US 20200173328A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2020/0173328 A1

(43) Pub. Date: Jun. 4, 2020

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(54) **CONTROLLER FOR EXHAUST GAS PURIFICATION SYSTEM**

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(21) Appl. No.: **16/783,251**

(22) Filed: **Feb. 6, 2020**

**Related U.S. Application Data**

(63) Continuation of application No. PCT/JP2018/030876, filed on Aug. 21, 2018.

(30) **Foreign Application Priority Data**

Aug. 23, 2017 (JP) ................................ 2017-160333

**Publication Classification**

(51) **Int. Cl.**
***F01N 3/20*** (2006.01)
***F01N 3/08*** (2006.01)

(52) **U.S. Cl.**
CPC ...... ***F01N 3/208*** (2013.01); *F01N 2900/1402* (2013.01); ***F01N 3/0842*** (2013.01)

(57) **ABSTRACT**

A NOx storage reduction type catalyst is equipped in an exhaust passage of an internal combustion engine and purifies NOx in exhaust gas. An ozone supply device supplies ozone to an upstream of the catalyst in the exhaust passage. A NOx sensor is provided at a downstream of the catalyst and detects a NOx amount in exhaust gas. An ECU includes a NOx amount acquisition unit which acquires a detected NOx amount detected by the NOx sensor in a state where the internal combustion engine operates and where the ozone supply device supplies the ozone. The ECU further includes a control unit which performs at least one of an ozone supply amount control by the ozone supply device and an abnormality diagnosis of the ozone supply device based on the detected NOx amount acquired by the NOx amount acquisition unit.

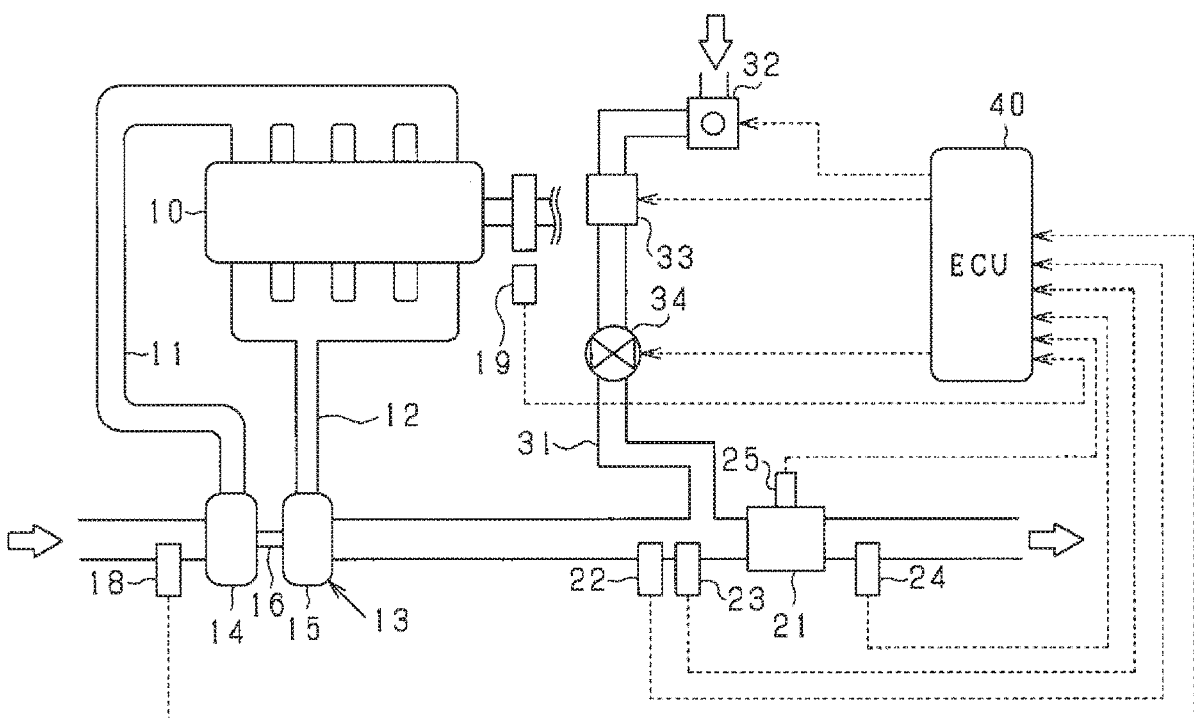


FIG. 1

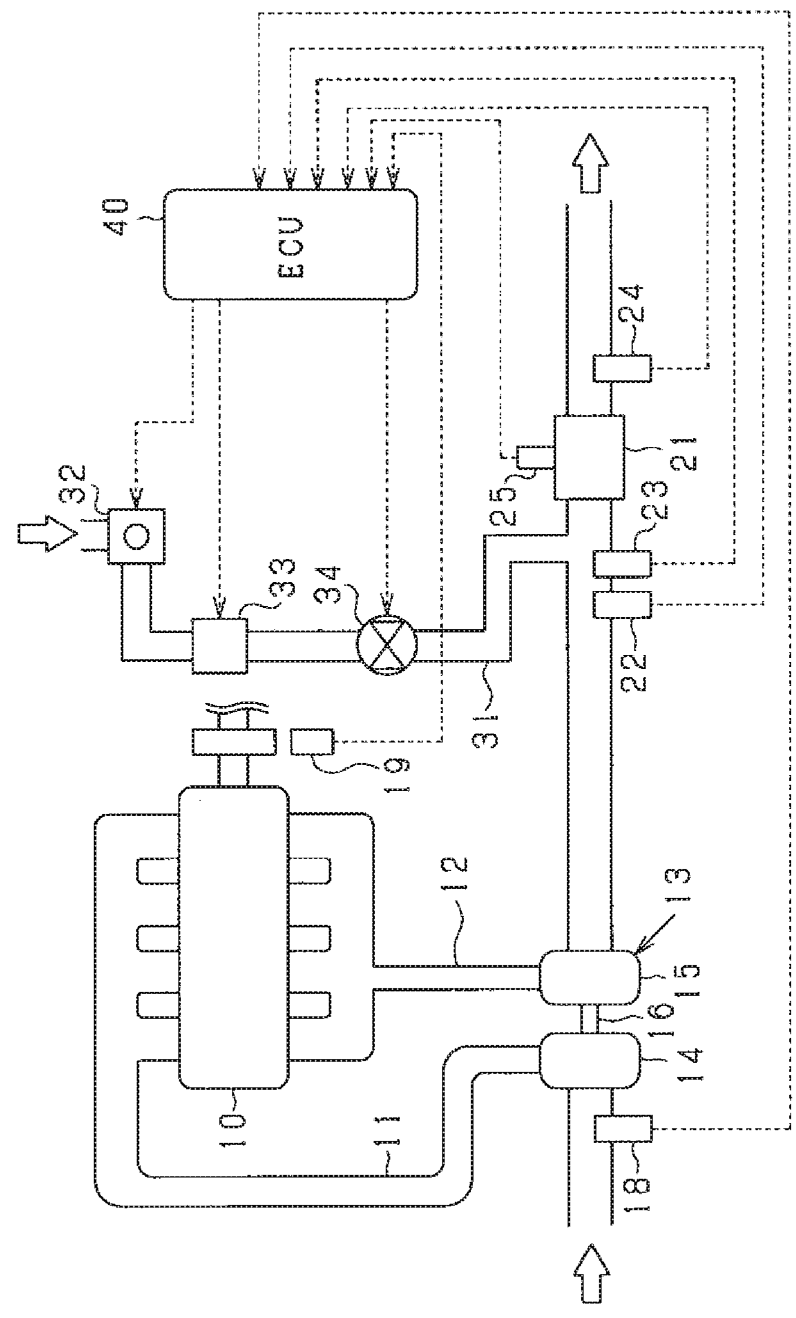


FIG. 2

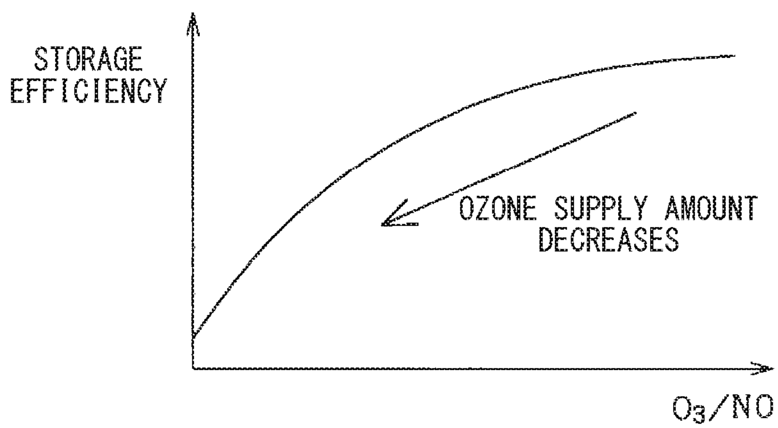


FIG. 3

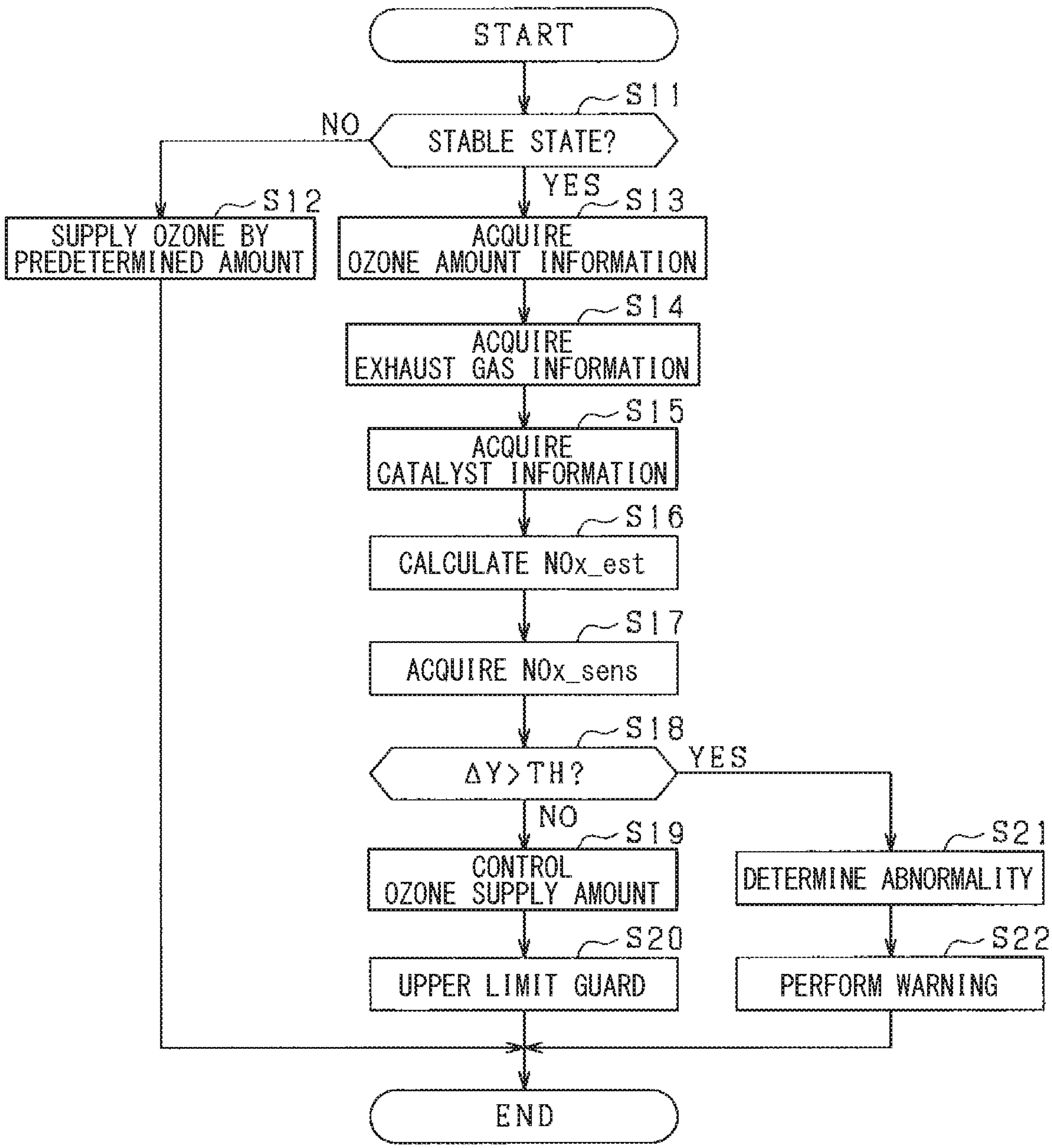

START
S11
STABLE STATE?
NO
YES
S12
SUPPLY OZONE BY PREDETERMINED AMOUNT
S13
ACQUIRE OZONE AMOUNT INFORMATION
S14
ACQUIRE EXHAUST GAS INFORMATION
S15
ACQUIRE CATALYST INFORMATION
S16
CALCULATE NOx_est
S17
ACQUIRE NOx_sens
S18
ΔY>TH?
YES
NO
S19
CONTROL OZONE SUPPLY AMOUNT
S20
UPPER LIMIT GUARD
S21
DETERMINE ABNORMALITY
S22
PERFORM WARNING
END

FIG. 4A

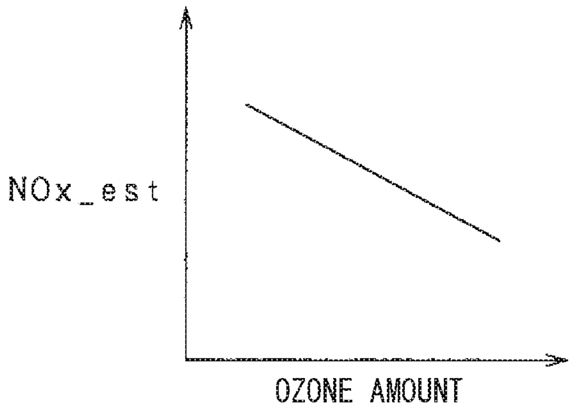



FIG. 4D

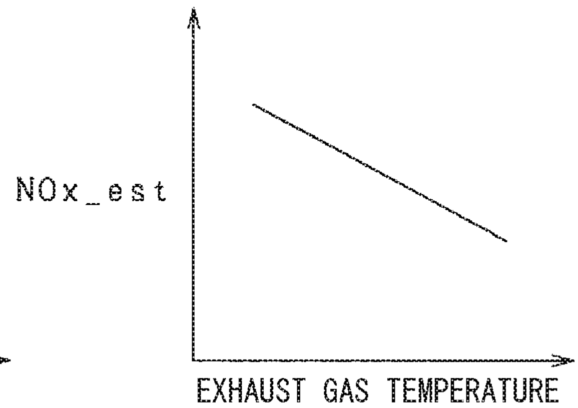



FIG. 4B

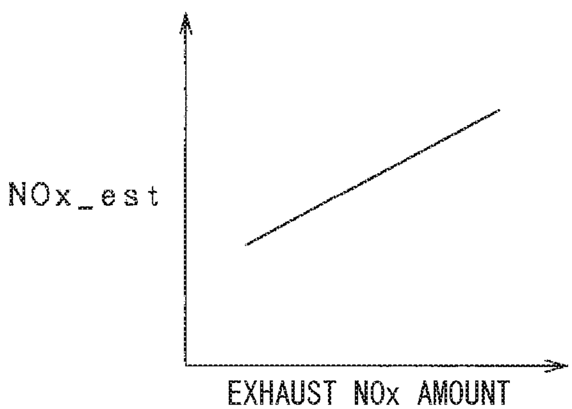



FIG. 4E

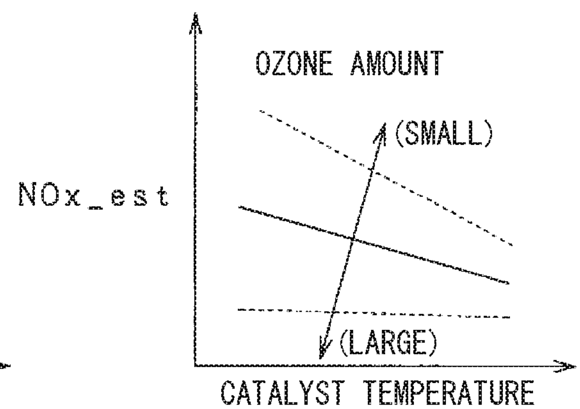



FIG. 4C

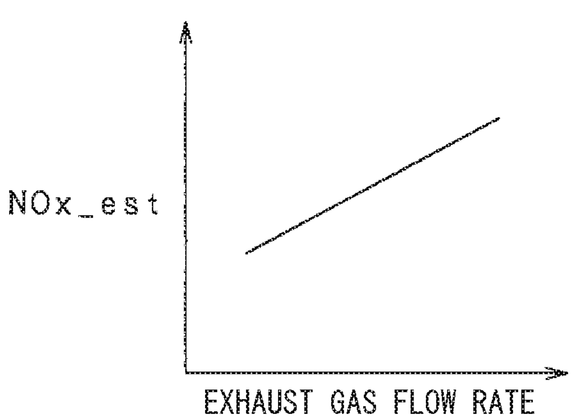



FIG. 4F

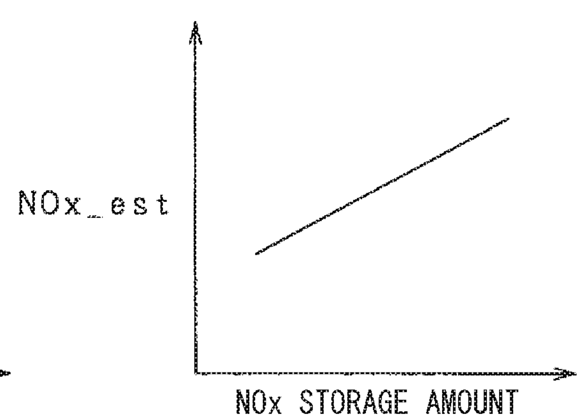


FIG. 5A

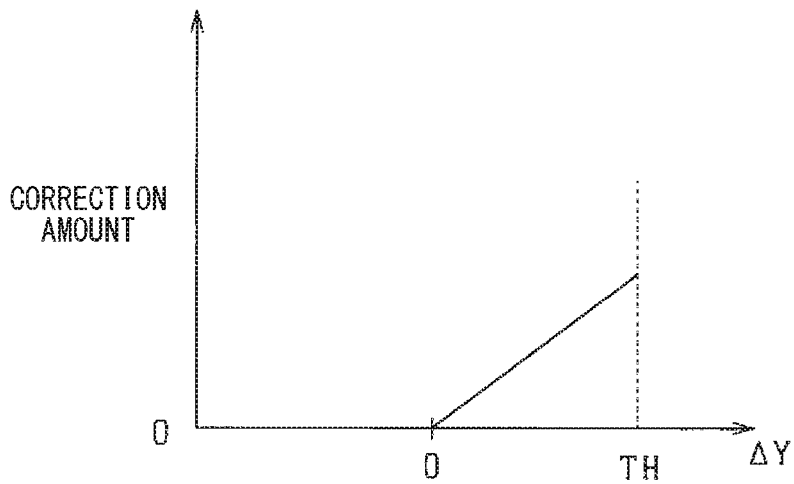
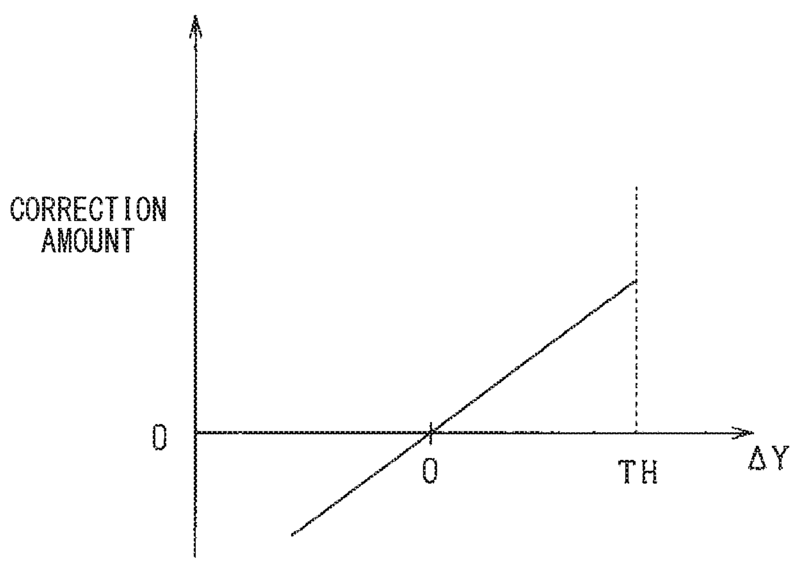



FIG. 5B



# CONTROLLER FOR EXHAUST GAS PURIFICATION SYSTEM

## CROSS REFERENCE TO RELATED APPLICATION

**[0001]** The present application is a continuation application of International Patent Application No. PCT/JP2018/030876 filed on Aug. 21, 2018, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2017-160333 filed on Aug. 23, 2017. The entire disclosures of all of the above applications are incorporated herein by reference.

## TECHNICAL FIELD

**[0002]** The present disclosure relates to a controller for an exhaust gas purification system that includes a NOx storage reduction type catalyst to purify NOx (nitrogen oxides).

## BACKGROUND

**[0003]** A known technique to purify NOx uses a NOx storage reduction type catalyst in an exhaust gas purification system of an internal combustion engine.

## SUMMARY

**[0004]** A controller, according to an aspect of the present disclosure, for the exhaust gas purification system includes a NOx amount acquisition unit, a calculation unit, and a control unit.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** 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:

**[0006]** FIG. **1** is a diagram showing an exhaust gas purification system of an engine.

**[0007]** FIG. **2** is a graph showing a relationship between a ratio of ozone to NO in exhaust gas and a storage efficiency.

**[0008]** FIG. **3** is a flow chart showing a control procedure of an ozone supply.

**[0009]** FIGS. **4**A to **4**F are views showing relationships between various parameters and estimated NOx amounts (NOx_est), respectively.

**[0010]** FIGS. **5**A and **5**B are views showing relationships between changes ΔY and correction amounts, respectively.

## DETAILED DESCRIPTION

**[0011]** Hereinafter, one example of the present disclosure will described.

**[0012]** According to the one example, a NOx storage reduction type catalyst is used to purify NOx in an exhaust gas purification system of an internal combustion engine. The NOx storage reduction type catalyst exhibits a storage efficiency for NO (nitric oxide) that is different from a storage efficiency for NO2 (nitrogen dioxide). The storage efficiency of NO is decreased in a low temperature, for example. Therefore, an ozone supply device supplies ozone to an upstream of the NOx storage reduction type catalyst in an exhaust passage of the internal combustion engine, and the ozone oxidizes NO in exhaust gas to NO2.

**[0013]** In the example, the exhaust gas purification system supplies ozone to an upstream of a NOx storage reduction type catalyst. In this state, in a case where an ozone supply device does not supply a proper amount of ozone, the NOx storage reduction type catalyst may not exhibit a desired performance of NOx purification.

**[0014]** The present disclosure is provided with a controller for an exhaust gas purification system configured to properly supply ozone and to properly purify NOx.

**[0015]** According to one aspect of the present disclosure, a controller is applicable to an exhaust gas purification system. The exhaust gas purification system includes a NOx storage reduction type catalyst equipped in an exhaust passage of an internal combustion engine and configured to purify NOx in exhaust gas, an ozone supply device configured to supply ozone to an upstream of the catalyst in the exhaust passage, and a NOx sensor provided at a downstream of the catalyst and configured to detect a NOx amount in exhaust gas. The controller for the exhaust gas purification system includes a NOx amount acquisition unit, a calculation unit, and a control unit. The NOx amount acquisition unit is configured to acquire a detected NOx amount detected by the NOx sensor in a state where the internal combustion engine operates and where the ozone supply device supplies the ozone. The calculation unit is configured to calculate an amount of NOx discharged to a downstream of the catalyst as an estimated NOx amount based on at least one of exhaust gas information about exhaust gas discharged from the internal combustion engine and catalyst information about the catalyst. The control unit is configured to implement comparison of the detected NOx amount acquired by the NOx amount acquisition unit with the estimated NOx amount calculated by the calculation unit and to perform at least one of an ozone supply amount control by the ozone supply device and an abnormality diagnosis of the ozone supply device based on a result of the comparison.

**[0016]** In the exhaust gas purification system, the ozone supply device supplies the ozone to the upstream of the NOx storage reduction type catalyst in the exhaust passage of the internal combustion engine, and NO in the exhaust gas is oxidized to NO2. Therefore, a NOx storage capacity of the NOx storage reduction type catalyst can be raised. In this case, when an amount of the ozone supplied by the ozone supply device is decreased unintentionally, the NOx storage capacity of the NOx storage reduction type catalyst is decreased, and a performance of a NOx purification may be decreased.

**[0017]** However, in the configuration described above, in a state where the internal combustion engine operates and where the ozone supply device supplies the ozone, the detected NOx amount detected by the NOx sensor is acquired. Based on the detected NOx amount, at least one of the ozone supply amount control by the ozone supply device and the abnormality diagnosis of the ozone supply device is performed. Accordingly, the ozone supply amount control or the abnormality diagnosis can be performed appropriately while observing a reduction of an actual NOx purification efficiency. Therefore, the ozone can be properly supplied, and a proper NOx purification can be performed.

**[0018]** Embodiments will be described below with reference to drawings. An exhaust gas purification system, which purifies exhaust gas discharged from a diesel engine on a vehicle, adds ozone from an ozone supply device especially to an upstream of a catalyst in the present embodiment. The same reference numerals are given to the same structures in the embodiments which will be described below, and the explanations for the structures with the same reference numerals are incorporated in the embodiments.

**[0019]** An engine **10** in FIG. **1** is a multiple-cylinder diesel engine and uses light oil as a fuel. Each of the cylinders of the diesel engine is connected to an air intake pipe **11** and an exhaust pipe **12**. A supercharger **13** is equipped in the engine **10**. An intake compressor **14** arranged at the air intake pipe **11**, an exhaust turbine **15** arranged at the exhaust pipe **12**, and a rotation shaft **16** which connects the intake compressor **14** to the exhaust turbine **15** are equipped in the supercharger **13**. When the exhaust turbine **15** is rotated by the exhaust gas, the intake compressor **14** starts rotating in conjunction with the rotation of the exhaust turbine **15**, and intake air is supercharged. An intercooler may be provided as a heat exchanger on the air intake pipe **11** at a downstream of the intake compressor **14**.

**[0020]** An air flow sensor **18** is provided to the air intake pipe **11** at an upstream of the intake compressor **14** and configured to detect an amount of air which passes through the air intake pipe **11**. A rotation speed sensor **19** is provided to an output shaft of the engine **10** and configured to detect a rotation speed of the engine.

**[0021]** A NOx storage reduction type catalyst is provided to the exhaust pipe **12** as a NOx purification device to purify NOx in the exhaust gas flowing in an exhaust passage provided in the exhaust pipe **12**. The NOx storage reduction type catalyst is referred to as NOx catalyst **21** hereinafter. The NOx catalyst **21** is, as generally known, configured to store the NOx included in the exhaust gas during a lean-burn combustion and to reduce and remove the NOx, which has been stored, with a reducing component such as HC or CO included in the exhaust gas during a rich-burn combustion. In the NOx catalyst **21**, for example, a silver as a reduction catalyst is carried on alumina coated on a surface of a carrier.

**[0022]** A NOx sensor **22** configured to detect an amount of the NOx in the exhaust gas discharged from the engine **10** and an exhaust gas temperature sensor **23** configured to detect an exhaust gas temperature are provided to the exhaust pipe **12** at an upstream of the NOx catalyst **21**. The sensors **22**, **23** are provided at an upstream of a supply pipe **31** which will be described below. A NOx sensor **24** is provided at a downstream of the NOx catalyst **21** and configured to detect the NOx amount at the downstream of the catalyst. The NOx catalyst **21** includes a catalyst temperature sensor **25** configured to detect a catalyst temperature. The NOx sensors **22**, **24** are each limiting current type gas sensors which are configured with a solid electrolyte, for example. For convenience of explanation, the NOx sensor **22** at the upstream of the catalyst is also referred to as upstream NOx sensor **22**, and the NOx sensor **24** at the downstream of the catalyst is referred to as downstream NOx sensor **24**, hereinafter. The catalyst temperature sensor **25** may be provided at the downstream of the NOx catalyst **21**.

**[0023]** In the exhaust gas purification system in the present embodiment, the ozone is supplied to the exhaust pipe **12** at the upstream of the NOx catalyst **21** and oxidizes NO in the exhaust gas to NO2. Because of this, a NOx storage capacity of the NOx catalyst **21** is raised. The structures of the exhaust gas purification system will be described below.

**[0024]** The supply pipe **31** is connected to the exhaust pipe **12** at the upstream of the NOx catalyst **21**. An air pump **32**, an ozone generator **33**, an on-off valve **34** are provided in this order from an upstream of the supply pipe **31**. The air pump **32** is a motor pump, for example, and configured to pressurize atmospheric air inhaled from the exterior and to send the air to the ozone generator **33**. The structure of the ozone generator **33** is generally known, and a detailed description with reference to a drawing is omitted. In brief, the ozone generator **33** includes multiple electrodes in a container in which a flow passage is formed. The ozone is generated by a high voltage application between the multiple electrodes. The on-off valve **34** is arranged to restrain a reverse flow of the exhaust gas from the exhaust pipe **12**. The ozone is supplied to the exhaust pipe **12** when the on-off valve **34** is opened, and the ozone supply is stopped when the on-off valve **34** is closed. The air pump **32** and the ozone generator **33** correspond to the ozone supply device.

**[0025]** To supply the ozone toward the exhaust pipe **12** during an operation of the engine, the air pump **32** is driven, and the on-off valve **34** is opened, under a state where the ozone generator **33** generates the ozone by a voltage application. Because of this, the ozone flows with air which passes the ozone generator **33** into the exhaust pipe **12**. Subsequently, the NOx catalyst **21** stores the NO and the NO2 and performs reduction and purification, while the oxidization is performed at the upstream of the NOx catalyst **21** to convert the NO2 from the NO.

**[0026]** An ECU **40** is a well-known electronic controller and includes mainly a microcomputer which includes CPU, ROM, RAM, and the like. The ECU **40** is configured to perform controls of an exhaust gas purification according to detection signals of the sensors described above, by executions of control programs stored in the ROM, respectively. The ECU **40** is configured to perform an ozone supply amount control which controls an amount of the ozone supplied by the ozone supply device at a desired amount. In this case, the ECU **40** controls statuses of the air pump **32**, the ozone generator **33**, and the on-off valve **34** to supply a prescribed amount of the ozone to the exhaust pipe **12**, for example. For example, when the ozone supply is requested during the lean-burn combustion in a state where the engine **10** operates, the ECU **40** performs the ozone supply to the exhaust pipe **12** according to the request.

**[0027]** A storage efficiency of the NOx catalyst **21** for the NO in the NOx in the exhaust gas is different from the storage efficiency for the NO2 in the NOx in the exhaust gas. In a state at a relatively low temperature, the storage efficiency of the NO becomes extremely lower. Therefore, the ozone is supplied to the exhaust pipe **12** to oxidize NO into NO2 at the low temperature. However, in a case where the ozone amount is insufficient by a deterioration of the performance of the ozone supply device, the oxidation of the NO into NO2 at the upstream of the catalyst may be insufficient. In this state, a ratio of the NO in the NOx is increased, and a NOx storage efficiency of the NOx catalyst **21** may be decreased.

**[0028]** FIG. **2** is a graph showing a relationship between a ratio of the ozone to the NO in the exhaust gas and a storage efficiency. As show in FIG. **2**, the storage efficiency of the NOx catalyst **21** decreases as the ratio of the ozone to the NO in the exhaust gas decreases.

**[0029]** In a case where the ozone supply device does not supply the ozone at an appropriate amount due to a malfunction or the like, the NOx catalyst **21** may not exhibit a desired performance of NOx purification. Therefore, in the present embodiment, in a state where the engine **10** operates and where the ozone supply device supplies the ozone, the ozone supply device acquires a detected NOx amount (NOx_sens) detected by the downstream NOx sensor **24**. Subsequently, based on the detected NOx amount (NOx_sens), the ozone supply device performs the ozone supply amount control and an abnormality diagnosis of the ozone supply device.

**[0030]** In this case, the ECU **40** calculates an amount of the NOx discharged to the downstream of the NOx catalyst **21** as an estimated NOx amount (NOx_est) based on exhaust gas information about the exhaust gas discharged from the engine **10** and based on catalyst information about the NOx catalyst **21**. Subsequently, the detected NOx amount (NOx_sens) detected by the downstream NOx sensor **24**, is compared with the estimated NOx amount (NOx_est). Based on the result of the comparison, the ozone supply amount control by the ozone supply device and the abnormality diagnosis of the ozone supply device are performed.

**[0031]** FIG. **3** is a flow chart showing a control procedure of an ozone supply, and its processing is performed by the ECU **40** at a prescribed cycle.

**[0032]** In FIG. **3**, at step S**11**, it is determined whether or not an operating state of the engine **10** under the operating state is in a stable state, but not in a transitional state. In this case, it may be determined that the engine operating state is stable in a case where the rotation speed of the engine is not larger than a predetermined value and a load change is not larger than a predetermined value within a predetermined period. The stability of the operating state of the vehicle may be determined based on an accelerator operation amount or the like. When step S**11** makes a negative determination, the processing proceeds to step S**12**. On the other hand, when step S**11** makes a positive determination, the processing proceeds to step S**13**.

**[0033]** In step S**12**, the operation of the air pump **32** or the ozone generator **33** is started with a predetermined control command value to supply a predetermined amount of the ozone to the exhaust pipe **12**. When step S**11** makes a negative determination, the abnormality diagnosis of the ozone supply device is not performed.

**[0034]** In step S**13**, ozone amount information which indicates the amount of the ozone supplied from the ozone generator **33** into the exhaust pipe **12** through the supply pipe **31** is acquired. At this point, the amount of the ozone may be estimated from a voltage applied to the electrode of the ozone generator **33** or an electricity consumption. In addition, the amount of the ozone may be calculated in consideration of a volume of air blown by the air pump **32**.

**[0035]** In step S**14**, exhaust gas information which is on the exhaust gas discharged from the engine **10** is acquired. The exhaust gas information includes an exhaust gas parameter such as an exhaust NOx amount which indicates an amount of NOx discharged from the engine **10**, a flow rate of the exhaust gas, or a temperature of the exhaust gas or the like. The exhaust NOx amount is calculated from a detection signal of the upstream NOx sensor **22**. The flow rate of the exhaust gas is calculated from a detection signal of the air flow sensor **18**. The temperature of the exhaust gas is calculated from a detection signal of the exhaust gas temperature sensor **23**. The exhaust NOx amount, the flow rate of the exhaust gas, or the temperature of the exhaust gas may be estimated by using a predetermined estimation model, a predetermined expression or the like, based on the rotation speed of the engine or an engine load.

**[0036]** In step S**15**, the catalyst information about the NOx catalyst **21** is acquired. The catalyst information includes a catalyst parameter such as a temperature of the NOx catalyst **21** or a NOx storage amount which indicates an amount of NOx which has already been stored in the NOx catalyst **21** or the like. The catalyst temperature is calculated from the detection signal of the catalyst temperature sensor **25**. The NOx storage amount is calculated by estimation from an operation history of the engine **10** or the like. For example, the NOx storage amount may be estimated based on a number of a fuel injection or an amount of the fuel reduction after the rich-burn combustion.

**[0037]** Subsequently, in step S**16**, the amount of the NOx discharged to the downstream of the NOx catalyst **21** is calculated as an estimated NOx amount (NOx_est) based on the ozone amount information, the exhaust gas information, and the catalyst information which are acquired in steps S**13** to S**15** described above. Here, a relationship between each parameter in the ozone amount information, the exhaust gas information, and the catalyst information and the estimated NOx amount (NOx_est) will be described below.

**[0038]** In FIG. **4**A shows a relationship between the ozone amount as the ozone amount information and the estimated NOx amount (NOx_est). The ECU **40** calculates a larger value as the estimated NOx amount (NOx_est) as the ozone amount becomes smaller.

**[0039]** In FIG. **4**B shows a relationship between the exhaust NOx amount as the exhaust gas information and the estimated NOx amount (NOx_est). The ECU **40** calculates a larger value as the estimated NOx amount (NOx_est) as the exhaust NOx amount becomes larger.

**[0040]** In FIG. **4**C shows a relationship between the flow rate of the exhaust gas as the exhaust gas information and the estimated NOx amount (NOx_est). The ECU **40** calculates a larger value as the estimated NOx amount (NOx_est) as the flow rate of the exhaust gas becomes larger. An exhaust gas pressure may be used as the exhaust gas information, instead of the flow rate of the exhaust gas. In this case, the ECU **40** calculates a larger value as the estimated NOx amount (NOx_est) as the exhausted gas pressure becomes larger.

**[0041]** In FIG. **4**D shows a relationship between the temperature of the exhaust gas as the exhaust gas information and the estimated NOx amount (NOx_est). The ECU**40** calculates a larger value as the estimated NOx amount (NOx_est) as the temperature of the exhaust gas becomes lower.

**[0042]** In FIG. **4**E shows a relationship between the catalyst temperature as the catalyst information and the estimated NOx amount (NOx_est). The ECU**40** calculates a larger value as the estimated NOx amount (NOx_est) as the catalyst temperature becomes lower. The relationship between the catalyst temperature and the estimated NOx amount (NOx_est) depends on the ozone amount, and a relationship under consideration of the ozone amount may be defined. In this case, as shown in broken lines in FIG. **4**E, as the ozone amount becomes smaller, the estimated NOx amount (NOx_est) may be increased, and a gradient of the estimated NOx amount (NOx_est), which is negative gradient, to the catalyst temperature may be increased.

**[0043]** FIG. **4**F shows a relationship between the NOx storage amount as the catalyst information and the estimated NOx amount (NOx_est). The ECU**40** calculates a larger value as the estimated NOx amount (NOx_est) as the NOx storage amount becomes larger.

**[0044]** The relationships shown in FIGS. **4**A to **4**F may be specified as maps or formulas in advance. In addition, the values of parameters may be substituted into the map or the formula to calculate the estimated NOx amount (NOx_est). The estimated NOx amount (NOx_est) may be calculated with one or two of the exhaust NOx amount, the flow rate of the exhaust gas, and the temperature of the exhaust gas as the exhaust gas information. Further, the estimated NOx amount (NOx_est) may be calculated with one of the catalyst temperature and the NOx storage amount as the catalyst information. Further, the estimated NOx amount (NOx_est) may be calculated with one or two of the ozone amount information, the exhaust gas information, and the catalyst information.

**[0045]** Subsequently, in step S**17**, the detected NOx amount (NOx_sens) detected by the downstream NOx sensor **24** is acquired. The detected NOx amount (NOx_sens) corresponds to an actual NOx amount at the downstream of the NOx catalyst **21**.

**[0046]** In step S**18**, it is determined whether or not a difference ΔY is larger than a predetermined threshold TH. The difference ΔY is obtained by a subtraction of the estimated NOx amount (NOx_est) from the detected NOx amount (NOx_sens) and defined as follows.

$$\Delta Y = NOx\_sens - NOx\_est$$

At this point, in step S**18**, it is determined whether or not the NOx amount at the downstream of the catalyst is large relative to an ozone amount (primary ozone amount) by which the ozone supply device should supply ozone. The threshold TH may be determined based on an allowable amount of NOx at the downstream of the NOx catalyst **21**, that is, based on an allowable leakage amount of NOx which is determined based on environmental standards or the like.

**[0047]** In a case of ΔY≤TH, the processing proceeds to step S**19**, and a feedback control of the ozone supply amount is performed based on the difference ΔY In this case, a correction amount which is added to the ozone supply amount (supply command) is increased and corrected is set according to the difference ΔY, and the ozone supply amount is updated by the correction amount. More specifically, as shown in FIG. **5**A, the correction amount is set at a larger value as the difference ΔY becomes larger within a range of 0 to the threshold TH, that is, as the detected NOx amount (NOx_sens) becomes larger with respect to the estimated NOx amount (NOx_est). In a case of ΔY≤0, the correction amount may be 0. An updated ozone supply amount is calculated by addition of the correction amount to the ozone supply amount at this point.

**[0048]** The correction amount may be set variably according to the difference ΔY, or may be a constant correction amount to be added. In addition, the correction amount may be set by using a relationship shown in FIG. **5**B. According to FIG. **5**B, when the difference ΔY is a positive number, that is in a case of NOx_sens>NOx_est, the ozone supply amount is corrected and increased by a positive correction amount. When the difference ΔY is a negative number, that is in a case of NOx_sens<NOx_est, the ozone supply amount is corrected and decreased by a negative correction amount.

**[0049]** At subsequent step S**20**, an upper limit guard processing is performed on the ozone supply amount which has been updated. More specifically, it is determined whether or not the updated ozone supply amount reaches a predetermined upper limit value. In a case where the updated ozone supply amount reaches the upper limit value, the ozone supply amount is restricted to the upper limit value. Therefore, the ozone supply amount is restricted in a range to the upper limit value and is controlled by the feedback control according to the difference ΔY at each time.

**[0050]** In a case where the ozone supply amount is increased, for example, an applied voltage may be raised to increase a generation amount of the ozone by the ozone generator **33**. In addition, the volume of air blown by the air pump **32** may be increased. In a case of ΔY<TH, it is determined that the ozone supply device is in a normal condition.

**[0051]** In a case of ΔY≥TH, the processing proceeds to step S**21**, and the ECU **40** determines that abnormality is caused in the ozone supply device. At subsequent step S**22**, a warning by a malfunction warning lamp or a sound is performed to inform that the ozone supply device is in an abnormal condition. In addition, the ozone supply by the ozone supply device is stopped.

**[0052]** In the present embodiment described above, significant effects described below are obtained.

**[0053]** In a state where the engine **10** operates and where the ozone supply device supplies the ozone, the ECU **40** acquires the detected NOx amount (NOx_sens) detected by the downstream NOx sensor **24** and performs the ozone supply amount control and the abnormality diagnosis based on the detected NOx amount (NOx_sens). Accordingly, the ozone supply amount control or the abnormality diagnosis can be performed appropriately while observing a reduction of an actual NOx purification efficiency. Therefore, the ozone can be properly supplied, and a proper NOx purification can be performed.

**[0054]** In a case where an abnormality is caused in the ozone supply device, and where a desired performance of NOx purification cannot be provided, an appropriate measure can be performed by the warning or by a stopping of the ozone supply.

**[0055]** Based on the exhaust gas information of the engine **10** and the catalyst information about the NOx catalyst **21**, the NOx amount at the downstream of the catalyst is calculated as the estimated NOx amount (NOx_est). Subsequently, based on a comparison result between the estimated NOx amount (NOx_est) and the detected NOx amount (NOx_sens) detected by the downstream NOx sensor **24**, the ozone supply amount control and the abnormality diagnosis of the ozone control device are performed. Therefore, the ozone supply amount control and the abnormality diagnosis can be performed appropriately, even when a state of the exhaust gas and/or a state of the NOx catalyst **21** is changed according to the engine operating state or the like.

**[0056]** The ECU **40** is configured to calculate the estimated NOx amount (NOx_est) based on the exhaust NOx amount, the flow rate of the exhaust gas, and the temperature of the exhaust gas discharged from the engine **10**, and issues such as an accuracy deterioration of the ozone supply amount control or of the abnormality diagnosis due to a change of the each parameter can be restrained.

**[0057]** The estimated NOx amount (NOx_est) is calculated based on the temperature of the NOx catalyst **21** and on the NOx storage amount of the NOx catalyst **21**. Therefore, issues such as the accuracy deterioration of the ozone supply amount control or of the abnormality diagnosis due to the change of the each parameter can be restrained.

**[0058]** The ECU **40** is configured to acquire the amount of the ozone supplied to the exhaust pipe **12** and to calculate the estimated NOx amount (NOx_est) based on the ozone amount. Therefore, issues such as the accuracy deterioration of the ozone supply amount control or of the abnormality diagnosis due to the change of the ozone amount can be restrained.

**[0059]** In a case where the difference ΔY between the detected NOx amount (NOx_sens) and the estimated NOx amount (NOx_est) is smaller than the threshold TH, the ozone supply amount control is performed based on the difference ΔY. In a case where the difference ΔY is larger than the threshold TH, the abnormality diagnosis of the ozone supply device is performed. Therefore, on the ozone supply device, the ozone supply amount control and the abnormality diagnosis can be performed appropriately, as required. In this case, before the ECU **40** determines that the ozone supply device is abnormal, the ozone supply amount control enables to obtain a stable purification performance at the NOx catalyst **21**.

**[0060]** The ozone supply amount is controlled based on the detected NOx amount (NOx_sens) in a range of the ozone supply amount to a predetermined upper limit value, and the abnormality diagnosis of the ozone supply device is performed in a case where the ozone supply amount is the upper limit value. In this case, the maximum ozone supply is performed in a control range in which the ozone can be supplied, and the abnormality diagnosis of the ozone supply device is performed under a state where the maximum ozone supply is performed. Therefore, the abnormality diagnosis can be performed properly while the ozone is supplied as possible.

**[0061]** In a case where the operating state of the engine **10** is in the stable state, but not in the transitional state, the ozone supply amount control and the abnormality diagnosis are performed. Therefore, a control accuracy of the ozone supply amount control can be enhanced. In addition, an erroneous diagnosis of the abnormality diagnosis can be suppressed, and a diagnosis accuracy can be enhanced.

## OTHER EMBODIMENTS

**[0062]** The embodiments described above may be changed, for example, as below.

**[0063]** In the above embodiment, the ECU **40** performs the ozone supply amount control and the abnormality diagnosis. However, the ECU **40** may perform only one of them. For example, the ECU **40** may perform the ozone supply amount control based on the difference ΔY between the detected NOx amount (NOx_sens) and the estimated NOx amount (NOx_est). Alternatively, the ECU **40** may perform the abnormality diagnosis of the ozone supply device based on the difference ΔY between the detected NOx amount (NOx_sens) and the estimated NOx amount (NOx_est).

**[0064]** In the above embodiment, the ozone supply amount control and the abnormality diagnosis are performed based on the difference ΔY between the detected NOx amount (NOx_sens) and the estimated NOx amount (NOx_est). However, the ozone supply amount control and the abnormality diagnosis may be performed based on only the detected NOx amount (NOx_sens) out of the detected NOx amount (NOx_sens) and the estimated NOx amount (NOx_est). In this case, the ozone supply device is configured to supply the ozone at a constant amount. In addition, the ECU **40** sets the ozone supply amount based on the detected NOx amount (NOx_sens), and more specifically, the ozone supply amount becomes larger as the detected NOx amount (NOx_sens) becomes larger. When the detected NOx amount (NOx_sens) is larger than a predetermined value, the ECU **40** detects that the abnormality of the ozone supply device is caused.

**[0065]** The exhaust gas purification system is not limited to the system shown in FIG. **1** and may include an oxide catalysis at the upstream of the NOx catalyst **21**, or may include a DPF or a DPF with a catalyst at the downstream of the NOx catalyst **21**.

**[0066]** The exhaust gas purification system in the embodiments described above may be applied not only to the diesel engine, but also to another type of the engine such as a gasoline engine. The exhaust gas purification system may also be applied to an engine not for a vehicle.

**[0067]** The present disclosure has been described according to the present embodiments. However, the present disclosure is not limited by the embodiments or structure. The present disclosure encompasses various variations and modifications within equivalents. A wording of at least one of A, and B encompasses a definition of only A, a definition of only B, and a definition of both A and B. This present disclosure also encompasses various combinations and embodiments, and furthermore, encompasses one or more or less of elements and combinations thereof.

**1**. A controller applicable to an exhaust gas purification system which includes a NOx storage reduction type catalyst equipped in an exhaust passage of an internal combustion engine and configured to purify NOx in exhaust gas, an ozone supply device configured to supply ozone to an upstream of the catalyst in the exhaust passage, and a NOx sensor provided at a downstream of the catalyst and configured to detect a NOx amount in exhaust gas, the controller for the exhaust gas purification system comprising:

- a NOx amount acquisition unit configured to acquire a detected NOx amount detected by the NOx sensor in a state where the internal combustion engine operates and where the ozone supply device supplies the ozone;
- a calculation unit configured to calculate an amount of NOx discharged to a downstream of the catalyst as an estimated NOx amount based on at least one of exhaust gas information about exhaust gas discharged from the internal combustion engine and catalyst information about the catalyst; and
- a control unit configured to implement comparison of the detected NOx amount acquired by the NOx amount acquisition unit with the estimated NOx amount calculated by the calculation unit and to perform at least one of an ozone supply amount control by the ozone supply device and an abnormality diagnosis of the ozone supply device based on a result of the comparison.

**2**. The controller for the exhaust gas purification system according to claim **1**, wherein

- the calculation unit is configured to use an exhaust gas parameter, which is at least one of an amount of NOx discharged from the internal combustion engine, a flow rate of the exhaust gas, and a temperature of the exhaust gas, as the exhaust gas information and to calculate the estimated NOx amount based on the exhaust gas parameter.

**3**. The controller for the exhaust gas purification system according to claim **1**, wherein

the calculation unit is configured to use a catalyst parameter, which is at least one of a temperature of the catalyst and a NOx storage amount which indicates an amount of NOx stored in the catalyst, as the catalyst information and to calculate the estimated NOx amount based on the catalyst parameter.

**4**. The controller for the exhaust gas purification system according to claim **1**, further comprising:

an ozone amount acquisition unit configured to acquire an amount of the ozone supplied to the exhaust passage by the ozone supply device, wherein

the calculation unit is configured to calculate the estimated NOx amount based on at least one of the exhaust gas information and the catalyst information and based on the ozone amount acquired by the ozone amount acquisition unit.

**5**. The controller for the exhaust gas purification system according to claim **1**, wherein

the control unit is configured to perform the ozone supply amount control by the ozone supply device out of the ozone supply amount control by the ozone supply device and the abnormality diagnosis of the ozone supply device, when a difference value obtained by a subtraction of the estimated NOx amount calculated by the calculation unit from the detected NOx amount acquired by the NOx amount acquisition unit is smaller than a predetermined value, and

the control unit is configured to perform the abnormality diagnosis out of the ozone supply amount control by the ozone supply device and the abnormality diagnosis of the ozone supply device, when the difference value is larger than the predetermined value.

**6**. The controller for the exhaust gas purification system according to claim **1**, wherein

the control unit is configured to control an amount of the ozone supplied by the ozone supply device based on the detected NOx amount acquired by the NOx amount acquisition unit in a range of the ozone supply amount to a predetermined upper limit value, and to perform the abnormality diagnosis of the ozone supply device in a case where the amount of the ozone supplied by the ozone supply device is the upper limit value.

**7**. A controller applicable to an exhaust gas purification system which includes a NOx storage reduction type catalyst equipped in an exhaust passage of an internal combustion engine and configured to purify NOx in exhaust gas, an ozone supply device configured to supply ozone to an upstream of the catalyst in the exhaust passage, and a NOx sensor provided at a downstream of the catalyst and configured to detect a NOx amount in exhaust gas, the controller for the exhaust gas purification system comprising:

a NOx amount acquisition unit configured to acquire a detected NOx amount detected by the NOx sensor in a state where the internal combustion engine operates and where the ozone supply device supplies the ozone; and

a control unit configured to perform at least one of an ozone supply amount control by the ozone supply device and an abnormality diagnosis of the ozone supply device based on the detected NOx amount acquired by the NOx amount acquisition unit, wherein,

the control unit is configured to control an amount of the ozone supplied by the ozone supply device based on the detected NOx amount acquired by the NOx amount acquisition unit in a range of the ozone supply amount to a predetermined upper limit value and to perform the abnormality diagnosis of the ozone supply device in a case where the amount of the ozone supplied by the ozone supply device is the upper limit value.

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