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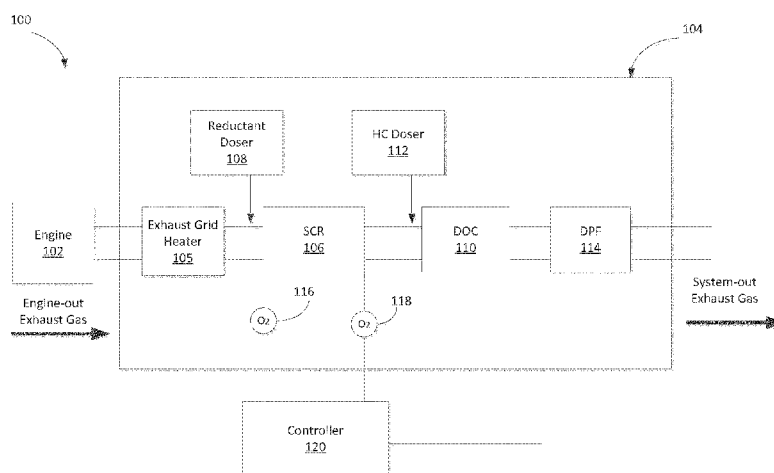


FIG. 1

(57) Abstract: Systems, methods, and apparatus for managing a hydrocarbon (HC) process are disclosed herein. The apparatus includes an oxygen amount module structured to receive data indicative of a first oxygen amount on an upstream side of a catalyst component of an aftertreatment system and a second oxygen amount on a downstream side of the catalyst component, a comparison module structured to compare the first oxygen amount to the second oxygen amount, and a thermal management module communicably coupled to each of the oxygen amount module and the comparison module, wherein the thermal management module is structured to conduct a thermal management process in the aftertreatment system to selectively control hydrocarbon (HC) desorption from the catalyst component responsive to the comparison.



METHOD TO IMPROVE HYDROCARBON DESORB FEATURE USING EXHAUST O₂ OR NO_x SENSORS

TECHNICAL FIELD

[0001] The present disclosure relates generally to exhaust after-treatment systems for use with internal combustion engines.

BACKGROUND

[0002] Internal combustion engines which use catalytic after-treatment systems frequently face the problem of hydrocarbon (HC) accumulation on the catalyst from operation at low temperature conditions. For example, when an engine is operated at idle for an extended period of time at sub-freezing temperatures, HC emissions may become deposited on the oxidation catalyst. A significant accumulation of HC emissions on the oxidation catalyst may cause elevated temperatures and eventual damage to the catalyst. The accumulated HCs are either desorbed or oxidized (or both) during subsequent operation at higher temperatures. It is important to manage these events appropriately because the energy released from the uncontrolled combustion of the HCs can damage the after-treatment system. Some management systems provide for an across-the-board time period for the controlled HC desorption process. For example, the systems may provide that any controlled HC desorption process would last 30 minutes. However, the across-the-board time period might be too long if the initial HC loading is low while too short if the initial HC loading is high. Some management systems adopt a “feed-forward” approach based on modeling of engine-out HCs. For example, the systems may determine when to stop the controlled HC desorption process based on estimated adsorb/desorb rate of HCs on the catalyst as a function of the temperature. The efficiency of such management relies on the accuracy of the modeling of the engine-out HC. Due to variations of ambient temperature, ambient pressure, fuel type, hardware variation, and inaccurate representation of the desorb process, the time to stop the thermal management for HC desorption might be grossly inaccurate. Therefore, a more efficient method for managing the HC desorption process is desired.

SUMMARY OF THE INVENTION

[0003] One embodiment relates to an apparatus including an oxygen amount module structured to receive data indicative of a first oxygen amount on an upstream side of a catalyst component of an aftertreatment system and a second oxygen amount on a downstream side of the catalyst component, a comparison module structured to compare the first oxygen amount to the second oxygen amount, and a thermal management module communicably coupled to each of the oxygen amount module and the comparison module. The thermal management module is structured to conduct a thermal management process in the aftertreatment system to selectively control hydrocarbon (HC) desorption from the catalyst component responsive to the comparison.

[0004] Another embodiment relates to a system including an engine structured to emit exhaust gas, an after-treatment system fluidly coupled to the engine and structured to receive the exhaust gas from the engine. The after-treatment system includes a catalyst component, a first sensor positioned on an upstream side of the catalyst structured to measure a first oxygen amount in the exhaust gas on the upstream side, and a second sensor positioned on a downstream side of the catalyst structured to measure a second oxygen amount in the exhaust gas on the downstream side. The system further includes a controller communicably coupled with the engine and the after-treatment system. The controller is structured to receive data indicative of the first oxygen amount and the second oxygen amount, compare the first oxygen amount to the second oxygen amount, and conduct a thermal management process in the after-treatment system to selectively control hydrocarbon (HC) desorption from the catalyst component responsive the comparison.

[0005] Still another embodiment relates to a method including receiving data indicative of oxidation of hydrocarbon (HC) in an after-treatment system, and conducting a thermal management process in the after-treatment system to selectively control HC desorption based on the data.

[0006] These and other features, together with the organization and manner of operation thereof, will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, wherein like elements have like numerals throughout the several drawings described below.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. 1 is a schematic diagram illustrating a system including an engine and an exhaust after-treatment system, according to an example embodiment.

[0008] FIG. 2 is a graph illustrating a hydrocarbon (HC) loading on a selective catalytic reduction (SCR) catalyst and a rate of HC release changing over time.

[0009] FIG. 3 is a graph illustrating a difference between an oxygen Mole fraction at an upstream of a catalyst component and an oxygen Mole fraction at a downstream of the catalyst component that changes over time.

[0010] FIG. 4 is a graph illustrating, for various initial HC loadings, a difference between an oxygen Mole fraction at an upstream of a catalyst component and an oxygen Mole fraction at a downstream of the catalyst component that changes over time.

[0011] FIG. 5 is a block diagram illustrating the function and structure of a controller utilized in the system of FIG. 1, according to an example embodiment.

[0012] FIG. 6 is a flow chart of a method of managing HC desorption process for the system of FIG. 1, according to an example embodiment.

DETAILED DESCRIPTION

[0013] Referring to the figures generally, the various embodiments disclosed herein relate to methods, systems, and apparatus of managing hydrocarbon (HC) desorb process for an exhaust after-treatment system used with an internal combustion engine. An internal combustion engine which uses a catalytic after-treatment system frequently faces the problem of HC accumulation on the catalyst from operation at low temperature conditions. The accumulated HCs are desorbed during controlled operation at higher temperatures. The present disclosure provides a method of efficiently managing the HC desorption process. The method compares a first oxygen amount measured at an upstream of a catalyst component of the after-treatment system and a second oxygen amount measured at a downstream of the catalyst component. The difference between the first and second oxygen amounts indicates the amount of oxygen consumed by HC oxidation passing through the catalyst. The difference would be high when the HC desorption is significant; the difference would be low when the HC desorption is done or almost done.

Therefore, if the first and second oxygen amounts are close, the method may stop the thermal management process for HC desorption. If the difference of the first and second oxygen amounts is beyond some predetermined threshold, the method may let the thermal management process for HC desorption continue. The method may also adjust the time period of the thermal management process based on the changing rate of the difference between the first and second oxygen amounts. For example, if the difference is changing slowly, the method can reduce the time period of controlled HC desorption. If the difference is changing fast, the method can increase the time period of controlled HC desorption. In this manner, the exhaust after-treatment is protected from wasting time in thermal management or risking failure from uncontrolled HC desorption. Thus, the efficiency of controlled HC desorption will be improved.

[0014] Referring to FIG. 1, a schematic diagram illustrating a system 100 including an engine 102 and an exhaust after-treatment system 104 is shown according to an example embodiment. The system 100 may be, for example, a vehicle. The engine 102 may be an internal combustion engine, such as a diesel type engine, a gasoline type engine, a natural gas type engine, etc. The exhaust after-treatment system 104 is fluidly coupled with the engine 102 and configured to receive an engine-out exhaust gas through, for example, a tube. The engine-out exhaust gas may include various regulated pollutants such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulates (e.g., soot). The after-treatment system 104 is configured to remove the regulated pollutants when the engine-out exhaust gas is passing through. If the engine 102 is a diesel type, the after-treatment system 104 may include at least one of a selective catalytic reduction catalyst (SCR), a diesel oxidation catalyst (DOC), and a diesel particulate filter (DPF). If the engine 102 is a gasoline type, the after-treatment system 104 may include a three-way catalytic converter. Although a diesel type engine is shown and described with respect to FIG. 1, the method disclosed herein may be similarly implemented for a gasoline or natural gas engine.

[0015] The exhaust after-treatment system 104 may include a series of exhaust after-treatment components, shown as a selective catalytic reduction (SCR) catalyst 106, a diesel oxidation catalyst (DOC) 110, and a diesel particulate filter (DPF) 114 arranged along an exhaust flow path in a direction shown by the arrows in FIG. 1. The SCR 106 is furthest upstream (closest to the engine 102) and the DPF 114 is furthest downstream

(furthest from the engine 102). In other words, the engine-out exhaust gas flows from the engine 102 through the SCR 106, then through the DOC 110, then through the DPF 114, then releases as the system-out exhaust gas. It shall be understood that the order of the catalyst components may vary, for example, the SCR 106 may be arranged downstream of DOC 110 and the DPF 114 in different exhaust after-treatment systems.

[0016] The engine-out exhaust gas may include various regulated pollutants such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulates (e.g., soot). Each of the exhaust after-treatment components 106, 110, and 114 is configured to perform an after-treatment operation on the exhaust gas passing through or over the respective component. The SCR 106 may be employed to reduce the emission of NO_x. In particular, SCR catalysts can convert NO_x (NO and NO₂ in some fraction) into nitrogen gas (N₂) and water vapor (H₂O) with the facilitation of a reductant. In some embodiments, the SCR catalysts may include any suitable NO_x absorber catalyst such as, platinum, palladium, rhodium, cerium, iron, manganese, copper, vanadium based catalysts, or combinations thereof. The SCR catalyst may be disposed on any suitable substrate such as, a ceramic (e.g., cordierite) or metallic (e.g., kanthal) monolith core, or a washcoat made of aluminum oxide, titanium dioxide, silicon dioxide, or any other suitable material, or combinations thereof. In some embodiments, ammonia (NH₃) may be used as the reductant facilitating the decomposition of NO_x. In some embodiments, diesel exhaust fluid (DEF), which is for example a urea-water solution, may be used as the reductant to aid in the reduction of NO_x. The SCR 106 may be fluidly coupled to a reductant doser 108 and configured to receive the reductant (e.g., DEF) therefrom through, for example, a tube. In operation, the DEF may be injected into the exhaust flow path from the reductant doser 108. The injected DEF spray may be heated by the engine-out exhaust gas to vaporize the urea-water solution and trigger the decomposition of urea into NH₃. The engine-out exhaust gas, including the NH₃ decomposed from the urea, further mixes while flowing over the SCR catalyst, where NO_x and NH₃ are converted primarily into N₂ and H₂O. In this manner, NO_x included in the engine-out exhaust gas is removed or reduced.

[0017] The DOC 110 may be employed to reduce the amount of CO and HCs present in the engine-out exhaust gas via oxidation techniques. In other words, the DOC 110 is adapted to oxidize and burn CO and HC emissions in the engine-out exhaust gas. The HCs may include a plurality of diverse components such as, methane (CH₄), ethane

(C₂H₆), propane (C₃H₈), butane (C₄H₁₀), benzene (C₆H₆), toluene (C₇H₈), xylene (C₈H₁₀), ethylene (C₂H₄), and components with greater carbon numbers or various intermediates, etc. In some embodiments, the oxidation catalyst may include a Pt group catalyst, for example, a Pd-PdO catalyst. In some embodiments, the oxidation catalyst may comprise NH₃ oxidation catalyst to facilitate decomposition of any unused NH₃ emerging from the SCR 106. In a different after-treatment system in which the DOC 110 is arranged upstream of the SCR 106, the DOC 110 can also convert NO to NO₂ to facilitate fast SCR reactions. In some embodiments, the DOC 110 may be fluidly coupled to a HC doser 112 and configured to receive HC therefrom through, for example, a tube. The injected HCs can oxidize over the DOC 110 to raise the temperature of the engine-out exhaust gas passing therethrough. The temperature of the exhaust gas may be raised periodically to, for example, induce active regeneration of the DPF 114. In some embodiments, in-cylinder dosing may be used instead of HC dosing via the HC doser 112 for injecting HC to the exhaust gas flow.

[0018] The DPF 114 may be employed to remove particulate matter such as soot particles from the engine-out exhaust gas. In some embodiments, the DPF 114 may include filter surfaces (e.g., ceramic or sintered metal) to filter sooty particulate matter.

[0019] The exhaust after-treatment system 104 may optionally include an exhaust grid heater 105 positioned upstream of the SCR 106 and configured to heat the engine-out exhaust gas to facilitate further treatment operations by the SCR 106, the DOC 110, and the DPF 114.

[0020] The exhaust after-treatment system 104 may include a first oxygen sensor 116 and a second oxygen sensor 118. The first oxygen sensor 116 may be disposed upstream of the SCR 106, for example, at an inlet of the SCR 106, and configured to measure a first amount of oxygen on the upstream side of the SCR catalyst. The second oxygen sensor 118 may be positioned downstream of the SCR 106, for example, at an outlet of the SCR 106, and configured to measure a second amount of oxygen on the downstream side of the SCR 106. The first amount of oxygen is indicative of the amount of oxygen in the engine-out exhaust gas entering the SCR 106. The second amount of oxygen is indicative of the amount of oxygen in the engine-out exhaust gas exiting the SCR 106. In some embodiments, the first and second amounts of oxygen may each be a Mole fraction of

oxygen in the exhaust gas. In some embodiments, the first and second oxygen sensors 116 and 118 may output voltage and/or current signals representative of the amount of oxygen. In some embodiments, at least one of the first and second oxygen sensors 116 and 118 may be an oxygen channel of a NO_x sensor. It shall be also understood that the arrangement of the first and second oxygen sensors 116 and 118 may vary. For example, the first and second oxygen sensors 116 and 118 may be arranged at the inlet and outlet of the DOC 110, respectively, or at the inlet and outlet of the DPF 114, respectively. In some embodiments, the first and second oxygen sensors 116 and 118 may be arranged at the inlet and outlet of different after-treatment components. For example, the first oxygen sensor 116 may be disposed at the inlet of the SCR 106; the second oxygen sensor 118 may be disposed at the outlet of the DOC 110 or the DPF 114. In some embodiments, the first oxygen sensor 116 may be disposed at the inlet of the DOC 110; the second oxygen sensor 118 may be disposed at the outlet of the DPF 114.

[0021] In some embodiments, the after-treatment system 104 may include additional sensors, such as a temperature sensor, differential pressure sensor, gauge and/or absolute pressure sensor, NH₃ sensor, flow rate sensor, etc.

[0022] The system 100 may further include a controller 120 communicably coupled with the engine 102 and the after-treatment system 104 and configured to manage operation conditions of the engine 102 and various functionalities of the after-treatment system 104, such as reductant (e.g., DEF) dosing, HC dosing, HC load estimation/detection, thermal management for HC desorption, etc. In particular, the controller 120 may adjust one or more operating conditions (e.g., speed) of the engine 102 to increase the temperature and/flow of the engine-out exhaust gas. The controller 120 may be configured to receive measurements of the oxygen amount from the first and second oxygen sensor 116 and 118. Communication of the controller 120 with the engine 102 and the after-treatment system 104 may be via any number of wired or wireless communications. For example, a wired connection may include a serial cable, a fiber optic cable, a CAT5 cable, or any other form of wired connection. In comparison, a wireless connection may include the Internet, Wi-Fi, cellular, radio, etc. In one embodiment, a controller area network (CAN) bus provides the exchange of signals, information, and/or data. The CAN bus includes any number of wired and wireless connections. The controller 120 may be structured as an electronic

control module (ECM). The function and structure of the controller 120 will be described in greater detail below in conjunction with FIG. 5.

[0023] The controller 120 may be configured to manage HC desorption process for the exhaust after-treatment system 104. During normal operating conditions of the engine 102, HC emissions, as part of the engine-out exhaust gas, are either oxidized by the DOC 110, or slipped-off and exhausted to the ambient. When the engine 102 is operating at idle for an extended period of time at sub-freezing temperatures, however, the combustion in the engine 102 may be unstable or incomplete such that the engine-out exhaust gas may include an increased amount of HC emissions, which is the result of sub-optimal fuel-air ratio of the combustion mixture entering the engine 102. An increasing in the amount of HC emissions may be so significant that the SCR 106, the DOC 110, and the DPF 114 are unable to oxidize or slip off the HC into the ambient at a sufficient rate. Consequently, the SCR 106, the DOC 110, and the DPF 114 may have the HC emissions deposited thereon. In other words, the increased HC emissions may load up the SCR 106, the DOC 110, and the DPF 114. Such loading-up may significantly reduce the operating efficiency of the after-treatment system 104. In some embodiments, the controller 120 may determine to start a HC desorption process if the engine 120 has been operating at an idle speed for a predetermined amount of time and at a sub-freezing temperature. The predetermined amount of time that the engine 102 operates at the idle speed at sub-freezing ambient temperature is indicative of a specific amount of HC emissions being exhausted from the engine 102 that is sufficient to load up the SCR 106, the DOC 110, and the DPF 114. The predetermined amount of time may be empirically determined during testing and development of the engine 102. In some embodiment, to desorb the HC loaded on the SCR 106, the DOC 110, and the DPF 114, the controller 120 may adjust one or more operating conditions of the engine 102 to increase the temperature and/or flow of the engine-out exhaust gas. For example, increase of the speed of the engine 102 will increase the temperature of the engine-out exhaust gas. In some embodiments, a heater may be used to increase the temperature of the flow entering the after-treatment system 104. Following the initial increase of the temperature, an exothermic reaction will take off that causes the HC to react with oxygen present in the exhaust gas and further drives the temperature inside the after-treatment system 104 up. The increased temperature will be carried by the increased flow rate of the engine-out exhaust gas to the SCR 106, the DOC 110, and the DPF 114, thereby desorbing the desorbing the deposited HC from these after-

treatment components. In some embodiments, the controller 120 may enable the exhaust grid heater 105 to heat the engine-out exhaust gas to raise the temperature of the exhaust gas to facilitate the HC desorption process.

[0024] In some embodiments, the controller 120 may determine to stop thermal management for the HC desorption process based on measurements from the first sensor 116 and the second sensor 118. As discussed above, the first oxygen amount measured by the first sensor 116 is indicative of the amount of oxygen in the engine-out exhaust gas entering the SCR 106. The second oxygen amount measured by the second sensor 118 is indicative of the amount of oxygen in the engine-out exhaust gas exiting the SCR 106. The difference between the first and second amounts indicates the oxygen consumed by HC oxidation in the SCR 106. If the amount of deposited HC on the SCR 106 is high and the HC desorption is significant, the amount of oxygen consumed by HC oxidation would be high. If the HC desorption is substantially done and the amount of deposited HC on the SCR 106 is low, the amount of oxygen consumed by HC oxidation would be low. In some embodiments, the controller 120 may determine to stop thermal management for the HC desorption process if the first and second oxygen amounts are close. The thermal management may be stopped by decreasing the engine speed to normal and/or disabling the exhaust grid heater 105. In some embodiments, the controller 120 may determine to continue the thermal management for the HC desorption process if the difference between the first and second oxygen amounts is beyond some predetermined threshold. In some embodiments, the controller 120 may adjust the time period of the thermal management based on the changing rate of the difference between the first and second oxygen measurements. For example, if the difference is changing slowly, the controller 120 may reduce the time period of controlled HC desorption. If the difference is changing fast, the controller 120 may increase the time period of controlled HC desorption.

[0025] Referring to FIG. 2, a graph illustrating a HC loading on a SCR catalyst and a rate of HC release changing over time is shown. The data was from a QSK 60L engine. Curve 201 shows the HC loading on a SCR catalyst changing over time; curve 202 shows the rate of HC release. Initially, at the start of the controlled HC desorption process, both HC loading and rate of HC release were high and slowed down over time.

[0026] Referring to FIG. 3, a graph illustrating a difference of the first oxygen amount measured by the first sensor 116 and the second oxygen amount measured by the second sensor 118 that changes over time is shown. The amount of oxygen was presented as an oxygen Mole fraction in the exhaust gas. Curve 301 shows the difference changing over time. Line 302 shows the capability of the oxygen sensors, which is 0.05% in this example.

[0027] Referring to FIG. 4, a graph illustrating, for various initial HC loadings, a difference of the first oxygen amount measured by the first sensor 116 and the second oxygen amount measured by the second sensor 118 that changes over time is shown. Curve 402 shows the difference changing over time for an initial HC loading that was a nominal HC loading. Curve 401 shows the difference changing over time for an initial HC loading that was 200% of the nominal HC loading. Curve 403 shows the difference changing over time for an initial HC loading that was 50% of the nominal HC loading. Line 404 shows the capacity of the oxygen sensors, which is 0.05% in this example. As shown, for the situation in which the initial HC loading was the nominal HC loading, it took about 1000 seconds for the difference to drop to 0.05%. For the initial HC loading that was 200% of the nominal loading, it took longer than 1300 seconds for the difference to drop to 0.05%. For the initial HC loading that was 50% of the nominal loading, it took shorter than 400 seconds for the difference to drop to 0.05%. As such, the desired time period of thermal management for the HC desorption process varies greatly depending on the initial HC loading. Some conventional controllers treat all cases the same and do an across-the-board thermal management for 30 minutes. However, if the initial HC loading was low, energy was in the thermal management; if the initial HC loading was high, the failure with premature stop was at risk. With the embodiments disclosed herein, the controller 120 would be able to either curtail or extend thermal management time period based on feedback from the first and second sensors 116 and 118. Therefore, the efficiency of the HC desorption process would be improved. Next generation sensors with increased oxygen measurement accuracy will further increase the viability of the scheme.

[0028] Referring to FIG. 5, a block diagram illustrating the function and structure of a controller 500 that may be utilized in the system 100 of FIG. 1 is shown, according to an example embodiment. The controller 500 is shown to include a processing circuit 502 including a processor 504 and a memory 506. The processor 504 may be implemented as

a general-purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a digital signal processor (DSP), a group of processing components, or other suitable electronic processing components. The one or more memory devices 506 (e.g., NVRAM, RAM, ROM, Flash Memory, hard disk storage, etc.) may store data and/or computer code for facilitating the various processes described herein. Thus, the one or more memory devices 506 may be communicably connected to the processor 504 and provide computer code or instructions to the processor 504 for executing the processes described herein. Moreover, the one or more memory devices 506 may be or include tangible, non-transient volatile memory or non-volatile memory. Accordingly, the one or more memory devices 506 may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described herein.

[0029] The memory 506 is shown to include various modules for completing the activities described herein. More particularly, the memory 506 includes an oxygen amount module 508, a comparison module 510, and a thermal management module 512 comprising an engine management module 514 and a heater management module 516. The modules are adapted to control the HC desorption process for the exhaust after-treatment system 104. While various modules with particular functionality are shown in FIG. 5, it should be understood that the controller 500 and memory 506 may include any number of modules for completing the functions described herein. For example, the activities of multiple modules may be combined as a single module, as additional modules with additional functionality may be included, etc. Further, it should be understood that the controller 500 may further control other vehicle activity beyond the scope of the present disclosure.

[0030] Certain operations of the controller 500 described herein include operations to interpret and/or to determine one or more parameters. Interpreting or determining, as utilized herein, includes receiving values by any method known in the art, including at least receiving values from a datalink or network communication, receiving an electronic signal (e.g. a voltage, frequency, current, or PWM signal) indicative of the value, receiving a computer generated parameter indicative of the value, reading the value from a memory location on a non-transient computer readable storage medium, receiving the value as a run-time parameter by any means known in the art, and/or by receiving a value

by which the interpreted parameter can be calculated, and/or by referencing a default value that is interpreted to be the parameter value.

[0031] The oxygen amount module 508 may be structured to receive, gather, and/or acquire an upstream oxygen amount measured by the first sensor 116 and a downstream oxygen amount measured by the second sensor 118. In some embodiments, the oxygen amount is presented as oxygen Mole fraction in the exhaust gas. In one embodiment, the oxygen amount module 508 includes a communication circuitry for facilitating reception of the oxygen measurements. In another embodiment, the oxygen amount module 508 includes machine-readable content for receiving and storing the oxygen measurements. In yet another embodiment, the oxygen amount module 508 includes any combination of communication circuitry and machine-readable content.

[0032] The comparison module 510 may be structured to compare the upstream oxygen amount to the downstream oxygen amount. In some embodiments, the comparison module 510 may determine a difference or a ratio of the upstream oxygen amount to the downstream oxygen amount. In some embodiments, the comparison module 510 may also determine a changing rate of the difference between the first measurement and the second measurement, i.e., how fast the difference is changing. In one embodiment, the comparison module 510 includes a circuitry configured for comparing the upstream oxygen amount to the downstream oxygen amount. In another embodiment, the comparison module 510 includes machine-readable contents for comparing the upstream oxygen amount to the downstream oxygen amount. In yet another embodiment, the comparison module 510 includes any combination of circuitry and machine-readable content.

[0033] The thermal management module 512 may be structured to manage a thermal condition (e.g., temperature) for the HC desorption process in the after-treatment system 104 based on the comparison of the upstream oxygen amount to the downstream oxygen amount. The thermal management module 512 may include an engine management module 514 structured to manage operation conditions of the engine 514 based on the comparison, and a heater management module 516 structured to selectively enable or disable the exhaust grid heater 105 based on the comparison. In some embodiments, responsive to the comparison that the difference between the first and second oxygen

amounts is within a predetermined threshold, the thermal management module 512 may stop the thermal management process for the HC desorption. Specifically, if the speed of the engine has been increased during the thermal management, the engine management module 514 may reduce the engine speed to a normal level. If the exhaust grid heater 105 has been enabled during the thermal management, the heater management module 516 may disable the exhaust grid heater 105. In some embodiments, responsive to the comparison that the difference between the first and second oxygen amounts is beyond the predetermined threshold, the thermal management module 512 may let the thermal management process for the HC desorption continue. Specifically, the engine management module 514 may keep the engine speed at the increased speed. The heater management module 516 may keep the exhaust grid heater on. In some embodiments, the thermal management module 512 may adjust the time period of the thermal management process based on the changing rate of the difference between the first and second oxygen amounts. For example, responsive to a determination that the difference is changing slowly, the engine management module 514 may reduce the time period of the engine being at the increased speed; the heater management module 516 may reduce the time period of the exhaust grid heater 105 being on. Responsive to a determination that the difference is changing fast, the engine management module 514 may extend the time period of the engine being at the increased speed; the heater management module 516 may extend the time period of the exhaust grid heater 105 being on. In one embodiment, the thermal management module 512, the engine management module 514, and the heater management module 516 may be implemented as circuitry, machine-readable content, or any combination thereof.

[0034] Referring to FIG. 6, a flow chart of a method 600 of managing HC desorption process for the exhaust after-treatment system 104 of FIG. 1 is shown, according to an example embodiment. Because method 600 may be implemented with the system 100, reference may be made to one or more features of the system 100 to explain method 600.

[0035] At process 602, the controller 120 receives data indicative of a first oxygen amount measured by the first sensor 116 on an upstream side of a catalyst and data indicative of a second oxygen amount measured by the second sensor 118 on a downstream side of the catalyst. In some embodiments, the oxygen amount is presented as oxygen Mole fraction in the exhaust gas.

[0036] At process 604, the controller 120 compares the first oxygen amount to the second oxygen amount. In some embodiments, the controller 120 determines a difference or a ratio of the first oxygen amount to the second oxygen amount. In some embodiments, the controller 120 also determines a changing rate of the difference between the first and second oxygen amounts, *i.e.*, how fast the difference is changing.

[0037] At process 606, the controller 120 manages a thermal condition for HC desorption process based on the comparison. In some embodiments, responsive to the comparison that the difference between the first and second oxygen amounts is within a predetermined threshold, the controller 120 stops the thermal management process for the HC desorption. Specifically, if the speed of the engine 102 has been increased during the thermal management, the controller 120 reduces the engine speed to a normal level. If the exhaust grid heater 103 has been enabled during the thermal management, the controller 120 disables the exhaust grid heater 103. In some embodiments, responsive to the comparison that the difference between the first and second oxygen amounts is beyond the predetermined threshold, the controller 120 lets the thermal management for the HC desorption process continue. Specifically, the controller 120 keeps the engine speed at the increased speed and/or keeps the exhaust grid heater 103 on. In some embodiments, the controller 120 adjusts the time period of the thermal management based on the changing rate of the difference between the first and second oxygen amounts. For example, responsive to a determination that the difference is changing slowly (e.g., lower than a predetermined rate), the controller 120 reduces the time period of the engine being at the increased speed and/or the time period of the exhaust grid heater 103 being on. Responsive to a determination that the difference is changing fast (e.g., higher than a predetermined rate), the controller 120 extends the time period of the engine being at the increased speed and/or extends the time period of the exhaust grid heater 103 being on.

[0038] It should be noted that the processes of the methods described herein may be utilized with the other methods, although described in regard to a particular method. It should further be noted that the term “example” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0039] Example and non-limiting module implementation elements include sensors (e.g., coupled to the components and/or systems in FIG. 1) providing any value determined herein, sensors providing any value that is a precursor to a value determined herein, datalink and/or network hardware including communication chips, oscillating crystals, communication links, cables, twisted pair wiring, coaxial wiring, shielded wiring, transmitters, receivers, and/or transceivers, logic circuits, hard-wired logic circuits, reconfigurable logic circuits in a particular non-transient state configured according to the module specification, any actuator including at least an electrical, hydraulic, or pneumatic actuator, a solenoid, an op-amp, analog control elements (springs, filters, integrators, adders, dividers, gain elements), and/or digital control elements.

[0040] The schematic flow chart diagrams and method schematic diagrams described above are generally set forth as logical flow chart diagrams. As such, the depicted order and labeled steps are indicative of representative embodiments. Other steps, orderings and methods may be conceived that are equivalent in function, logic, or effect to one or more steps, or portions thereof, of the methods illustrated in the schematic diagrams.

[0041] Additionally, the format and symbols employed are provided to explain the logical steps of the schematic diagrams and are understood not to limit the scope of the methods illustrated by the diagrams. Although various arrow types and line types may be employed in the schematic diagrams, they are understood not to limit the scope of the corresponding methods. Indeed, some arrows or other connectors may be used to indicate only the logical flow of a method. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of a depicted method. Additionally, the order in which a particular method occurs may or may not strictly adhere to the order of the corresponding steps shown. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and program code.

[0042] Many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom VLSI

circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[0043] Modules may also be implemented in machine-readable medium for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[0044] Indeed, a module of computer readable program code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. Where a module or portions of a module are implemented in machine-readable medium (or computer-readable medium), the computer readable program code may be stored and/or propagated on in one or more computer readable medium(s).

[0045] The computer readable medium may be a tangible computer readable storage medium storing the computer readable program code. The computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0046] More specific examples of the computer readable medium may include but are not limited to a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), a digital versatile

disc (DVD), an optical storage device, a magnetic storage device, a holographic storage medium, a micromechanical storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, and/or store computer readable program code for use by and/or in connection with an instruction execution system, apparatus, or device.

[0047] The computer readable medium may also be a computer readable signal medium. A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electrical, electro-magnetic, magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport computer readable program code for use by or in connection with an instruction execution system, apparatus, or device. Computer readable program code embodied on a computer readable signal medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, Radio Frequency (RF), or the like, or any suitable combination of the foregoing

[0048] In one embodiment, the computer readable medium may comprise a combination of one or more computer readable storage mediums and one or more computer readable signal mediums. For example, computer readable program code may be both propagated as an electro-magnetic signal through a fiber optic cable for execution by a processor and stored on RAM storage device for execution by the processor.

[0049] Computer readable program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone computer-readable package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network,

including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0050] The program code may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0051] Accordingly, the present disclosure may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the disclosure is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

WHAT IS CLAIMED IS:

1. An apparatus, comprising:
 - an oxygen amount module structured to receive data indicative of a first oxygen amount on an upstream side of a catalyst component of an aftertreatment system and a second oxygen amount on a downstream side of the catalyst component;
 - a comparison module structured to compare the first oxygen amount to the second oxygen amount; and
 - a thermal management module communicably coupled to each of the oxygen amount module and the comparison module, wherein the thermal management module is structured to conduct a thermal management process in the aftertreatment system to selectively control hydrocarbon (HC) desorption from the catalyst component responsive to the comparison.
2. The apparatus of claim 1, wherein the first oxygen amount is a first oxygen mole fraction in an exhaust gas on the upstream side of the catalyst component of the after-treatment system, and wherein the second oxygen amount is a second oxygen mole fraction in the exhaust gas on the downstream side of the catalyst component.
3. The apparatus of claim 1, wherein the catalyst component comprises at least one of a selective catalytic reduction (SCR) catalyst, a diesel oxidation catalyst (DOC), and a diesel particulate filter (DPF).
4. The apparatus of claim 1, wherein the thermal management module comprises an engine management module configured to increase a speed of an engine coupled to the after-treatment system for facilitating the HC desorption, and wherein the engine management module is further structured to reduce the speed of the engine responsive to the comparison based on a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.
5. The apparatus of claim 1, wherein the thermal management module comprises a heater management module structured to enable an exhaust grid heater of the after-treatment system for facilitating the HC desorption, and wherein the heater management module is further structured to disable the exhaust grid heater responsive to the

comparison based on a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.

6. The apparatus of claim 1, wherein the thermal management module is further structured to adjust a time period of the thermal management process based on a changing rate of a difference between the first oxygen amount and the second oxygen amount.

7. The apparatus of claim 6, wherein the thermal management module comprises an engine management module configured to increase a speed of an engine coupled to the after-treatment system for facilitating the HC desorption, and wherein the engine management module is further structured to reduce the time period of the thermal management process responsive to the changing rate of the difference being lower than a first predetermined threshold, and to extend the time period responsive to the changing rate of the difference being higher than a second predetermined threshold.

8. The apparatus of claim 6, wherein the thermal management module comprises a heater management module structured to enable an exhaust grid heater of the after-treatment system for facilitating the HC desorption, and wherein the heater management module is further structured to reduce the time period of the thermal management process responsive to the changing rate of the difference being lower than a first predetermined threshold, and to extend the time period responsive to the changing rate of the difference being higher than a second predetermined threshold.

9. A system, comprising:

- an engine structured to emit exhaust gas;

- an after-treatment system fluidly coupled to the engine and structured to receive the exhaust gas from the engine, the after-treatment system comprising:

- a catalyst component;

- a first sensor positioned on an upstream side of the catalyst structured to measure a first oxygen amount in the exhaust gas on the upstream side; and

- a second sensor positioned on a downstream side of the catalyst structured to measure a second oxygen amount in the exhaust gas on the downstream side; and

- a controller communicably coupled with the engine and the after-treatment system, wherein the controller is structured to:

receive data indicative of the first oxygen amount and the second oxygen amount;

compare the first oxygen amount to the second oxygen amount; and

conduct a thermal management process in the after-treatment system to selectively control hydrocarbon (HC) desorption from the catalyst component responsive to the comparison.

10. The system of claim 9, wherein the first oxygen amount is a first oxygen mole fraction in the exhaust gas on the upstream side of the catalyst component, and wherein the second oxygen amount is a second oxygen mole fraction in the exhaust gas on the downstream side of the catalyst component.

11. The system of claim 9, wherein the catalyst component comprises at least one of a selective catalytic reduction (SCR) catalyst, a diesel oxidation catalyst (DOC), and a diesel particulate filter (DPF).

12. The system of claim 9, wherein the controller is further structured to increase a speed of the engine for facilitating the HC desorption, and wherein the controller is further structured to reduce the speed of the engine responsive to the comparison based on a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.

13. The system of claim 9, further comprising an exhaust grid heater configured to heat the exhaust gas, wherein the controller is further structured to enable the exhaust grid heater for facilitating the HC desorption, and wherein the controller is further structured to disable the exhaust grid heater responsive to the comparison based on a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.

14. The system of claim 9, wherein the controller is further structured to adjust a time period of the thermal management process based on a changing rate of a difference between the first oxygen amount and the second oxygen amount.

15. A method, comprising:

receiving data indicative of oxidation of hydrocarbon (HC) in an after-treatment system; and

conducting a thermal management process in the after-treatment system to selectively control HC desorption based on the data.

16. The method of claim 15, wherein the data comprises a first oxygen amount on an upstream side of a catalyst component of the aftertreatment system and a second oxygen amount on a downstream side of the catalyst component.

17. The method of claim 16, wherein the catalyst component comprises at least one of a selective catalytic reduction (SCR) catalyst, a diesel oxidation catalyst (DOC), and a diesel particulate filter (DPF).

18. The method of claim 16, further comprising:
increasing a speed of an engine coupled to the after-treatment system for facilitating the HC desorption; and
reducing the speed of the engine responsive to a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.

19. The method of claim 16, further comprising:
enabling an exhaust grid heater of the after-treatment system for facilitating the HC desorption; and
disabling the exhaust grid heater responsive to a difference between the first oxygen amount and the second oxygen amount being within a predetermined range.

20. The method of claim 16, further comprising:
adjusting a time period of the thermal management process based on a changing rate of a difference between the first oxygen amount and the second oxygen amount.

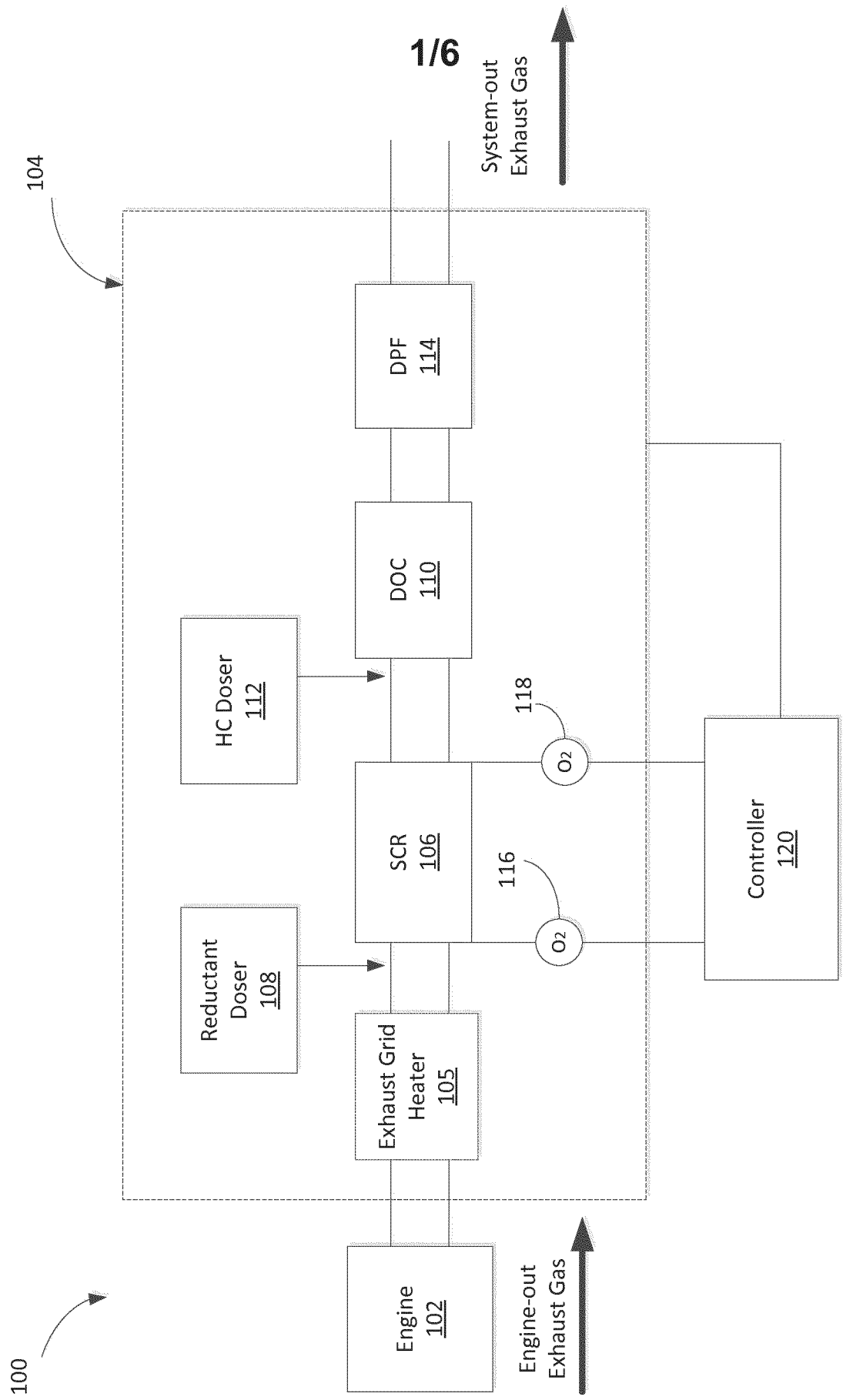


FIG. 1

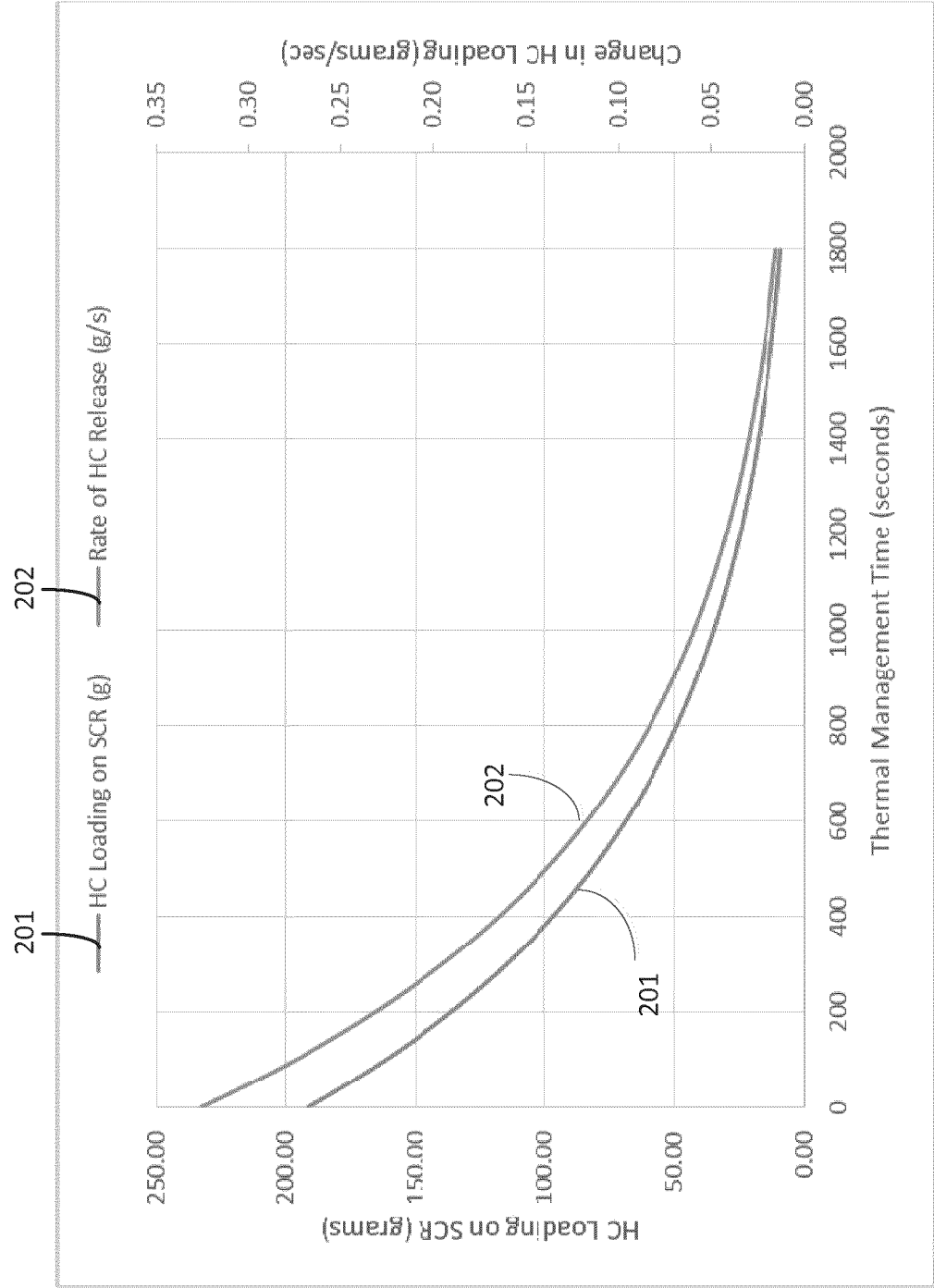


FIG. 2

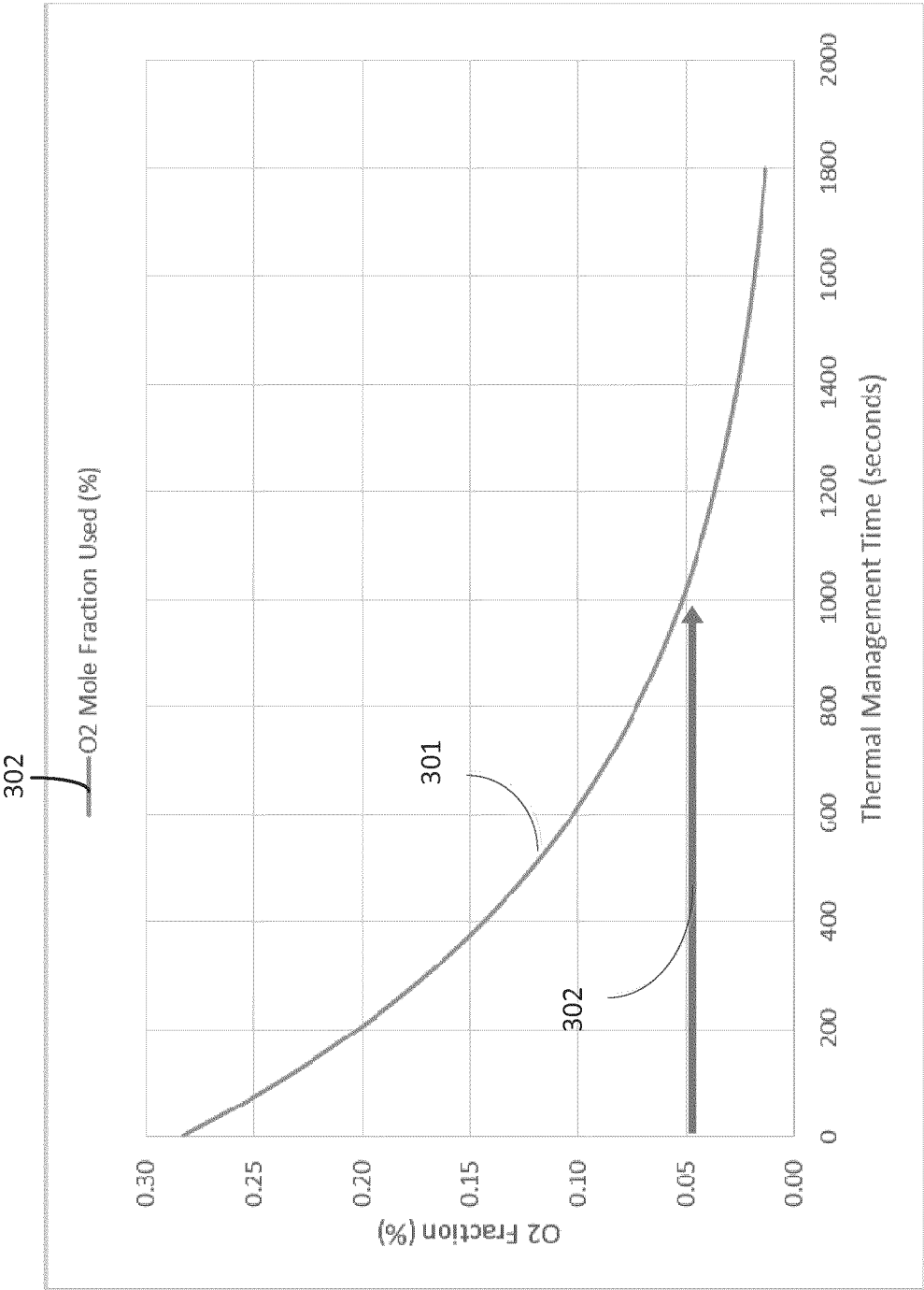


FIG. 3

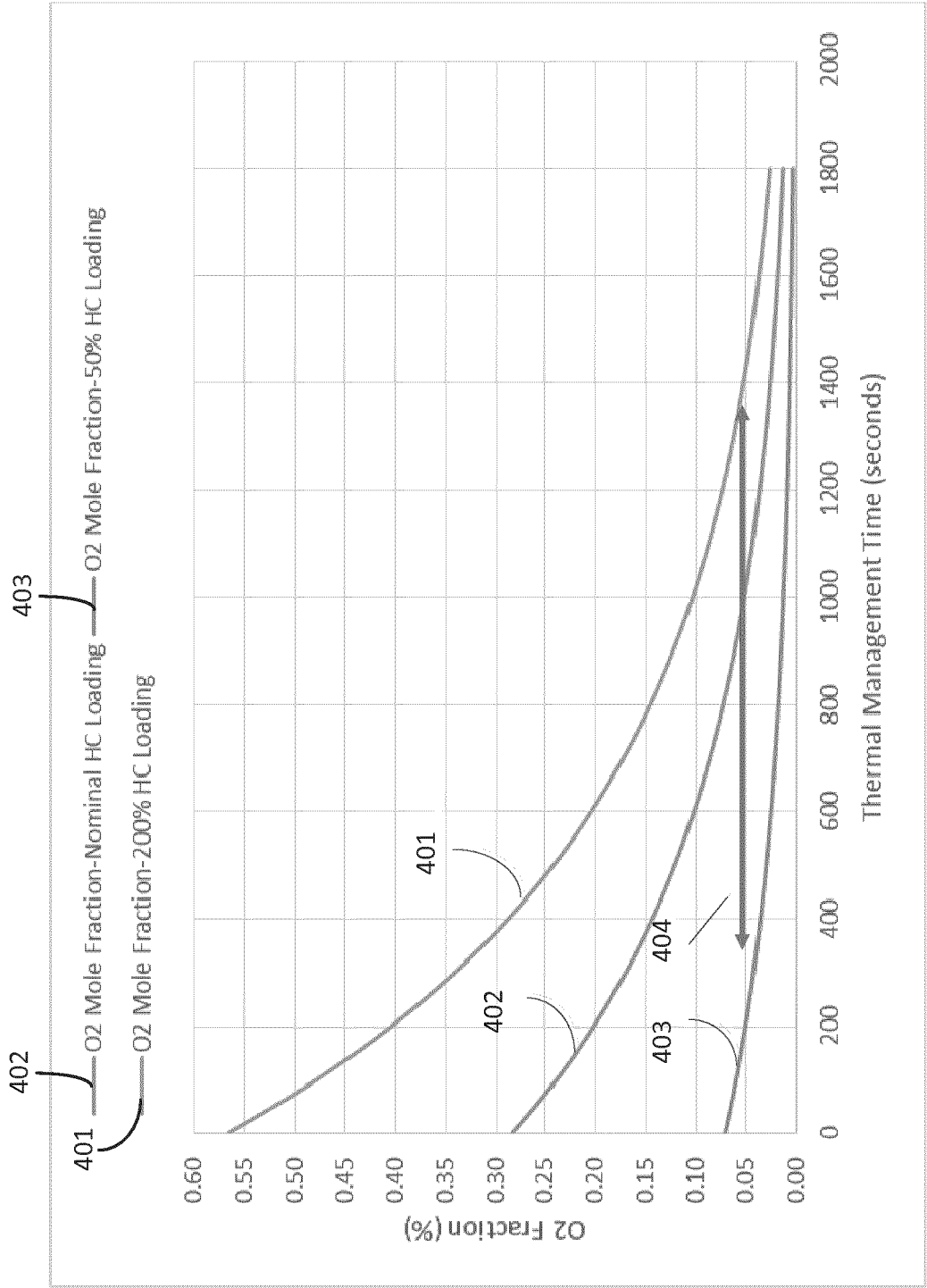


FIG. 4

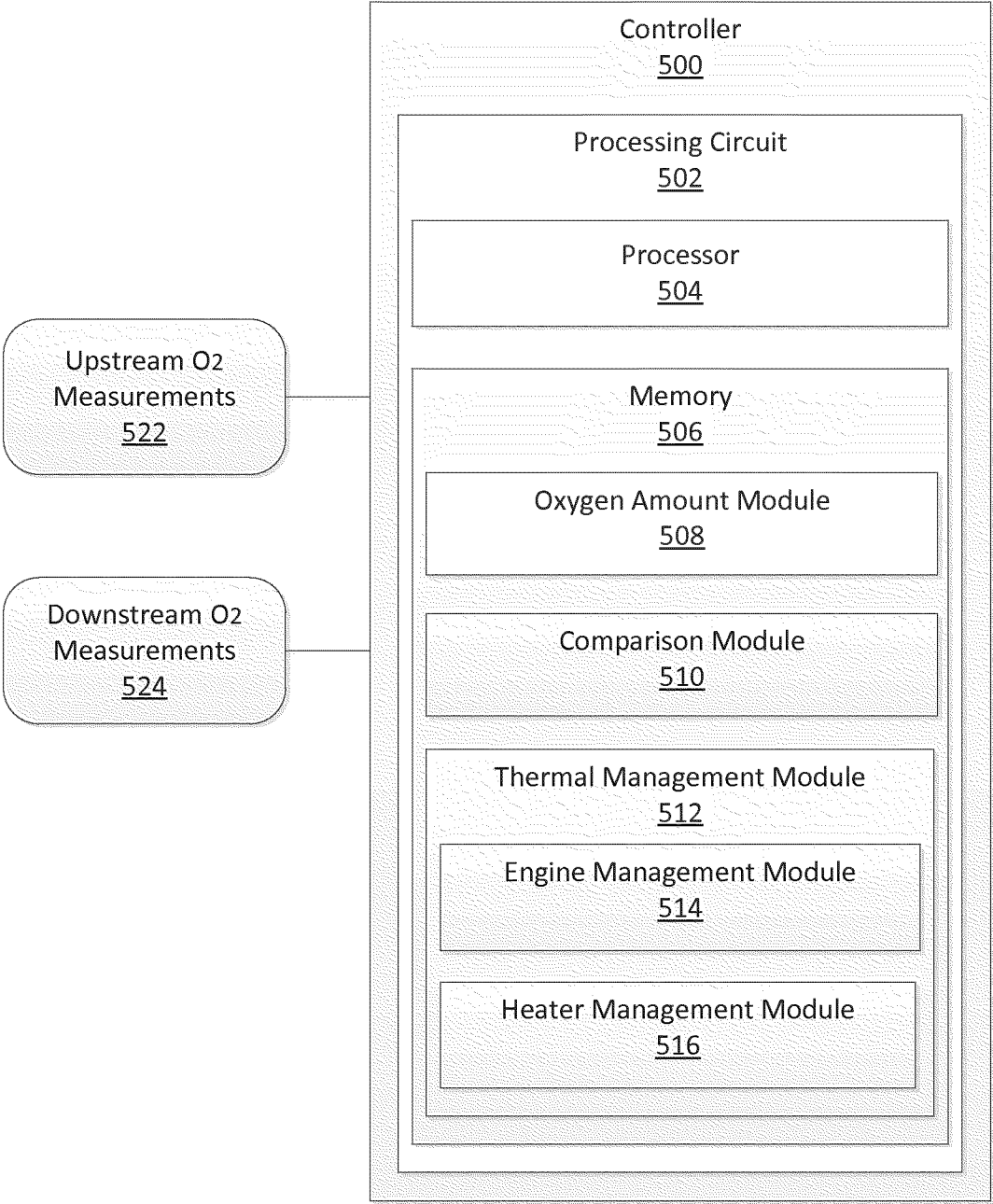


FIG. 5

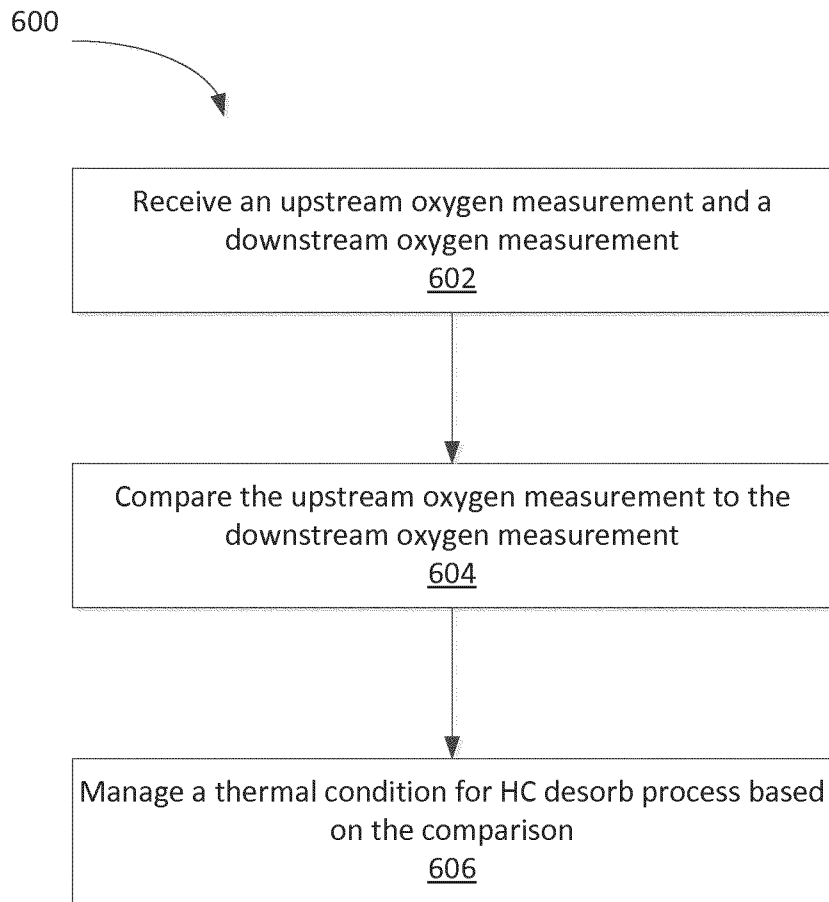
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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2015/055118

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01N 3/08 (2015.01)

CPC - F01N 3/0871 (2015.11)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - B01D 53/94; F01N 3/00, 3/08, 3/20, 9/00 (2015.01)

CPC - F01N 3/035, 3/0814, 3/0871, 3/208, 2560/025; Y02T 10/24 (2015.11) (keyword delimited)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 55/283; 60/274, 276, 286, 295, 297

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar, Google.com, YouTube.com

Search terms used: exhaust, oxygen sensor, difference, desorb, hydrocarbon, downstream, upstream, catalyst

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,926,263 B2 (STROH et al) 19 April 2011 (19.04.2011) entire document	1-3, 9-11, 15-17
A	US 5,373,696 A (ADAMCZYK, JR. et al) 20 December 1994 (20.12.1994) entire document	1-20
A	US 7,814,747 B2 (BANDL-KONRAD et al) 19 October 2010 (19.10.2010) entire document	1-20
A	US 7,997,063 B2 (THANASIU et al) 16 August 2011 (16.08.2011) entire document	1-20
A	US 8,359,837 B2 (STROIA et al) 29 January 2013 (29.01.2013) entire document	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

*

Special categories of cited documents:

"A"

document defining the general state of the art which is not considered to be of particular relevance

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document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O"

document referring to an oral disclosure, use, exhibition or other means

"P"

document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

30 November 2015

Date of mailing of the international search report

29 DEC 2015

Name and mailing address of the ISA/

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