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(19) **United States**(12) **Patent Application Publication****Fujita et al.**(10) **Pub. No.: US 2009/0120073 A1**(43) **Pub. Date: May 14, 2009**(54) **EXHAUST GAS PURIFYING APPARATUS
FOR INTERNAL COMBUSTION ENGINE**(30) **Foreign Application Priority Data**

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(JP)**Publication Classification**(51) **Int. Cl.**
F01N 3/20 (2006.01)(52) **U.S. Cl.** **60/295; 60/301**(57) **ABSTRACT**

An exhaust pipe is provided with an oxidation catalyst, a SCR catalyst (ammonia selective reduction catalyst), and an ammonia slip catalyst. In the exhaust pipe, the urea water adding valve is provided between the oxidation catalyst and the SCR catalyst. A NO_x sensor which detects the NO_x quantity in an exhaust gas is provided downstream of the SCR catalyst. An ECU controls the urea water adding valve to add the urea water to the exhaust gas. While the urea water is added to the exhaust gas, the ECU successively obtains a NO_x sensor output, and computes an adding quantity command value in which the NO_x sensor output becomes minimum.

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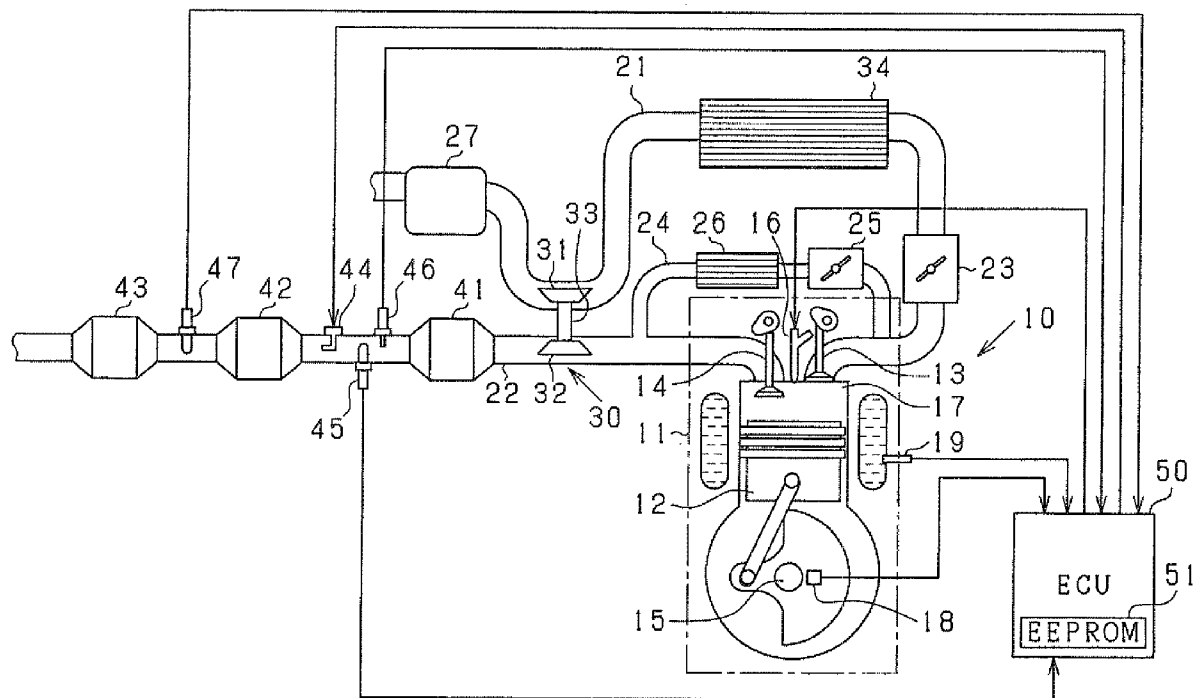
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FIG. 2A

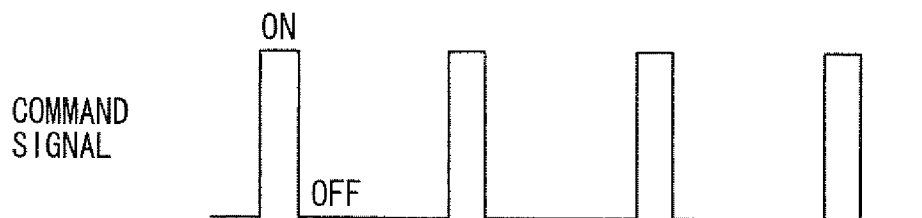


FIG. 2B

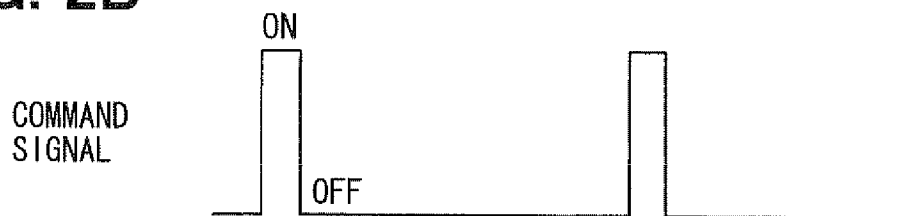


FIG. 2C

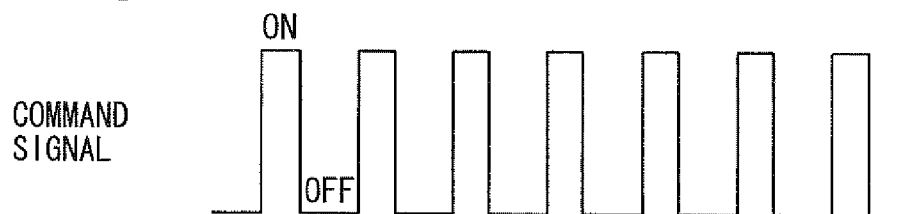


FIG. 3

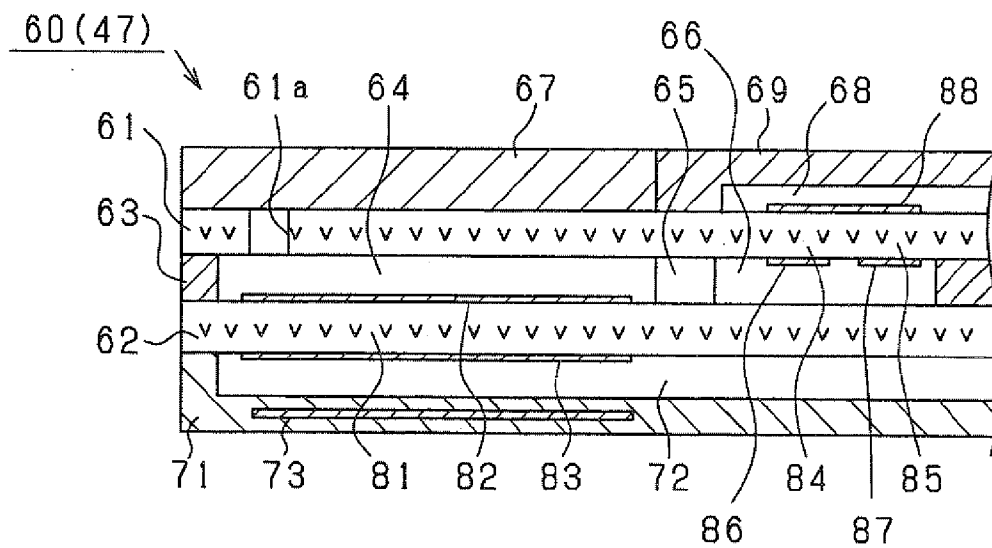


FIG. 4A

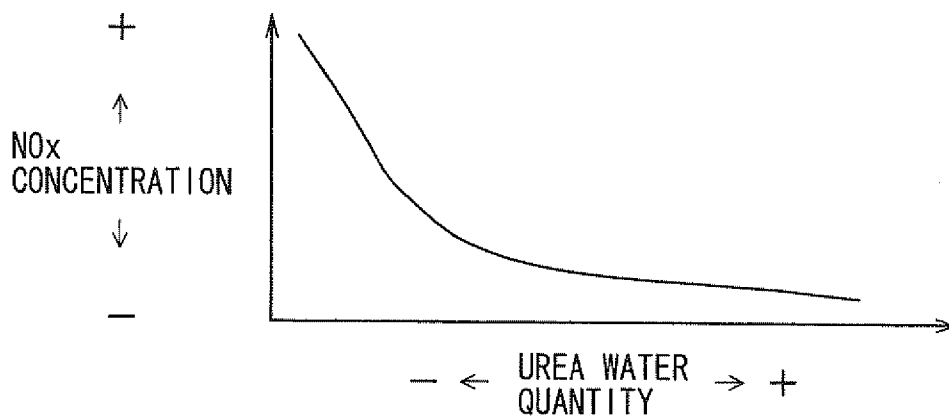


FIG. 4B

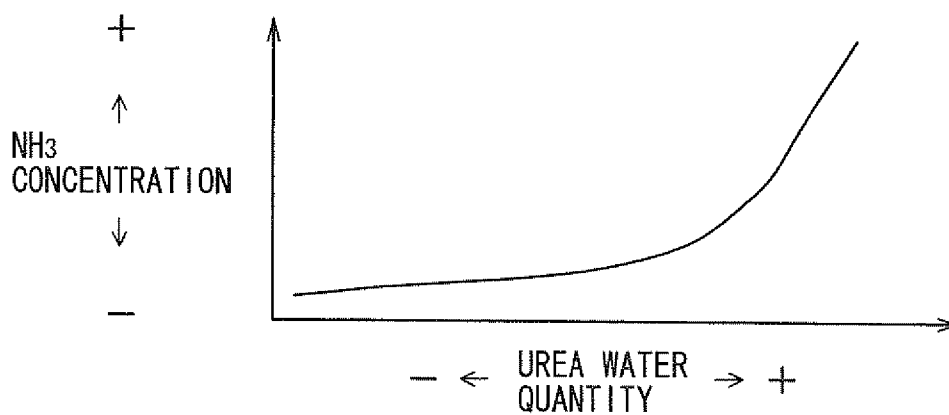


FIG. 4C

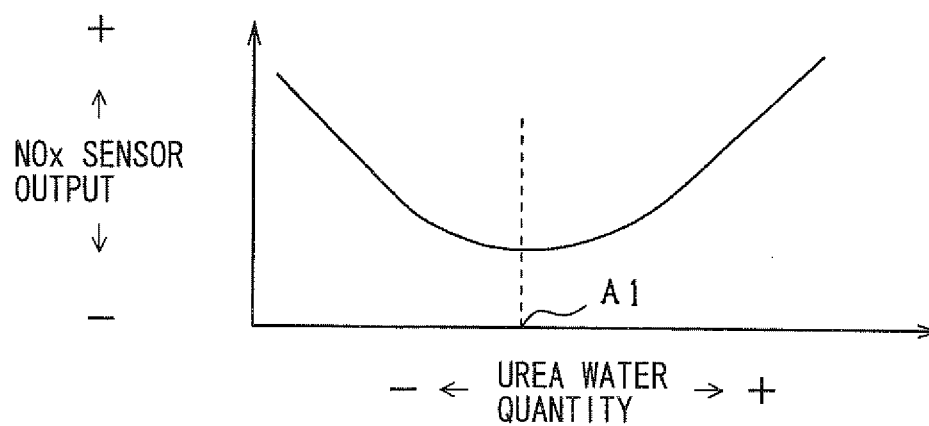


FIG. 5

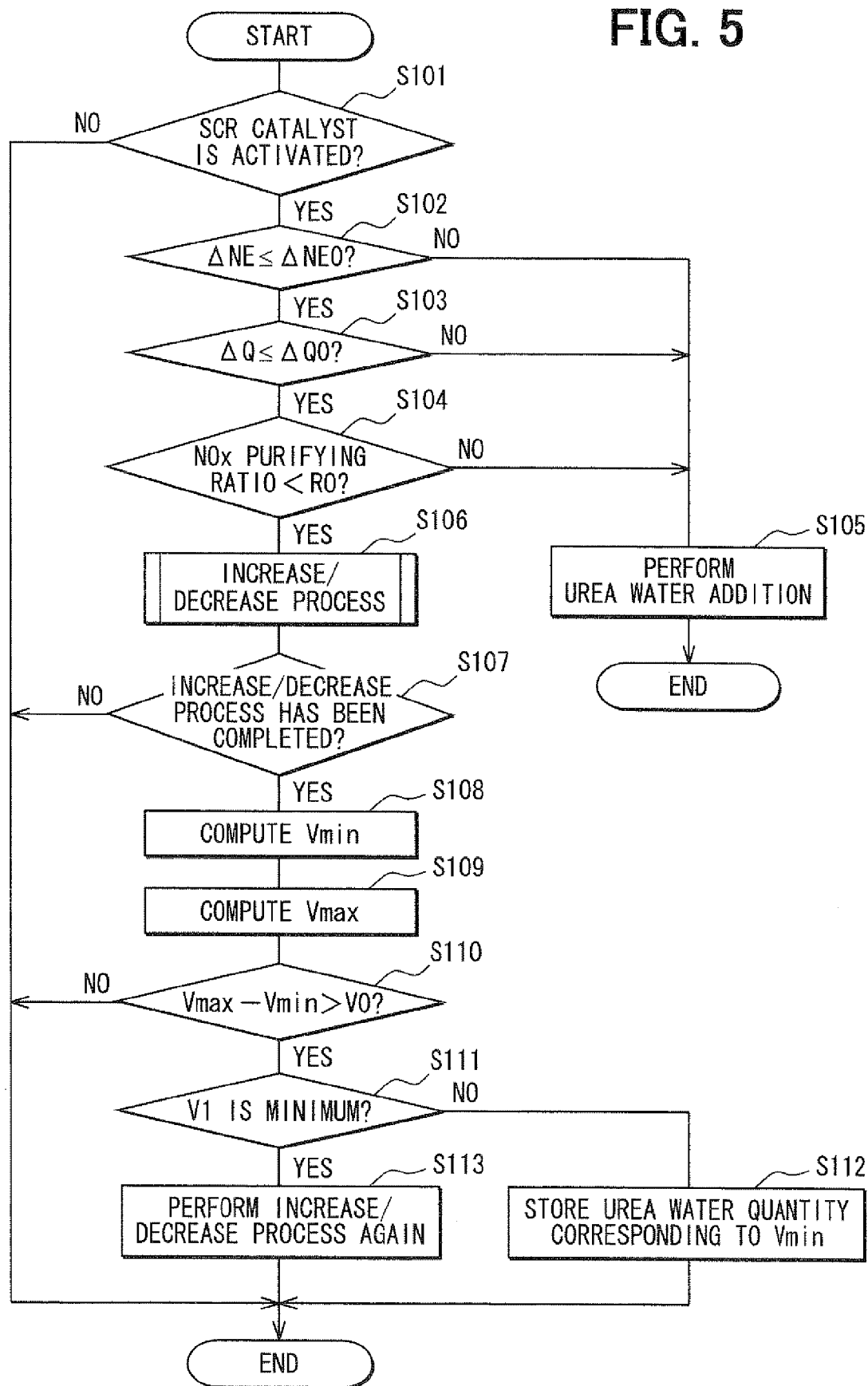


FIG. 6

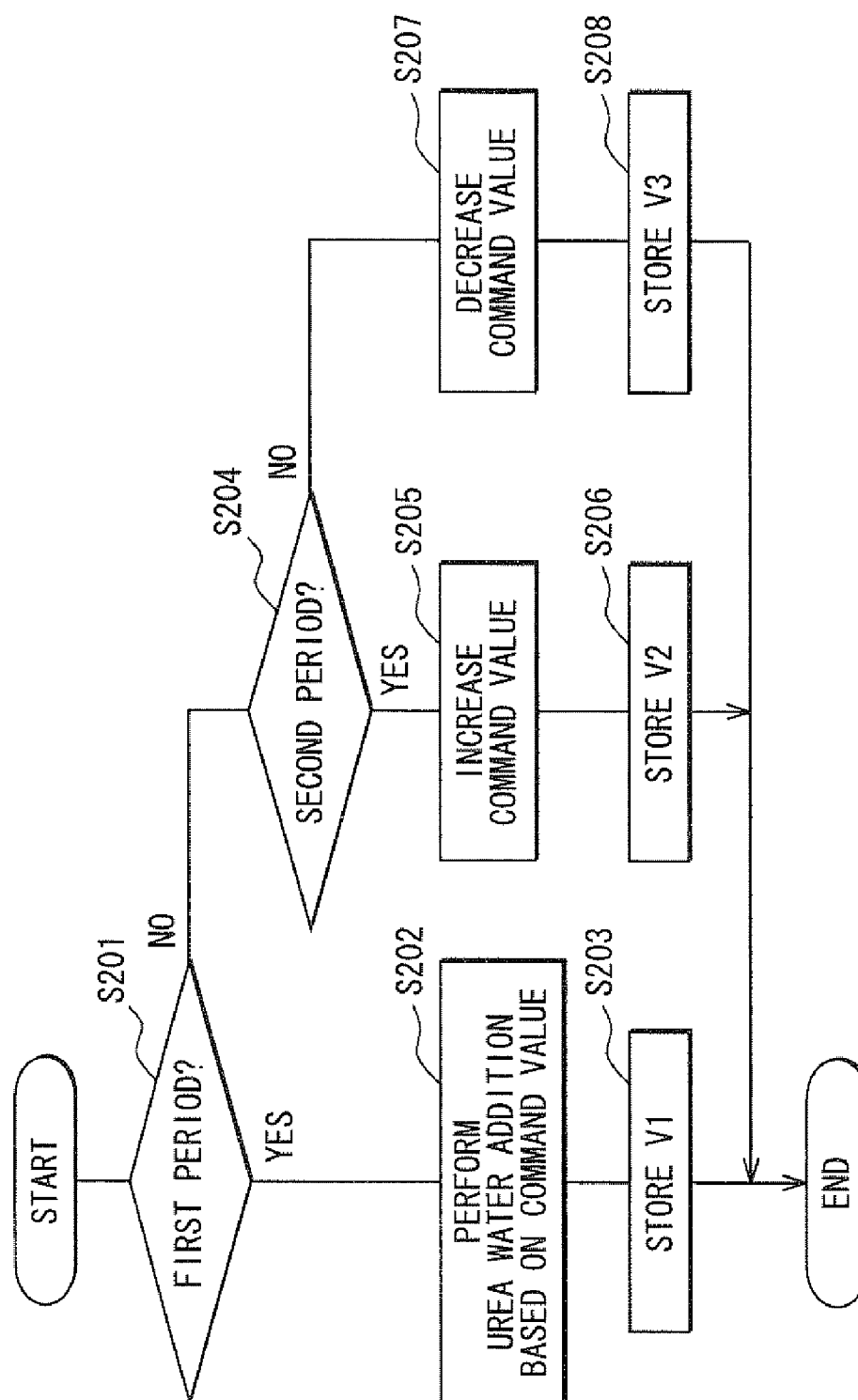


FIG. 7

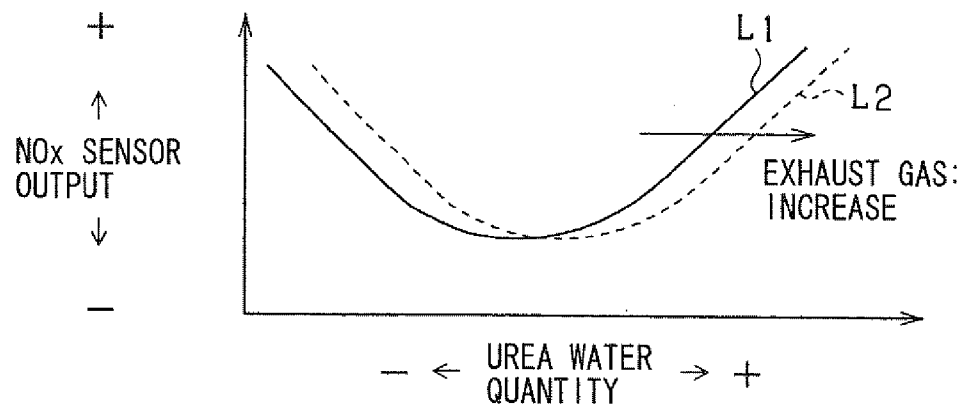


FIG. 8A

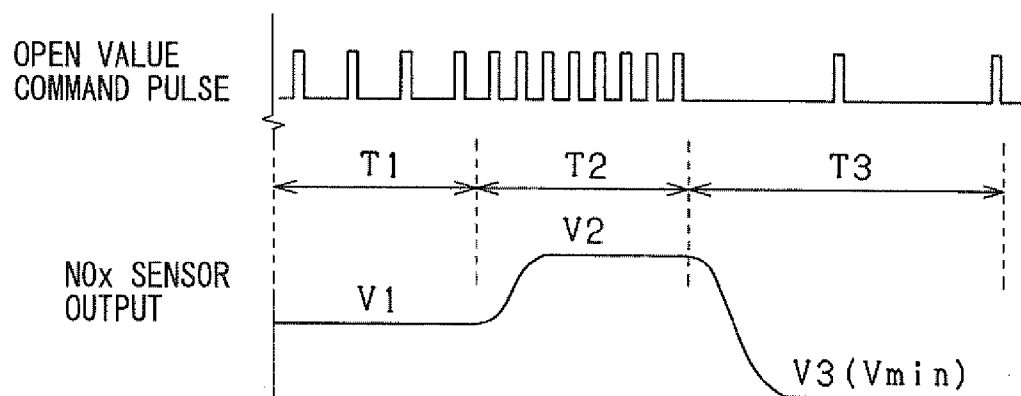


FIG. 8B

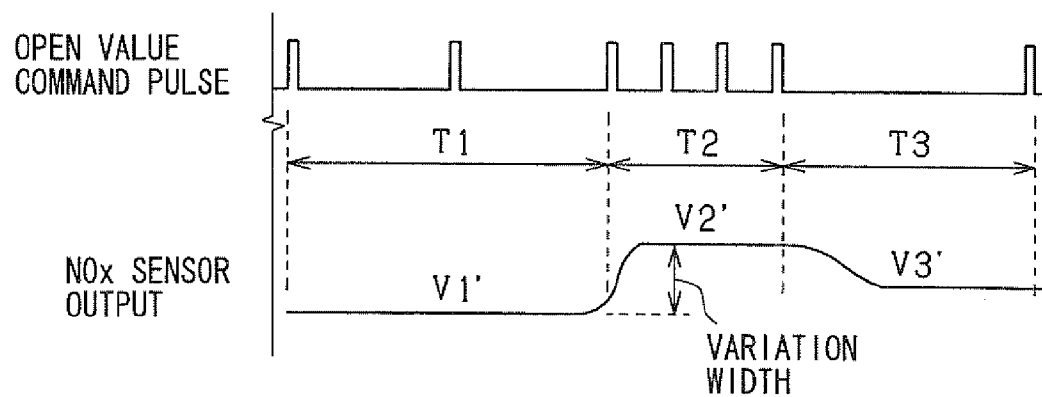


FIG. 9A

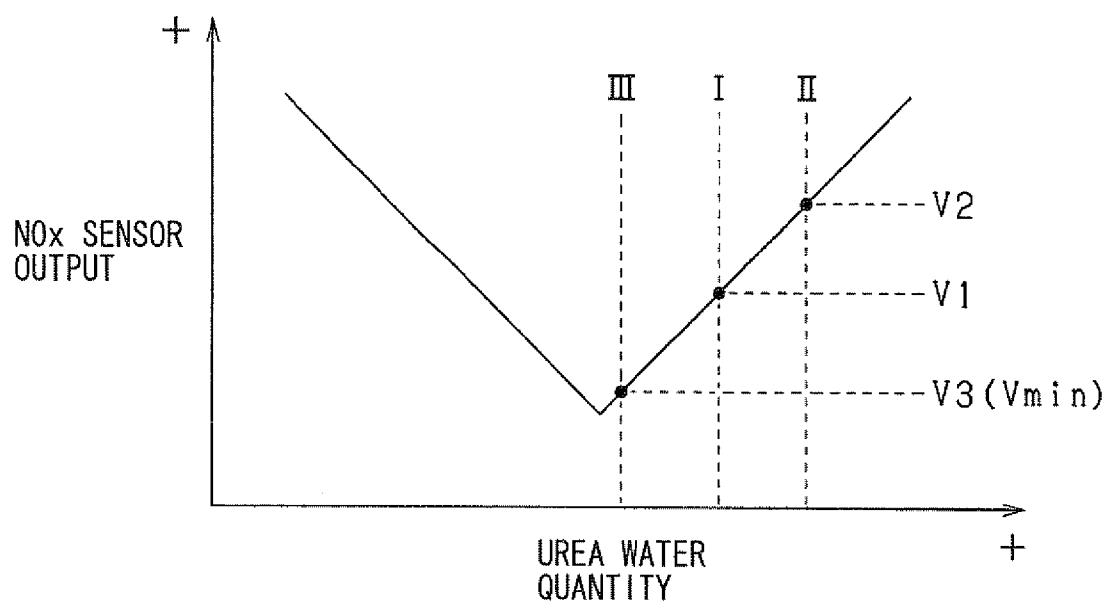


FIG. 9B

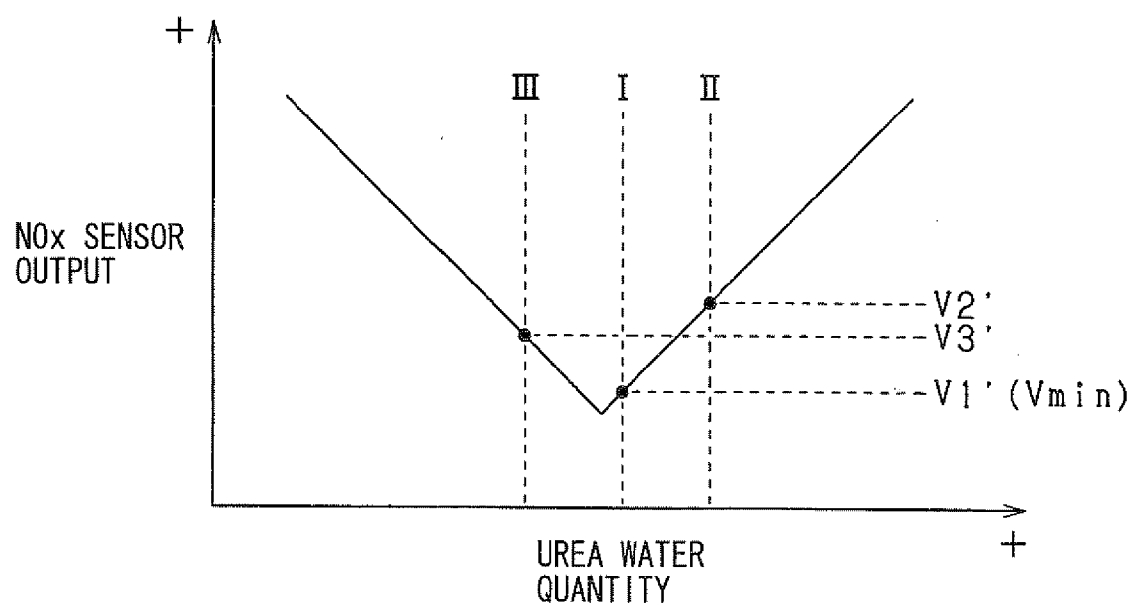


FIG. 10A

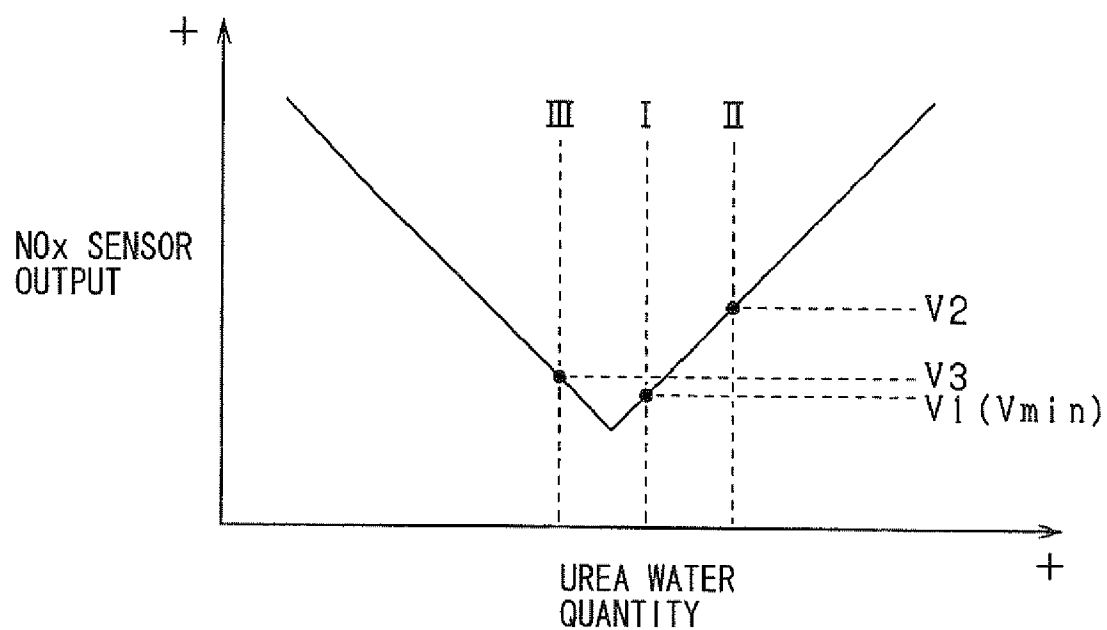


FIG. 10B

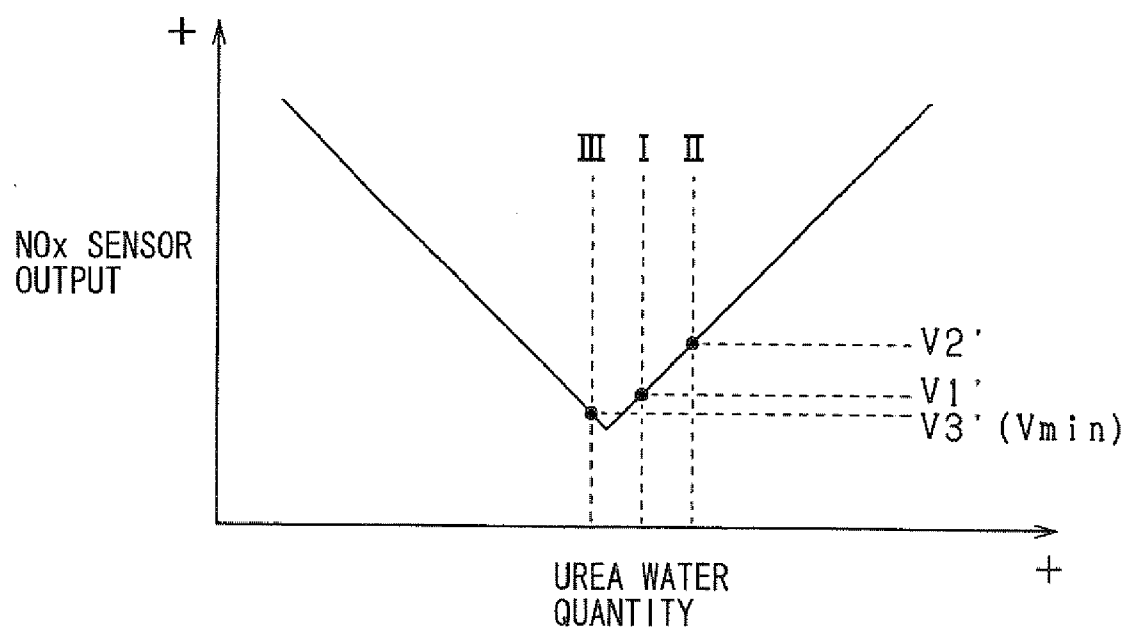


FIG. 11A

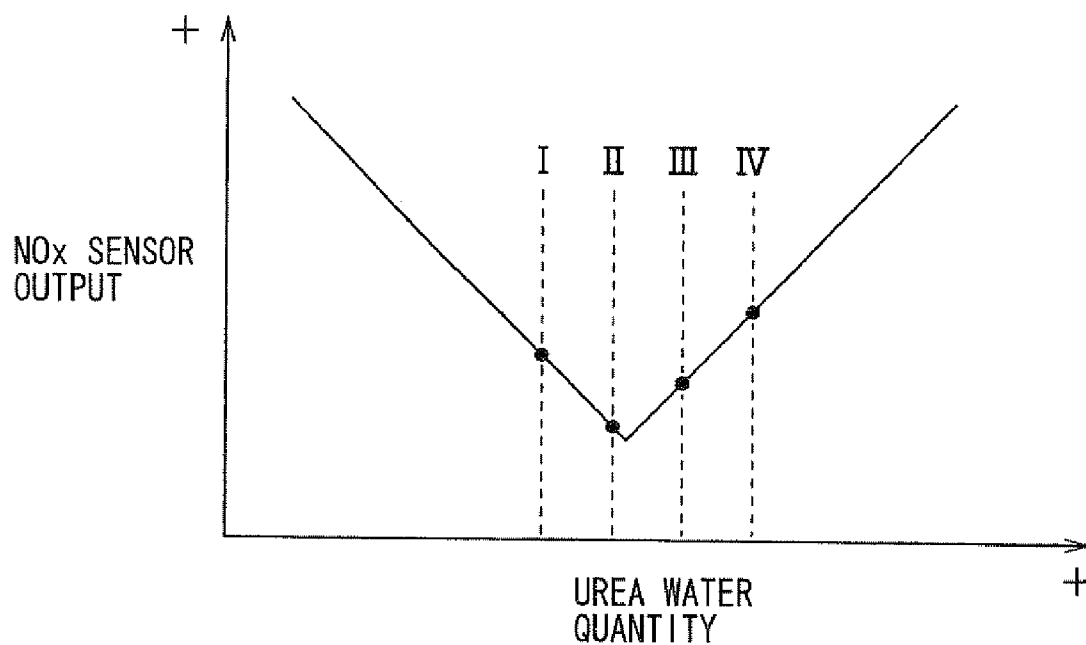
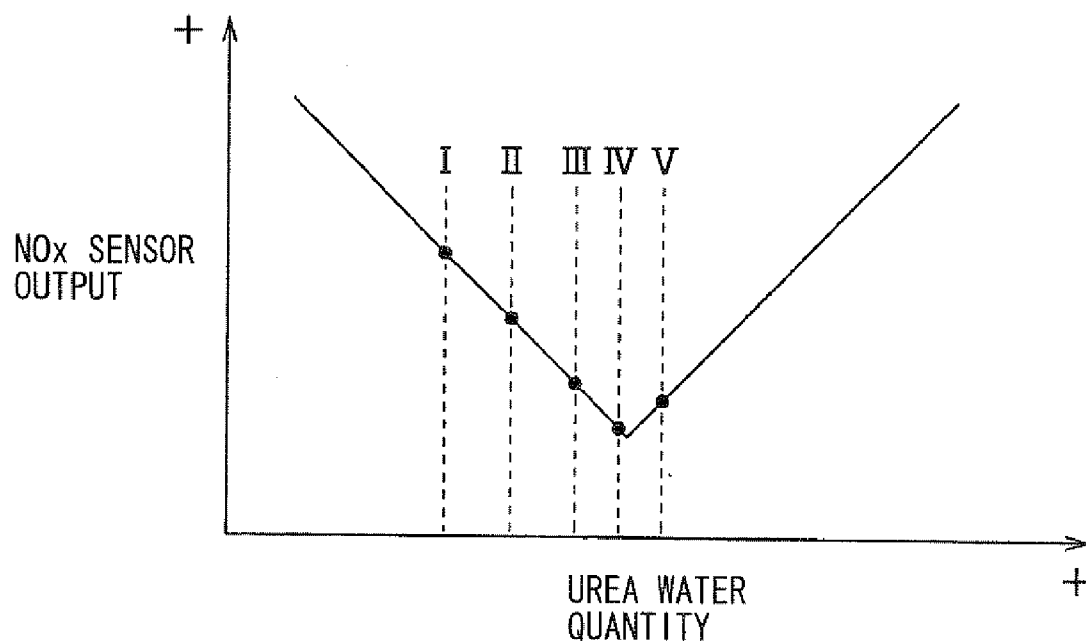


FIG. 11B



EXHAUST GAS PURIFYING APPARATUS FOR INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based on Japanese Patent Application No. 2007-290828 filed on Nov. 8, 2007, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to an exhaust gas purifying apparatus for an internal combustion engine, which is preferably applied to an exhaust gas purifying system of Selective Catalytic Reduction (SCR) type using ammonia reducing agent such as urea aqueous solution (urea water).

BACKGROUND OF THE INVENTION

[0003] A urea Selective Catalytic Reduction (SCR) system has been developed as an exhaust gas purifying apparatus which purifies nitrogen oxide (NOx) in an exhaust gas exhausted from an internal combustion engine, especially from a diesel engine. The urea SCR system has following configuration:

[0004] That is, in the urea SCR system, a selective catalytic reduction type NOx reduction catalyst (SCR catalyst) is provided in an exhaust gas pipe connected to an engine body, and a urea water adding valve (UWA valve) is provided upstream of the SCR catalyst in order to add a urea water into the exhaust pipe. The exhaust gas and the urea water are supplied to the NOx reduction catalyst so that the exhaust gas is purified by a reductive reaction of NOx on the NOx reduction catalyst. In resolving NOx, the urea water is hydrolyzed by exhaust gas heat to generate ammonia (NH₃), and the NOx is selectively reduced by ammonia on the NOx reduction catalyst, whereby the exhaust gas is purified.

[0005] A NOx sensor is provided downstream of the NOx reduction catalyst so that NOx concentration is detected. Based on an output of the NOx sensor, a NOx purifying ratio is computed. In the exhaust gas purifying apparatus shown in JP-2003-314256A, NOx sensors are respectively provided upstream and downstream of the NOx reduction catalyst. Based on each output of the NOx sensors, the NOx purifying ratio is computed. Besides, while the engine is stably running, a supply condition of the reducing agent is switched to compute a difference in the NOx purifying ratio between a case where the reducing agent is supplied and a case where no reducing agent is supplied. Based on the difference in the NOx purifying ratio, an ammonia adsorbed quantity and the reducing agent added quantity are computed.

[0006] Generally, the NOx sensor includes a sensor element comprised of a solid electrolyte and a pair of electrodes, and senses ammonia (NH₃) as well as NOx. When ammonia excessive for the NOx reduction catalyst is discharged to downstream of the catalyst (when ammonia slip is generated), the output of the NOx sensor is varied according to a discharged quantity of ammonia. In such a case, there is a possibility that the NOx purifying ratio is erroneously computed based on the NOx sensor output. If the accuracy of the NOx purifying ratio is deteriorated, the accuracy of the ammonia adsorbed quantity and the reducing agent added quantity is

also deteriorated, which may cause a decrease of the NOx purifying ratio and an increase of the ammonia slip quantity.

SUMMARY OF THE INVENTION

[0007] The present invention is made in view of the above matters, and it is an object of the present invention to provide an exhaust gas purifying apparatus for an internal combustion engine, which can correctly detect NOx quantity downstream of the NOx reduction catalyst so that the NOx purifying ratio can be appropriately computed.

[0008] According to the present invention, an exhaust gas purifying apparatus for an internal combustion engine includes a NOx reduction catalyst (for example, ammonia selective reduction catalyst) provided in an exhaust gas pipe. Reducing agent (for example, ammonia reducing agent such as urea aqueous solution) is added to the exhaust gas, and NOx purification is performed in the NOx reduction catalyst. NOx quantity downstream of the NOx reduction catalyst is detected by a NOx sensor. A NOx purifying ratio is computed based on the detected NOx quantity.

[0009] An adding quantity control means controls an adding quantity of the reducing agent by the reducing agent adding means. While the reducing agent is added to the exhaust gas, a NOx sensor output is successively obtained and an adding quantity command value in which the NOx sensor output becomes minimum is computed.

[0010] The NOx sensor detects the reducing agent as well as NOx in the exhaust gas, which becomes surplus for NOx reduction catalyst. When the urea water adding quantity is increased, NOx concentration downstream of NOx reduction catalyst is gradually decreased. Furthermore, when the reducing agent is increased, the ammonia concentration (ammonia slip quantity) is increased. In this case, as shown FIG. 4C, the NOx sensor output line is downwardly convex with respect to the reducing agent (urea water) adding quantity. When the NOx sensor output is minimum, the NOx concentration and the ammonia concentration downstream of the NOx reduction catalyst are low and the NOx purifying ratio is maximum.

[0011] According to the present invention, the adding quantity of the reducing agent is variously changed, the NOx sensor output is obtained with respect to each adding quantity of the reducing agent, and an adding quantity command value is computed according to the adding quantity of the reducing agent in which the NOx sensor output becomes minimum.

[0012] Thereby, the surplus quantity of the reducing agent (ammonia slip quantity) is reduced and the NOx purifying ratio becomes maximum. As the result, the NOx quantity downstream of the NOx reduction catalyst is correctly detected, so that the NOx purifying ratio can be properly computed.

[0013] According to another aspect of the invention, the adding quantity of the reducing agent may be varied at least into increasing side or decreasing side relative to the adding quantity command value as a reference. According to this configuration, it can be grasped properly whether the adding quantity command value is optimum and whether the adding quantity makes the NOx sensor output minimum.

[0014] According to another aspect of the present invention, at least three steps of reducing agent additions are performed while the adding quantity of the reducing agent is varied by a predetermined variation width. Further, the reducing agent addition is performed again while the variation width is made small in a case that the sensor output becomes

minimum with respect to a medium quantity of reducing agent among at least three steps of reducing agent additions

[0015] That is, there is a possibility that the most appropriate adding quantity command value may exist between the maximum adding quantity and the minimum adding quantity, in which the NOx sensor output becomes minimum. In such a case, the reducing agent addition is performed again while the variation width is made small, whereby the optimum value of the adding quantity command value can be accurately obtained.

[0016] According to another aspect of the invention, based on a difference between the NOx sensor output before changing the reducing agent adding quantity and the NOx sensor output after changing the reducing agent adding quantity, it can be estimated whether the reducing agent adding quantity in which the NOx sensor output is minimum is in an increasing side or a decreasing side. Based on this estimated result, the reducing agent adding quantity may be increased or decreased. For example, when the NOx sensor output is increased due to the variation in the reducing agent adding quantity, an increase/decrease direction of the reducing agent adding quantity is reversed. Alternatively, when the NOx sensor output is decreased due to the variation in the reducing agent adding quantity, the reducing agent adding quantity is varied in the same increase/decrease direction.

[0017] According to this configuration, the reducing agent adding quantity is varied only in a direction where the minimum sensor output exists. Thus, the increase/decrease process of the reducing agent adding quantity can be simplified.

[0018] According to another aspect of the invention, a variation width of the reducing agent adding quantity may be varied based on the output value of the NOx sensor. For example, as the NOx sensor output increases, the variation width of the reducing agent adding quantity increases. When the NOx sensor output is relatively large, the variation ratio of the NOx sensor output is also relatively large with respect to a variation in the reducing agent adding quantity. When the NOx sensor output is relatively small, the variation ratio of the NOx sensor output is also relatively small. Thus, it is desirable to set the variation width of the reducing agent adding quantity based on the output value of the NOx sensor.

[0019] According to another aspect of the invention, it is desirable that the adding quantity command value is not newly computed when a difference between a minimum value of the sensor output and a maximum value of the sensor output, which are obtained due to a variation in adding quantity of the reducing agent, is within a specified value. That is, at vicinity where the NOx sensor output is minimum, the NOx sensor output hardly varies even if the reducing agent adding quantity is varied. Hence, unnecessary computation (update) of the adding quantity command value can be avoided.

[0020] According to another aspect of the invention, a period during which the reducing agent adding quantity is decreased is longer than a period during which the reducing agent adding quantity is increased. That is, comparing a case that the urea water adding quantity is increased with a case that the urea water adding quantity is decreased, a response speed of the NOx sensor differs. The response speed is slow in the latter case. This is because the reducing agent consuming speed in the NOx reduction catalyst is slower than the reducing agent adsorbing speed (ammonia adsorbing speed) in the NOx reduction catalyst. According to the above configuration, the NOx sensor output can be appropriately

obtained even in both cases where the reducing agent adding quantity is increased or decreased.

[0021] The adding quantity command value in which the NOx sensor output is minimum does not vary successively. When the engine driving condition is stable, the adding quantity command value is constant value. Thus, it is desirable to store the adding quantity command value in a back up memory as a learning value and to update the learning value as needed. Thereby, since the adding quantity command value may be computed in a minimum frequency, a computation load for computing the adding quantity command value can be reduced. For example, every when an ECU is energized, the adding quantity command value may be computed only once.

[0022] The characteristic of NOx sensor output with respect to the reducing agent adding quantity varies according to the engine driving condition. Thus, it is desirable that the adding quantity command value is stored in the memory along with a driving condition of the internal combustion engine at a time of controlling the adding quantity of the reducing agent. Thereby, even if the driving condition of the engine is varied, an appropriate adding quantity command value can be established.

[0023] According to another aspect of the invention, an exhaust gas purifying apparatus includes an oxidation catalyst (for example, ammonia slip catalyst) which is arranged downstream of the NOx reduction catalyst for purifying the reducing agent, and a determination means for determining whether the oxidation catalyst is active or not. When the determination means determines the oxidation catalyst is inactive, the command value computing means performs a computation of the adding quantity command value.

[0024] That is, when the oxidation catalyst downstream of the NOx reduction catalyst is inactive, if the reducing agent is discharged downstream of the NOx reduction catalyst, the reducing agent may not be appropriately purified. According to the above configuration, when the oxidation catalyst is inactive, the adding quantity command value is computed so that it can be restricted that the reducing agent is discharged downstream of the NOx reduction catalyst and the reducing agent is discharged into the atmosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Other objects, features and advantages of the present invention will become more apparent from the following description made with reference to the accompanying drawings, in which like parts are designated by like reference numbers and in which:

[0026] FIG. 1 is a construction view schematically showing an engine control system in an embodiment of the invention;

[0027] FIGS. 2A-2C are time charts for explaining valve open command pulses;

[0028] FIG. 3 is a cross sectional view showing a sensor element of a NOx sensor;

[0029] FIGS. 4A-4C are graphs respectively showing NOx concentration, NH₃ concentration, and NOx sensor output downstream of a catalyst with respect to a urea water adding quantity;

[0030] FIG. 5 is a flowchart showing a urea water adding quantity control process;

[0031] FIG. 6 is a flowchart showing an increase/decrease process of a urea water adding quantity;

[0032] FIG. 7 is a graph showing a characteristic of a NOx sensor output;

[0033] FIGS. 8A and 8B are time charts showing a transition of the NOx sensor output in a case of decreasing the urea water adding quantity;

[0034] FIGS. 9A and 9B are graphs schematically showing the NOx sensor output;

[0035] FIGS. 10A and 10B are graphs schematically showing the NOx sensor output; and

[0036] FIGS. 11A and 11B are graphs schematically showing the NOx sensor output.

DETAILED DESCRIPTION OF EMBODIMENTS

[0037] Hereafter, an embodiment of the present invention is described. In this embodiment, a multi-cylinder diesel engine is controlled. An electronic control unit (ECU) performs a various kind of controls to the engine. The diesel engine has a common-rail fuel injection system and a urea SCR system. Referring to FIG. 1, the system is schematically explained, hereinafter.

[0038] The engine 10 includes an engine body 11 which has a piston 12, an intake valve 13, and an exhaust valve 14. A reciprocative movement of the piston 12 rotates a crankshaft 15. A fuel injector 16 is provided on a cylinder head with respect to each cylinder. The fuel injector 16 injects fuel into a combustion chamber 17 directly, which is combusted in the combustion chamber 17.

[0039] The crankshaft 15 is provided with a crank angle sensor 18 which detects a rotation of the crankshaft 15. A cylinder block is provided with a coolant temperature sensor 19 which detects coolant temperature.

[0040] A fuel supply system will be briefly described hereinafter. The fuel supply system is provided with a high-pressure pump and a common rail. The high-pressure pump pumps up the fuel in the fuel tank and supplies the fuel to the common rail. The high pressure fuel of 10-200 MPa is stored in the common rail and is supplied to the fuel injector 16 of each cylinder. The fuel pressure in the common rail is suitably adjusted according to the engine driving condition.

[0041] An intake pipe (including a manifold portion) 21 is connected to an intake port of the engine 11. An exhaust pipe (including a manifold portion) 22 is connected to an exhaust port of the engine 11. The intake pipe 21 is provided with a throttle actuator 23 which includes an electric drive throttle valve. The intake pipe 21 and the exhaust pipe 22 are connected with each other through an EGR pipe 24. The EGR pipe 24 is provided with an EGR valve 25 and an EGR cooler 26. An air cleaner 27 is provided at a most upstream portion of the intake pipe 21.

[0042] This fuel supply system is provided with a turbocharger 30. The turbocharger 30 is provided with an intake compressor 31 arranged in the intake pipe 21 and an exhaust turbine 32 arranged in the exhaust pipe 22. The exhaust turbine 32 is rotated by the exhaust gas flowing through the exhaust pipe 22. This rotation is transmitted to the intake compressor through a shaft 33. The intake compressor 31 compresses the intake air flowing through the intake pipe 21. The compressed air is cooled by an intercooler 34 and supplied to downstream of the intake pipe 21.

[0043] The intake pipe 21 is provided with a various kind of sensors, such as an air-flow meter, an intake air pressure sensor, an intake air temperature sensor, and the like.

[0044] The exhaust gas purifying system will be described hereinafter. The exhaust pipe 22 is provided with an oxidation catalyst 41, a SCR catalyst (ammonia selective reduction catalyst) 42, and an ammonia slip catalyst 43. The SCR cata-

lyst 42 corresponds to the NOx reduction catalyst. Between the oxidation catalyst 41 and the SCR catalyst 42, a urea water adding valve (UWA valve) 44 is provided in the exhaust pipe 22 in order to supply the urea water as the reducing agent into the exhaust pipe 22. The UWA valve 44 has substantially the same structure as a well-known fuel injector, and injects the urea water from its injection port on receiving an injection command signal. A urea water tank (not shown) stores the urea water therein. The urea water is successively supplied to the UWA valve 44 by a urea water supply pump (not shown) while the engine is running.

[0045] When the urea water is injected into the exhaust pipe 22, the exhaust gas and the urea water flow into the SCR catalyst 42 in which the reductive reaction of NOx is performed to purify the exhaust gas.

[0046] Specifically, the injected urea water is hydrolyzed to generate ammonia (NH₃) as described in following chemical equation.



[0047] When the exhaust gas flows through the SCR catalyst 42, NOx in the exhaust gas is selectively reduced as described in following chemical equations.



[0048] Non-reacted ammonia is discharged with the exhaust gas into the downstream. Non-reacted ammonia is removed by the ammonia slip catalyst 43 arranged downstream of the SCR catalyst 42.

[0049] An oxygen concentration sensor 45 and an exhaust gas temperature sensor 46 are provided in the exhaust pipe 22 between an oxidation catalyst 45 and the SCR catalyst 46 in order to detect the oxygen concentration in the exhaust gas and the exhaust gas temperature. A NOx sensor 47 detecting NOx concentration in the exhaust gas is arranged downstream of the SCR catalyst 42. Based on an output of the NOx sensor, the NOx purifying ratio of the SCR catalyst 42 is computed.

[0050] The exhaust pipe 22 is provided with a diesel particulate filter (DPF: not shown) capturing particulate matters (PM) in the exhaust gas.

[0051] The ECU 50 includes a microcomputer comprised of a CPU, a ROM, a RAM and the like. The ECU 50 receives detected signals from the above sensors, a rail pressure sensor detecting fuel pressure in the common rail, an accelerator sensor detecting accelerator operated quantity, and the like. The ECU 50 performs a fuel injection control, a fuel pressure control (rail pressure control) and the like based on the engine speed, the accelerator operated quantity and the like. The fuel injection operation of the fuel injector 16 and the fuel pumping operation of the high-pressure pump are controlled. Furthermore, the ECU 50 controls the throttle actuator 23 and the EGR valve 25 based on the current engine driving condition.

[0052] The ECU 50 has an EEPROM 51 as a backup memory. The EEPROM 51 stores a various leaning value and diagnosis data. A standby RAM can be used as the backup memory in stead of the EEPROM.

[0053] The ECU 50 computes the NOx quantity downstream of the SCR catalyst 42 and the NOx purifying ratio based on the output of the NOx sensor 47. Further, the ECU 50 controls a urea water adding quantity based on the NOx purifying ratio. The NOx purifying ratio (X1) is computed

based on a NOx discharged quantity (Y1) from the engine and a NOx quantity (Y2) downstream of the SCR catalyst 42. The NOx discharge quantity (Y1) is computed by used of maps or formulas according to the current engine driving condition (engine speed, fuel injection quantity). The NOx quantity (Y2) is computed based on the output of the NOx sensor 47.

[0054] The ECU 50 sends an open valve command signal to the UWA valve 44 periodically so that a driving portion (solenoid portion) of the UWA valve 44 is energized. When the solenoid is energized to open the UWA valve 44, the urea water is injected from the UWA valve 44. An output cycle (output frequency) of the open valve command signal is adjusted so that the urea water adding quantity is increased or decreased. FIG. 2A shows a base open valve command signal to the UWA valve 44. When the output interval of the open valve command signal is made longer than that of the base open valve command signal, as shown in FIG. 2B, the urea water adding quantity is decreased. When the output interval of the open valve command signal is made shorter as shown in FIG. 2C, the urea water adding quantity is increased. The UWA valve 44 may be temporarily closed in order to decrease the urea water adding quantity.

[0055] Referring to FIG. 3, a configuration of the NOx sensor 47 will be described, hereinafter. FIG. 3 is a cross sectional view showing a sensor element 60 of the NOx sensor 47. The sensor element 60 includes a pump cell, sensor cell, and a monitor cell which are laminated. Since the monitor cell has a function of discharging Oxygen in the gas as well as the pump cell, the monitor cell can be referred to as an auxiliary pump cell or a second pump cell.

[0056] In the sensor element 60, solid electrolyte layers 61, 62, which are made of oxygen ion conductive material such as zirconia, are laminated through a spacer 63 which is made of insulating material such as alumina. The upper solid electrolyte layer 61 is provided with an exhaust gas inlet 61a through which the exhaust gas is introduced into a first chamber 64. The first chamber 64 communicates with a second chamber 66 through a restricting portion 65. A porous diffusion layer 67 is arranged on an upper surface of the upper solid electrolyte layer 61 in order to introduce or discharge the exhaust gas with a specified diffusion resistance, and an insulating layer 69 is also arranged on the upper surface of the upper solid electrolyte layer 61 to define an atmosphere passage 69.

[0057] An insulating layer 71 is arranged on a lower surface of the lower solid electrolyte layer 62 to define an atmosphere passage 72.

[0058] The lower solid electrolyte layer 62 is provided with a pump cell 81 which faces the first chamber 64. The pump cell 81 introduces or discharges the oxygen into or from the first chamber 64 to adjust a residual oxygen concentration in the first chamber 64 to a specified value. The pump cell 81 is provided with a pair of electrodes 82, 83 on its upper surface and its lower surface. The upper electrode 82 in the first chamber 64 is a NOx inactive electrode. When a specified voltage is applied between the electrodes 82, 83, the pump cell 81 degrades oxygen in the first chamber 64, so that the degraded oxygen is discharged into the atmosphere passage 72 from the lower electrode 83.

[0059] The upper solid electrolyte layer 61 is provided with a monitor cell 84 and a sensor cell 85 which face the second chamber 66. After the degraded oxygen is discharged by the pump cell 81, the monitor cell 84 generates electric power according to the residual oxygen concentration or generates

electric output according to applied electric voltage. The sensor cell 85 detects NOx concentration of gas in the second chamber 66.

[0060] The monitor cell 84 and the sensor cell 85 are adjacently aligned, and include a pair of electrodes 86, 87 in the second chamber 66 and a common electrode 88 in the atmosphere passage 88. That is, the monitor cell is comprised of the upper solid electrolyte layer 61, the electrode 86 and the common electrode 88, and the sensor cell 85 is comprised of the upper solid electrolyte layer 61, the electrode 87 and the common electrode 88. The electrode 86 of the monitor cell 84 is made of noble metal such as Au—Pt, which is inactive to NOx. The electrode 87 of the sensor cell 85 is made of noble metal such as Pt, Rh, which is active to NOx. Although FIG. 3 shows that the monitor cell 84 and the sensor cell 85 are aligned in series in an exhaust gas flow, the monitor cell 84 and the sensor cell 85 are actually arranged in parallel.

[0061] A heater 73 is embedded in the insulating layer 71 for heating whole of the sensor element 60. The heater 73 receives electricity from a battery and generates heat energy in order to activate whole of the sensor element including the pump cell 81, the monitor cell 84 and the sensor cell 85.

[0062] In the sensor element 60 described above, the exhaust gas is introduced into the first chamber 64 through the porous diffusion layer 67 and the exhaust gas inlet 61a. When the exhaust gas flows around the pump cell 81 and a pump-cell voltage is applied between the pump cell electrodes 82, 83, the degradation of oxygen occurs so that the oxygen is introduced or discharged through the pump cell 81 according to the oxygen concentration in the first chamber 64. Since the electrode 82 in the first chamber 64 is inactive to NOx, NOx is not degraded in the pump cell 81, but only oxygen is degraded in the pump cell 81 to be discharged into the atmosphere passage 72 from the electrode 83. Hence, the pump cell 81 maintains the interior of first chamber 64 at a specified low oxygen concentration.

[0063] The gas passed through the pump cell 81 flows into the second chamber 66, and the monitor cell 84 generates outputs according to the residual oxygen concentration in the gas. The output of the monitor cell 84 is detected as a monitor cell current by applying a specified monitor cell voltage between the monitor cell electrodes 86, 88. Besides, when a specified sensor cell voltage is applied between the sensor cell electrodes 87, 88, NOx is reduced and the oxygen is generated. The generated oxygen is discharged into the atmosphere passage 68 from the electrode 88. At this moment, NOx concentration in the exhaust gas is detected based on the electric current flowing through the sensor cell 85. This electric current is referred to as sensor cell current.

[0064] When the urea water is injected by the UWA valve 44, the NOx purifying ratio of the SCR catalyst 42 is computed based on the output of the NOx sensor 47. In such a case, since the NOx sensor senses ammonia (NH₃) as well as NOx in the exhaust gas, if the excessive ammonia exists downstream of the SCR catalyst 42 due to the ammonia slip, the NOx sensor erroneously outputs its detected signal due to the ammonia detection. Hence, the NOx purifying ratio is erroneously computed, so that the urea water adding quantity can not be precisely controlled.

[0065] That is, when ammonia is excessive in the SCR catalyst 42 and the excessive ammonia is discharged downstream of the SCR catalyst 42, the gas containing ammonia flows from the first chamber 64 to the second chamber 66 and the chemical reaction of ammonia is arisen in the sensor cell

85. Specifically, an oxidation reaction is arisen in the sensor cell **85** as shown in following chemical equation, and the output of the NOx sensor increases along with the oxidation reaction.



[0066] FIGS. 4A to 4C respectively show relationship between the urea water adding quantity and the NOx concentration downstream of the catalyst, between the urea water adding quantity and the NH₃ concentration, and between the urea water adding quantity and the NOx sensor output.

[0067] As shown in FIGS. 4A and 4B, when the urea water adding quantity is increased, NOx is purified by the SCR catalyst **42** to be decreased and NH₃ concentration is increased around after the NOx purifying ratio is saturated. As described above, since the NOx sensor senses ammonia as well as NOx, the output of the NOx sensor increases as the NOx and the ammonia are increased. That is, the NOx sensor output line is downwardly convex with respect to the urea water adding quantity as shown in FIG. 4C.

[0068] In FIG. 4C, when the urea water adding quantity is “A1”, the NOx sensor output is a minimum value. In a region where the urea water adding quantity is less than “A1”, as the urea adding water quantity increases, the NOx purifying ratio increases and the NOx sensor output decreases. In a region where the urea water adding quantity is greater than “A1”, as the urea adding water quantity decreases, the NOx sensor output decreases. Hence, the urea water adding quantity in which the NOx sensor output is minimum corresponds to the water adding quantity in which the ammonia slip quantity is small and the NOx purifying ratio is maximum. By controlling the urea water adding quantity in such a manner that the NOx sensor output becomes minimum, the NOx purifying ratio becomes high and the ammonia slip quantity becomes minimum.

[0069] In the characteristic shown in FIG. 4C, a variation gradient of the NOx sensor output relative to the variation in the urea water adding quantity is small around the minimum value of the NOx sensor output. As the urea water adding quantity is apart from the minimum value, the variation gradient of the NOx sensor output becomes large. Some NOx sensors have no variation gradient of its output around the minimum value thereof.

[0070] According to the present embodiment, the urea water adding quantity is adjusted and the NOx sensor output is obtained every urea water adding quantity. An adding quantity command value is computed based on the urea water adding quantity in which the NOx sensor output is minimum. The computed adding quantity command value is established as a target value, and the urea water adding quantity is controlled so as to agree with the target value.

[0071] Referring to FIG. 5, a urea water adding control process will be described hereinafter. This process is repeatedly performed by the ECU **50** at a predetermined time interval. In step **S101**, the computer determines whether the SCR catalyst **42** is activated. Specifically, the computer determines whether the exhaust gas temperature is greater than a specified value (for example, 150° C.). When the answer is Yes, the procedure proceeds to step **S102**.

[0072] In steps **S102-S104**, the computer determines whether an execution condition for the urea water adding quantity control is established. Specifically, in step **S102**, the computer determines whether an engine speed variation ΔNE between a previous engine speed and a current value speed is

less than a specified value ΔNE0 . In step **S103** the computer determines whether a fuel injection quantity variation ΔQ between a previous fuel injection quantity and a current fuel injection quantity is less than a specified value ΔQ0 . In step **S104**, the computer determines whether the NOx purifying ratio is less than a specified ratio “R0”. That is, in steps **S102** and **S103**, the computer determines whether the engine driving condition is stable. In step **S104**, the computer determines whether it is necessary to update the adding quantity command value based on the current NOx purifying ratio.

[0073] When any of answers in steps **S102-S104** is NO, the procedure proceeds to step **S105**. When all answers in steps **S102-S104** are YES, the procedure proceeds to step **S106**. In step **S105**, the urea water addition is performed based on the current adding quantity command value. This corresponds to a normal urea water adding process.

[0074] In step **S106**, an increase/decrease process of the urea water adding quantity is performed in order to update the adding quantity command value. Referring to FIG. 6, the increase/decrease process of the urea water adding quantity will be described in detail. In the increase/decrease process, the urea water adding quantity is varied in the order of the adding quantity command value, an adding quantity increase value, and an adding quantity decrease value. The NOx sensor output is successively obtained. A period where the urea water addition is performed based on the adding quantity command value is referred to as a first period, a period where the urea water addition is performed based on the adding quantity increase value is referred to as a second period, and a period where the urea water addition is performed based on the adding quantity decrease value is referred to as a third period, hereinafter.

[0075] In step **S201**, the computer determines whether it is in the first period now. When the answer is YES, the procedure proceeds to step **S202** in which the urea water addition is performed based on the adding quantity command value. And then, the procedure proceeds to step **S203** in which a NOx sensor output V1 is stored.

[0076] When the answer is NO in step **S201**, the procedure proceeds to step **S204** in which the computer determines whether it is in the second period. When the answer is YES in step **S204**, the procedure proceeds to step **S205** in which the adding quantity command value is increased by a specified value α and the urea water addition is performed based on the adding quantity increase value (adding quantity command value + α). Then, the procedure proceeds to step **S206** in which a NOx sensor output V2 is stored.

[0077] When the answer is NO in step **S204**, it can be assumed that it is in the third period. The procedure proceeds to step **S207** in which the adding quantity command value is decreased by the specified value α and the urea water addition is performed based on the adding quantity decrease value (adding quantity command value - α). Then, the procedure proceeds to step **S208** in which a NOx sensor output V3 is stored.

[0078] Referring back to FIG. 5, in step **S107**, the computer determines whether the above increase/decrease process has been completed. When the increase/decrease process shown in FIG. 6 has been completed, the procedure proceeds to step **S108**. When the answer is NO in step **S107**, the procedure ends once.

[0079] In step **S108**, the computer derives a minimum sensor output Vmin from the above NOx sensor outputs V1-V3.

In step **S109**, the computer derives a maximum sensor output $V_{\max}$ from the above NOx sensor outputs $V1$ - $V3$.

[0080] Then, the procedure proceeds to step **S110** in which the computer determines whether a difference between the maximum sensor output $V_{\max}$ and the minimum sensor output $V_{\min}$ is greater than a specified value $V0$. When the answer is NO in step **S110**, the computer determines that it is unnecessary to update the adding quantity command value, and the procedure ends. When the answer is YES in step **S110**, the procedure proceeds to step **S111**.

[0081] In step **S111**, the computer determines whether the NOx sensor output $V1$ is minimum sensor output $V_{\min}$. When the answer is NO, the procedure proceeds to step **S112**. When the answer is YES, the procedure proceeds to step **S113**.

[0082] In step **S112**, the urea water adding quantity corresponding to the minimum sensor output $V_{\min}$ is stored in the EEPROM **51** as the adding quantity command value. At this moment, one of the adding quantity increase value or the adding quantity decrease value is stored as a new adding quantity command value. This new adding quantity command value corresponds to a learning value. Thereby, the update of the adding quantity command value is completed.

[0083] In step **S113**, the variation width to the adding quantity command value is made small, and the adding quantity increase/decrease process is performed again. After the adding quantity increase/decrease process is performed again, the adding quantity command value is updated (step **S108**-**S12**).

[0084] Alternatively, when the answer is repeatedly YES for specified times in step **S111**, the variation width is made small and the adding quantity increase/decrease process is performed again. That is, when the urea water quantity increase/decrease process and the minimum sensor output retrieval have been repeatedly performed, and when the NOx sensor output based on the original adding quantity command value is the minimum sensor output $V_{\min}$ repeatedly for the specified times, the increase/decrease process (the process shown in FIG. 6) is performed again.

[0085] The adding quantity command value in which the NOx sensor output is minimum does not vary successively. When the engine driving condition is stable, the adding quantity command value is constant value. Thus, it is unnecessary to compute the adding quantity command value repeatedly when the engine driving condition is stable. For example, every when the ECU is energized, the adding quantity command value may be computed only once.

[0086] The characteristic of NOx sensor output with respect to the urea water adding quantity varies according to the engine driving condition. More specifically, when the exhaust gas quantity or the exhaust gas temperature is varied according to the engine driving condition, the characteristic of the NOx sensor output is varied. As shown in FIG. 7, when the exhaust gas quantity is increased, the characteristic of the sensor output varies from "L1" to "L2". Also when the exhaust gas temperature is decreased, the characteristic varies in the same manner. Thus, it is desirable that the adding quantity command value is learned with the engine driving condition. For example, the engine load (accelerator operation amount) and the engine speed are established as driving condition parameters, and the adding quantity command value is learned with respect to each parameter.

[0087] Alternatively, the adding quantity command value can be learned with respect to the exhaust gas quantity and the exhaust gas temperature.

[0088] The process of the adding quantity increase/decrease process and the minimum sensor output retrieval will

be described more specifically, hereinafter. FIGS. 8A and 8B are time charts showing a transition of the NOx sensor output when the urea water adding quantity is varied. FIGS. 9A-10B are graphs showing the characteristic of the NOx sensor output schematically.

[0089] FIGS. 8A and 8B show the first period **T1**, the second period **T2**, and the third period **T3**. FIGS. 9A-10B correspond to FIG. 4C. In FIGS. 9A-10B, the characteristics of the NOx sensor output is illustrated as V-shape in order to easily explain the NOx sensor output. In FIGS. 9A-10B, Roman numbers I, II, III represent a variation order of the urea water adding quantity. The Roman number "I" represents the urea water addition by the adding quantity command value, the number "II" represents the urea water addition by the adding quantity increase value, and the number "III" represents the urea water addition by the adding quantity decrease value.

[0090] The NOx sensor output varies according to the urea water adding quantity.

[0091] For example, in a case shown in FIG. 9A, the adding quantity command value, the adding quantity increase value, and the adding quantity decrease value are greater than the urea water adding quantity corresponding to the minimum sensor output. The NOx sensor output $V3$ is a minimum value. Thus, the adding quantity command value is updated by the urea water adding quantity corresponding to the NOx sensor output $V3$.

[0092] FIG. 8A is a time chart showing the case of FIG. 9A. As shown in FIG. 8A, an output interval of an open valve command pulse of the UWA valve **44** is varied so that the urea water adding quantity is varied. Along with the variation in the urea water adding quantity, the NOx sensor outputs $V1$, $V2$, $V3$ are obtained and the NOx sensor output $V3$ is the minimum sensor output $V_{\min}$.

[0093] The third period **T3** is longer than the second period **T2**. Comparing a case that the urea water adding quantity is increased with a case that the urea water adding quantity is decreased, a response speed of the NOx sensor differs. The response speed is slow in the latter case. This is because ammonia consuming speed in the SCR catalyst **42** is slower than ammonia adsorbing speed in the SCR catalyst **42**. As described above, by making difference in the urea water adding period between a case where the urea water quantity is increased and a case where the urea water quantity is decreased, the sensor output is appropriately obtained even if the urea water adding quantity is increased or decreased. Besides, in both cases, a minimum required time period can be established.

[0094] After the NOx sensor output $V3$ is obtained as the minimum sensor output $V_{\min}$, a similar adding quantity increase/decrease process is successively performed to retrieve a minimum sensor output $V_{\min}$. In this case, as shown in FIGS. 8B and 9B, the urea water addition is performed by the previously computed adding quantity command value ($V3$ in FIG. 9A) as a current adding quantity command value. After the NOx sensor output $V1'$ is obtained, the urea water addition by the adding quantity increase value and the urea water addition by the adding quantity decrease value are performed. Then, the NOx sensor outputs $V2'$ and $V3'$ are obtained. The NOx sensor output $V1'$ is a minimum sensor output, and the adding quantity command value is not updated. Besides, in FIG. 8B, a value of $(V2'-V1')$ corresponds to a variation width ($V_{\max}-V_{\min}$). If this variation width is less than a specified value, the adding quantity command value is not updated.

[0095] When the adding quantity increase/decrease process shown in FIGS. 9A and 9Bn is successively performed, it is previously known that the NOx sensor output is increased

($V2' > V1'$) in a case of increasing the adding quantity shown in FIG. 9B. Hence, the urea water adding quantity can be only decreased.

[0096] FIGS. 10A and 10B show a case where the adding quantity increase/decrease process is performed with respect to the current adding quantity command value and then the adding quantity increase/decrease process is performed again while the variation width is made small.

[0097] As shown in FIG. 10A, with respect to the adding quantity command value, the adding quantity increase value, and the adding quantity decrease value, the NOx sensor outputs $V1$ - $V3$ are obtained respectively. In this case, the NOx sensor output $V1$ is the minimum sensor output V_{min} . There is a possibility that a more appropriate adding quantity command value may exist between the maximum adding quantity (adding quantity increase value) and the minimum adding quantity (adding quantity decrease value), in which the NOx sensor output becomes smaller. Thus, as shown in FIG. 10B, the adding quantity increase/decrease process is performed again while the variation width relative to the adding quantity command value is made smaller.

[0098] In FIG. 10B, since the NOx sensor output $V3'$ is the minimum sensor output, the adding quantity command value is updated by the urea water adding quantity corresponding to the NOx sensor output $V3'$.

[0099] According to the present embodiment, following advantages can be obtained.

[0100] The urea water addition is performed while the urea water adding quantity is varied, and the NOx sensor output is obtained with respect to each adding quantity. The adding quantity command value is computed based on the urea water adding quantity in which the sensor output is the minimum value. Hence, the urea water adding quantity in which the ammonia slip quantity is small and the NOx purifying ratio is maximum can be established as the adding quantity command value. As the result, the NOx quantity downstream of the SCR catalyst 42 is correctly detected, so that the NOx purifying ratio can be properly computed.

[0101] Further, while the engine is running, the urea water addition by the urea water adding valve 44 is performed with the adding quantity command value as the target value, so that the NOx purifying ratio can be maintained at a maximum value. A discharge of ammonia to the downstream side of the SCR catalyst 42 is restricted as much as possible. That is, the NOx purifying ratio can be kept high and the ammonia slip can be reduced.

[0102] Three steps of the urea water addition are performed while the adding quantity command value is increased/decreased by a specified variation width. When the middle quantity of the three step urea water addition corresponds to the minimum NOx sensor output, the variation width is made smaller and the urea water adding quantity is varied again. Thus, the most appropriate adding quantity command value can be correctly obtained.

[0103] Only when the NOx purifying ratio is relatively low, the adding quantity command value is updated. Hence, unnecessary computation (update) of the adding quantity command value can be avoided when the NOx purifying ratio is appropriate and the adding quantity command value does not need to be updated.

[0104] When the difference between the maximum sensor output V_{max} and the minimum sensor output V_{min} is less than the specified value $V0$, the adding quantity command value is not newly computed. Thus, unnecessary computation (update) of the adding quantity command value can be avoided.

[0105] Since the adding quantity command value in which the NOx sensor output is minimum is stored in the EEPROM 51 as the learning value, the characteristic of the NOx sensor is constantly obtained to preferably perform the urea water addition. Besides, since the adding quantity command value may be computed in a minimum frequency, a computation load for computing the adding quantity command value can be reduced.

[0106] Further, since the adding quantity command value is stored in the EEPROM 51 with the engine driving condition, an appropriate adding quantity command value can be established even if the engine driving condition is changed.

[0107] The present invention is not limited to the embodiments described above, but may be performed, for example, in the following manner.

[0108] In the above embodiment, while the variation width is constant in varying the urea water adding quantity, the urea water adding quantity is varied from the adding quantity increase value to the adding quantity decrease value across the adding quantity command value. This order can be changed as follows. For example, as shown in FIG. 11A, the urea water adding quantity can be varied in an increasing direction only. In FIG. 11A, the urea water adding quantity is increased by a constant quantity in the order of the Roman numbers I to IV and the NOx sensor output is obtained. Alternatively, as shown in FIG. 11B, the urea water adding quantity may be increased while the variation width is being changed. In FIG. 11B, the variation quantity is relatively large when the urea water adding quantity is varied from "I" to "III" through "II". Then, the variation width is made small when the urea water adding quantity is varied from "III" to "V" through "IV".

[0109] The variation width of the urea water adding amount may be set according to the NOx sensor output. For example, as the NOx sensor output increases, the variation width of the urea water adding quantity increases. As shown in FIG. 4, when the NOx sensor output is relatively large, the variation ratio of the NOx sensor output is also relatively large. When the NOx sensor output is relatively small, the variation ratio of the NOx sensor output is also relatively small. Hence, by setting the variation width of the urea water adding quantity based on the NOx sensor output, the NOx sensor minimum output can be appropriately obtained.

[0110] Based on a difference between the NOx sensor output before changing the urea water adding quantity and the NOx sensor output after changing the urea water adding quantity, it can be estimated whether the urea water adding quantity in which the NOx sensor output is minimum is in an increasing side or a decreasing side. Based on this estimated result, the urea water adding quantity may be increased or decreased. For example, when the NOx sensor output is increased due to the variation in the urea water adding quantity, an increase/decrease direction of the urea water adding quantity is reversed. Alternatively, when the NOx sensor output is decreased due to the variation in the urea water adding quantity, the urea water adding quantity is varied in the same increase/decrease direction. According to this configuration, the urea water adding quantity is varied in a direction where the minimum sensor output exists. Thus, the increase/decrease process of the urea water adding quantity can be simplified.

[0111] When it is determined that the ammonia slip catalyst 43 is inactive, the increase/decrease operation of the urea water adding quantity and the update of the urea water adding command value may be performed. Specifically, the ECU 50 determines the condition of the ammonia slip catalyst 43 based on the temperature of the catalyst 43 or an elapsed time after the engine is started. When it is determined that the ammonia slip catalyst 43 is inactive, the increase/decrease process of the urea water adding quantity is performed. In such a case, the discharge of ammonia downstream of the SCR catalyst 42 is restricted and a discharge of ammonia to the atmosphere is restricted.

[0112] In the above embodiment, the urea water adding quantity is controlled by adjusting the output interval of the open valve command pulse to the UWA valve 44. Alternatively, the urea water adding quantity can be controlled by adjusting a pulse length of the open valve command pulse.

[0113] The NOx sensor can employ a configuration other than the configuration shown in FIG. 3. For example, the NOx sensor may include a pump cell and a sensor cell but a monitor cell (second pump cell). Alternatively, the oxygen pumping may be performed between the pump cell and the atmosphere.

[0114] As a reducing agent adding means, a urea water adding nozzle can be used in stead of the UWA valve 44. What is claimed is:

1. An exhaust gas purifying apparatus for an internal combustion engine which includes a NOx reduction catalyst provided in an exhaust gas pipe, a reducing agent adding means for adding a reducing agent upstream of the NOx reduction catalyst, and a NOx sensor detecting a NOx quantity downstream of the NOx reduction catalyst, the exhaust gas purifying apparatus performing a reducing agent addition by means of the reducing agent adding means according to an adding quantity command value of a target value, the exhaust gas purifying apparatus comprising;

an adding quantity control means for controlling an adding quantity of the reducing agent added by the reducing agent adding means; and

a command value computing means for computing the adding quantity command value in which a sensor output of the NOx sensor becomes minimum while obtaining the sensor output with respect to every adding quantity of the reducing agent controlled by the adding quantity control means.

2. An exhaust gas purifying apparatus according to claim 1, wherein

the adding quantity control means varies an adding quantity of the reducing agent at least into increasing side or decreasing side relative to the adding quantity command value as a reference.

3. An exhaust gas purifying apparatus according to claim 1, wherein

the adding quantity control means performs at least three steps of reducing agent additions while the adding quantity of the reducing agent is varied by a predetermined variation width, and

the adding quantity control means performs the reducing agent addition again while the variation width is made

small in a case that the sensor output becomes minimum with respect to a medium quantity of reducing agent among at least three steps of reducing agent additions

4. An exhaust gas purifying apparatus according to claim 1, further comprising

an estimation means for estimating whether an adding quantity of the reducing agent for obtaining minimum value of the sensor output is in a decreasing side or increasing side based on the sensor output before varying the adding quantity and the sensor output after varying the adding quantity, wherein

the adding quantity control means increases or decreases the adding quantity of the reducing agent based on an estimation by the estimation means.

5. An exhaust gas purifying apparatus according to claim 1, wherein

the adding quantity control means sets a variation width of the adding quantity of the reducing agent based on the output value of the NOx sensor.

6. An exhaust gas purifying apparatus according to claim 1, wherein

the command value computing means does not newly compute the adding quantity command value when a difference between a minimum value of the sensor output and a maximum value of the sensor output, which are obtained due to a variation in adding quantity of the reducing agent is within a specified value.

7. An exhaust gas purifying apparatus according to claim 1, wherein

the adding quantity control means decreases the adding quantity in a specified injection interval which is longer than another injection interval in which the adding quantity is increased.

8. An exhaust gas purifying apparatus according to claim 1, further comprising a learning means for storing the adding quantity command value in a back-up memory as a learning value and for updating the learning value as needed.

9. An exhaust gas purifying apparatus according to claim 8, wherein

the learning means stores the adding quantity command value along with a driving condition of the internal combustion engine at a time of controlling the adding quantity of the reducing agent.

10. An exhaust gas purifying apparatus according to claim 1, further comprising:

an oxidation catalyst arranged downstream of the NOx reduction catalyst for purifying the reducing agent; and a determination means for determining whether the oxidation catalyst is active or not, wherein

when the determination means determines the oxidation catalyst is inactive, the command value computing means performs a computation of the adding quantity command value.

11. An exhaust gas purifying apparatus according to claim 1, wherein

the NOx sensor is provided with a sensor element which includes a solid electrolyte and a NOx detecting electrode provided on the solid electrolyte.

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