust passage **17**.

(2) When the internal combustion engine **10** is idling, the quantity of the fuel introduced into the plurality of cylinders **11** is more stable than when the engine speed NE is changing. As a result, the air-fuel ratio is stable. Therefore, in the control device **60**, the processing circuit **61** calculates the detection value difference as the aromatics proportion Ra when the internal combustion engine **10** is idling and the warm-up of the catalyst **18** is completed. The processing circuit **61** uses the aromatics proportion Ra to set the

warm-up completion temperature Tct. Therefore, the control device **60** can increase the accuracy of setting the warm-up completion temperature Tct.

(3) When the fuel introduced into the plurality of cylinders **11** changes, the proportion of heavy components in the exhaust discharged from the plurality of cylinders **11** to the exhaust passage **17** may change. The phrase "the fuel introduced into the plurality of cylinders **11** changes" as used herein includes that fuel with a different proportion of alcohol is introduced into the cylinders **11**. During a period in which the operation of the internal combustion engine **10** is stopped, fuel with a different proportion of alcohol may be supplied to the fuel tank **30**.

Therefore, the processing circuit **61** sets the reference temperature T**1** to the warm-up completion temperature Tct when the refueling is performed from the time when the previous operation of the internal combustion engine **10** is ended to the time when the internal combustion engine **10** is started. That is, after the warm-up completion temperature Tct is lowered, the processing circuit **61** releases the condition in which the warm-up completion temperature Tct is lowered when it is detected that the fuel has been supplied. Thus, the control device **60** can suppress the catalyst warm-up process from being finished before the catalyst **18** is activated.

Modification

The above-described embodiment can be modified as follows. The above-described embodiments and the following modifications can be implemented in combination with each other as long as they are not technically contradictory.

- The processing circuit **61** does not necessarily set the reference temperature T**1** to the warm-up completion temperature Tct provided that the refueling has been performed.
- In the series of processes illustrated in FIG. **5**, the determination of S**15** may be omitted. If the catalyst **18** is activated, the processing circuit **61** may calculate the aromatics proportion Ra when the internal combustion engine **10** is not idling.
- The processing circuit **61** may employ a method different from the method of retarding the ignition timing as long as the temperature of the catalyst **18** can be increased in the catalyst warm-up process. For example, the processing circuit **61** may heat the catalyst **18** with a heater or the like, or may heat the catalyst **18** by energization.

What is claimed is:

1. An internal combustion engine control device that is applied to a spark ignition internal combustion engine including a fuel injection valve that injects fuel containing gasoline, a cylinder into which the fuel injected from the fuel injection valve is introduced, an exhaust passage through which exhaust generated by combustion of the fuel in the cylinder flows, a catalyst installed in the exhaust passage, an upstream air-fuel ratio sensor disposed upstream of the catalyst in the exhaust passage, and a downstream air-fuel ratio sensor disposed downstream of the catalyst in the exhaust passage, the internal combustion engine control device comprising a processing circuit configured to perform a catalyst warm-up process when a temperature of the catalyst is lower than a warm-up completion temperature, the catalyst warm-up process being a process of increasing the temperature of the catalyst, wherein

the processing circuit is configured to, when a proportion of a heavy component in the exhaust discharged from the cylinder to the exhaust passage is in a predetermined proportion range, set the warm-up completion temperature to a lower value than when the proportion is not in the proportion range.

2. An internal combustion engine control device that is applied to a spark ignition internal combustion engine including a fuel injection valve that injects fuel containing gasoline, a cylinder into which the fuel injected from the fuel injection valve is introduced, an exhaust passage through which exhaust generated by combustion of the fuel in the cylinder flows, a catalyst installed in the exhaust passage, an upstream air-fuel ratio sensor disposed upstream of the catalyst in the exhaust passage, and a downstream air-fuel ratio sensor disposed downstream of the catalyst in the exhaust passage, the internal combustion engine control device comprising a processing circuit configured to perform a catalyst warm-up process when a temperature of the catalyst is lower than a warm-up completion temperature, the catalyst warm-up process being a process of increasing the temperature of the catalyst, wherein

the processing circuit is configured to

calculate a detection value difference that is a difference between detection values from the two air-fuel ratio sensors when warm-up of the catalyst is completed, and

when the detection value difference is in a predetermined detection value difference range, set the warm-up completion temperature to a lower value than when the detection value difference is not in the detection value difference range.

3. The internal combustion engine control device according to claim **2**, wherein the processing circuit is configured to calculate the detection value difference when the internal combustion engine is idling and the warm-up of the catalyst is completed.

4. The internal combustion engine control device according to claim **1**, wherein the processing circuit is configured to stop setting the warm-up completion temperature to the lower value when refueling is detected after the warm-up completion temperature is set to the lower value.

5. The internal combustion engine control device according to claim **2**, wherein the processing circuit is configured to stop setting the warm-up completion temperature to the lower value when refueling is detected after the warm-up completion temperature is set to the lower value.

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