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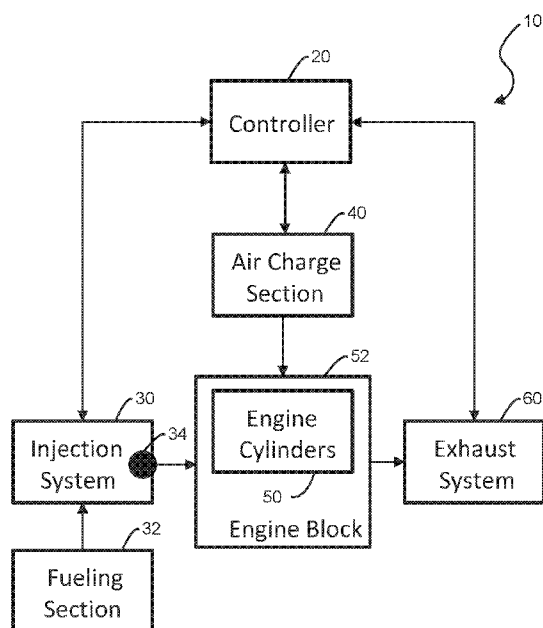


FIG. 1

(57) Abstract: A method of detecting a faulty injector in an engine includes initiating a cylinder deactivation mode for operating the engine. The method deactivates a first engine cylinder operating in the cylinder deactivation mode and calculates a first contribution value for the first engine cylinder based on an engine speed. The method also deactivates a second engine cylinder and calculates a second contribution value for the second engine cylinder based on the engine speed. The method then compares the first and second contribution values for any anomaly. Based on the comparison, the method generates an alert signal indicating the detection of the faulty injector.

SYSTEM AND METHOD FOR DETECTING A FAULTY FUEL INJECTOR DURING A CYLINDER DEACTIVATION MODE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of priority from U.S. Provisional Patent Application Serial No. 62/727,038, filed on September 5, 2018, the disclosure of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to engine systems. In particular, this disclosure relates to detecting one or more faulty fuel injectors in an engine during a cylinder deactivation mode.

BACKGROUND

[0003] An existing engine system, such as an internal combustion engine (ICE) (e.g., a gasoline or diesel engine), typically includes one or more fuel injectors to deliver fuel into corresponding cylinders in the engine. For example, fuel exits the fuel injectors in the form of a fuel stream and is mixed with air for subsequent combustion. After a prolonged use, the fuel injectors begin to degrade and cause malfunction in a fuel injection system of the engine. For example, an increased noise and vibration can be detected for the engine. To detect a faulty fuel injector, a current diagnostic tool evaluates engine cylinder contribution of each cylinder to output power to determine which injector is faulty and thus to be replaced.

[0004] However, at low idle conditions and low parasitic loads, the contribution of each injector to output power is relatively small and difficult to be measured, which can lead to an inaccurate detection of the faulty fuel injector. In certain cases, all fuel injectors of the engine are replaced without determining precisely which injector is at fault. Such fuel injector replacements can significantly increase operational costs and maintenance expenses for the engine. Accordingly, there are opportunities to develop an enhanced method and system for accurately detecting the faulty fuel injector of the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The above mentioned and other features and objects of this disclosure, and the manner of attaining them, will become more apparent and the disclosure itself will be better understood by reference to the following description of an embodiment of the disclosure taken in conjunction with the accompanying drawings, wherein:

[0006] FIG. 1 is a schematic diagram of an engine system in accordance with embodiments of the present disclosure;

[0007] FIG. 2 is a schematic diagram of an exemplary controller of the engine system of FIG. 1 in accordance with embodiments of the present disclosure; and

[0008] FIG. 3 is a flow chart of an exemplary detection method using the controller of FIG. 1 in accordance with embodiments of the present disclosure.

[0009] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of the present disclosure, the drawings are not necessarily to scale, and certain features may be exaggerated in order to better illustrate and explain the present disclosure. The exemplification set out herein illustrates an embodiment of the disclosure, in one form, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION

[0010] According to one embodiment, the present disclosure provides a method of detecting a faulty injector of an engine having a plurality of engine cylinders is provided. The method includes initiating a cylinder deactivation mode for operating the engine. The method also includes deactivating a first engine cylinder of the plurality of engine cylinders operating in the cylinder deactivation mode. The method also includes receiving information related to an engine speed of the engine and calculating a first contribution value of the first engine cylinder with respect to the engine speed. Further, the method includes calculating one or more second contribution values of the rest of the plurality of engine cylinders that are active during the cylinder deactivation mode with respect to the engine speed. In addition, the method includes comparing the first contribution value and the one or more second contribution values for anomaly, and generating an alert signal indicating the detection of the faulty injector based on

the comparison of the first contribution value and the one or more second contribution values for the anomaly.

[0011] In another aspect, when calculating the one or more second contribution values, the method includes deactivating a second engine cylinder of the plurality of engine cylinders and calculating a corresponding contribution value of the second engine cylinder with respect to the engine speed. The first contribution value and the one or more second contribution values may be calculated with respect to a pressure level associated with an exhaust system or an injection system.

[0012] In a further aspect, when comparing the first contribution value and the one or more second contribution values, the method includes determining a deviation for each of the first and second engine cylinders during the cylinder deactivation mode. The deviation for each of the first and second engine cylinders may be based on an engine speed or a pressure level. A difference is determined between the deviation for each of the first engine cylinders, where the difference is based on a predetermined threshold. The anomaly may be indicative of an over-fueling event or an under-fueling event for the faulty injector.

[0013] According to another embodiment, the present disclosure provides a system of detecting a faulty injector of an engine having a plurality of engine cylinders. The system includes a controller including a detection module that is configured to initiate a cylinder deactivation mode for operating the engine. The controller is also configured to deactivate a first engine cylinder of the plurality of engine cylinders operating in the cylinder deactivation mode. The controller is also configured to receive information related to an engine speed of the engine and calculate a first contribution value of the first engine cylinder with respect to the engine speed. Further, the controller is configured to calculate one or more second contribution values of the rest of the plurality of engine cylinders that are active during the cylinder deactivation mode with respect to the engine speed. In addition, the controller is configured to compare the first contribution value and the one or more second contribution values for anomaly, and generate an alert signal indicating the detection of the faulty injector based on the comparison of the first contribution value and the one or more second contribution values for the anomaly.

[0014] In another aspect, when configured to calculate the one or more second contribution values, the controller is further configured to deactivate a second engine cylinder of the plurality of engine cylinders and calculate a corresponding contribution value of the second engine cylinder with respect to the engine speed. The first contribution value and the one or

more second contribution values may be calculate with respect to a pressure level associated with an exhaust system or an injection system.

[0015] In a further aspect, when configured to compare the first contribution value and the one or more second contribution values, the controller is further configured to determine a deviation for each of the first and second engine cylinders during the cylinder deactivation mode. The deviation for each of the first and second engine cylinders may be based on an engine speed or a pressure level. A difference is determined between the deviation for each of the first engine cylinders, where the difference is based on a predetermined threshold. The anomaly may be indicative of an over-fueling event or an under-fueling event for the faulty injector.

[0016] The embodiment disclosed below is not intended to be exhaustive or limit the disclosure to the precise form disclosed in the following detailed description. Rather, the embodiment is chosen and described so that others skilled in the art may utilize its teachings. One of ordinary skill in the art will realize that the embodiments provided can be implemented in hardware, software, firmware, and/or a combination thereof. Programming code according to the embodiments can be implemented in any viable programming language such as C, C++, HTML, XHTML, JAVA or any other viable high-level programming language, or a combination of a high-level programming language and a lower level programming language.

[0017] While multiple embodiments are disclosed, still other embodiments of the presently disclosed subject matter will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the disclosed subject matter. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

[0018] FIG. 1 is a schematic illustration of an engine system 10, according to some embodiments. Engine system 10 can be operated by any suitable types of fuel, such as gasoline, diesel, natural gas, propane, or any combination of different types of fuel. As shown, engine system 10 includes a controller 20, an engine block 52 including one or more engine cylinders 50, an injection system 30 configured for pressurizing fuel from fueling system 32 and delivering the fuel into one or more engine cylinders 50 using corresponding fuel injectors 34, an air charge section 40 for delivering air into engine cylinders 52 for combustion, and an exhaust system 60 configured for receiving combusted air and fuel (i.e. exhaust). To help reduce emissions, air charge section 40 may include an intake modification system (not shown), such as a turbocharger or exhaust gas recirculation system (EGR). In addition, to help reduce emissions, exhaust

system 60 may include a diesel particulate filter (DPF) or selective catalytic reduction (SCR) system.

[0019] In some embodiments, engine system 10 is designed and configured to operate at a typical operating point (i.e. an engine load and an engine speed in a typical operating range) where emissions are mitigated to acceptable levels. A typical operating point often has a typical engine speed above an engine idle speed. In some embodiments, when the engine load is substantially below or above a range of typical operating point engine loads, emissions become unacceptably high.

[0020] Controller 20 is configured to select a number of cylinders to fire in response to the one or more engine parameters detected. In some embodiments, controller 20 is operatively coupled to sensors in injection system 30, engine block 52, and exhaust system 60, for example, to detect and monitor the one or more engine parameters. The one or more engine parameters may include, but are not limited to, engine speed, engine load, instantaneous air-fuel ratio of firing cylinders, a fuel injection quantity versus engine speed curve defined in a controller, exhaust port temperature, engine operating state, and which module controls engine operation.

[0021] In various embodiments, in response to a reduced engine load or reduced requested engine power, controller 20 is configured to selectively deactivate engine cylinders. When deactivating one or more cylinders 50, the fuel injection quantity can be increased per active engine cylinder resulting in improved combustion characteristics for similar engine speed. The fuel injection quantity, for example, can be higher than a nominal fuel injection quantity corresponding to the engine system operating with all engine cylinders firing (i.e. no deactivation). The improved combustion characteristics are capable of achieving lower smoke values for similar NOX emission. In some embodiments, the improved combustion characteristics reduce white smoke at low engine load, for example. In further embodiments, black smoke is reduced. In the deactivated cylinders, fresh air blow out can further reduce smoke value in the exhaust by increasing the ratio of air to combusted gasses in the exhaust (i.e. diluting the exhaust).

[0022] In some embodiments, engine system 10 is configured as a four-stroke engine. In the four-stroke configuration, controller 20 sets injection timing and fuel injection quantity for injection system 30 toward the end of the compression stroke to initiate the power stroke (i.e. combustion). After the power stroke, the exhaust is vented out of engine cylinders 50 and into exhaust system 60.

[0023] In some embodiments, injection system 30 is a high-pressure fuel injection system. High pressure fuel injection can be used to reduce NOX emission by improving fuel spray characteristics into engine cylinders 50. In various embodiments, injection system 30 is a common-rail injection system with a high-pressure fuel rail for delivering diesel fuel. In some embodiments, the fuel is pressurized in a range between 450 and 3000 bar. In various embodiments, the fuel is pressurized to 1600 bar (approximately 22,000 psi) or more. In yet other embodiments, the fuel is pressurized to 2200 bar (approximately 32,000 psi) or more. However, for some injector nozzle geometries, such as those without sufficient nozzle sac volume, high pressure fuel injection results in nozzle cavitation, excessive wear, and unacceptably high smoke values.

[0024] In some embodiments, controller 20 is configured to control various components of engine system 10 to operate engine system 10. Controller 20 can be configured to control fuel injection system 30 to operate engine system 10 with a selected number of cylinders to fire. In some embodiments, controller 20 is configured to control combustion timing (i.e. engine speed) individually for each engine cylinder 50, allowing controller 20 to selectively fire (i.e. activate) and not fire (i.e. deactivate) individual engine cylinders 50. In some embodiments, operating engine system 10 can include selecting a firing pattern and/or controlling the injection system with the selected firing pattern. In one example, the firing pattern can be sequential, but in another example, the firing pattern can be random. Other suitable firing patterns, such as predetermined sequences set up by controller 20, are also contemplated to suit different applications.

[0025] Further, controller 20 is configured to detect at least one faulty injector during a cylinder deactivation mode. In one embodiment, the cylinder deactivation mode refers to a condition in which at least one engine cylinder 50 is deactivated during engine operation. In one embodiment, controller 20 deactivates sequentially one engine cylinder 50 at a time during the cylinder deactivation mode. In other embodiments, controller 20 deactivates selectively two or more engine cylinders 50 at a time during the cylinder deactivation mode. In one example, engine system 10 can be operated in the cylinder deactivation mode for the purpose of improved fuel economy (e.g., on a highway with a consistent cruising speed). In the cylinder deactivation mode, a firing injector can be under additional load than at idle, thereby making its contribution to an engine speed more pronounced. By selectively rotating which engine cylinder 50 is deactivated in the cylinder deactivation mode, controller 20 records historical or previous

contribution data of respective engine cylinder 50 for subsequent comparison. Detailed description of the comparison is provided below in paragraphs related to FIGS. 2 and 3.

[0026] FIG. 2 is a schematic illustration of an exemplary controller 20 for controlling engine system 10, according to some embodiments. In this configuration, controller 20 includes a hardware description module (HDM) 302, a combustion control module (CCM) 304, a detection module 305, a processor 306, and a memory 308 (i.e. data storage module). HDM 302, CCM 304, and detection module 305 are operatively coupled to processor 306 so that processor 306 can receive signals from HDM 302 and provide signals to CCM 304. Processor 306 is also operatively coupled to detection module 305 to perform a faulty injector detection process during the cylinder deactivation mode. Further, processor 306 is operatively coupled to memory 308 so that processor 306 can send to and receive signals from memory 308 in connection with storing data. For example, memory 308 can include tables 310 for storing data relating to the faulty injector detection process.

[0027] In some embodiments, HDM 302 is operatively coupled to various components of engine system 10, such as engine sensors associated with engine system 10 to detect various signals representing engine parameters. In the embodiment shown, HDM 302 is coupled to a smoke value sensor 320 configured to monitor smoke value of the exhaust, which can be positioned in exhaust system 60. HDM 302 is also coupled to an engine speed sensor 322 configured to detect an engine speed, which can be positioned on engine block 52. For example, engine speed sensor 322 is configured to detect an angular velocity of a crankshaft or flywheel of engine system 10. In one embodiment, the angular velocity can be measured in revolutions per minute (RPM). Other sensors (not shown) can be operatively coupled to HDM 302 and configured to detect engine load, instantaneous air-fuel ratio of firing cylinders, a fuel injection quantity versus engine speed curve defined in a controller, exhaust port temperature, and engine operating state.

[0028] In some embodiments, CCM 304 is operatively coupled to various engine components in engine system 10, such as fuel injectors 34, to provide a signal representing the firing pattern selected. In the embodiment shown, CCM 304 is operatively coupled to active injectors 330 corresponding to cylinders to fire and deactivate injectors 332 corresponding to cylinders to not fire. In some embodiments, controller 20 can include various combustion control modules for controlling engine operation, such as a steady state combustion control module and a transient state combustion control module.

[0029] In some embodiments, detection module 305 is operatively coupled to processor 306 and configured to detect at least one faulty injector among active injectors 330 and deactivated injectors 332. Initially, detection module 305 is configured to operate engine system 10 in the cylinder deactivation mode. During the cylinder deactivation mode, detection module 305 determines which engine cylinder 50 is not contributing the same amount of power as the other cylinders. In one example, CCM 304 is configured to sequentially deactivate each engine cylinder 50 and detection module 305 is configured to calculate a contribution value of a corresponding deactivated cylinder with respect to an engine speed (e.g., a crankshaft or flywheel rotational speed). When at least two engine cylinders 50 have been sequentially deactivated, detection module 305 compares the contribution values of engine cylinders 50 for anomaly. In one embodiment, the anomaly can refer a condition where the contribution value is indicative of an over-fueling event or an under-fueling event of fuel injector 34.

[0030] In another embodiment, the contribution value can be calculated with respect to a pressure level associated with exhaust system 60. For example, the contribution value can be calculated based on a pressure pulse measured in an exhaust manifold of exhaust system 60 for a predetermined period. In yet another embodiment, the contribution value can be calculated with respect to a pressure level associated with injection system 30. For example, the contribution value can be calculated based on a fuel pressure measured in a high-pressure fuel rail in a common-rail injection system for a predetermined period.

[0031] When engine system 10 is at a low idle engine operating condition, the vehicle is not moving. As such, the fuel injector commanded on-times may be largely the same from injector to injector. However, during the cylinder deactivation mode, the vehicle is moving. As such, other factors (e.g., an operator's throttle pedal and/or a steepness of the terrain) can change. Thus, to ensure that the above comparisons were appropriate, detection module 305 compares the output of two fuel injectors based on the same commanded fueling.

[0032] In some embodiments, tables 310 in memory 308 store relevant data and provide output data as a function of input data. Input data can represent various engine parameters, such as the engine speed. Output data can represent a number of cylinders to fire (i.e. activate) or a number of cylinders not to fire (i.e. deactivate). Examples of relationships between data include, but are not limited to, estimated NOX emission, estimated smoke value, and fuel injection quantity as a function of various cylinder operating points (i.e. engine speed and per cylinder torque).

[0033] In some embodiments, detection module 305 compares the performance of injectors under similar conditions when the injectors were new. To do so, memory 308 stores the outputs of all the new injectors for multiple fueling commands. If all but one of the injectors had similar performances when compared to the as-new conditions, then detection module 305 can identify the one injector with the non-similar performance as being faulty for replacement purposes.

[0034] In some embodiments, processor 306 is configured for selecting a number of engine cylinders to fire and a fuel injection quantity per selected engine cylinder in response to the one or more engine system parameters such that a NOX emission is less than a first predetermined threshold and a smoke value is less than a second predetermined threshold. In determining the number of cylinders to be fired, the processor may be further configured to determine a fuel quantity for a cylinder such that injector spray characteristics are improved for each fired (i.e. active) cylinder.

[0035] Some aspects of this disclosure are described in terms of sequences of actions to be performed by elements of a controller, such as a module, unit, logic, a computer system, and/or other hardware capable of executing non-transient computer-readable instructions. These elements can be embodied in an engine controller of an engine system, such as an engine control unit (ECU), also described as an engine control module (ECM), or in a controller separate from, and communicating with an ECU. In some embodiments, engine controller 20 can be part of a controller area network (CAN) in which the controller, sensor, actuators communicate via digital CAN messages.

[0036] It will be recognized that in each of the embodiments, the various actions for implementing the control strategy could be performed by specialized circuits (e.g., discrete logic gates interconnected to perform a specialized function), by application-specific integrated circuits (ASICs), by program instructions (e.g. program modules) executed by one or more processors (e.g., a central processing unit (CPU) or microprocessor), or by a combination of both. All of which can be implemented in a hardware and/or a non-transient computer-readable medium of the ECU and/or other controller or plural controllers. Logic of embodiments consistent with the disclosure can be programmed, for example, to include one or more singular or multidimensional lookup tables and/or calibration parameters. The non-transient computer-readable medium can comprise a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a

portable compact disc read-only memory (CD-ROM), or any other solid-state, magnetic, and/or optical disk medium capable of storing information. Thus, various aspects can be embodied in many different forms, and all such forms are contemplated to be consistent with this disclosure.

[0037] FIG. 3 illustrates an exemplary faulty injector detection process in accordance with embodiments of the subject matter disclosed herein. As disclosed herein, engine system 10 is not particularly limited and can perform any of the methods described within the scope of this disclosure. In FIG. 3, a method 300 of performing the faulty injector detection process is shown using controller 20.

[0038] At block 302, detection module 305 initiates the cylinder deactivation mode for operating engine system 10. For example, ECM or ECU can operate engine system 10 in the cylinder deactivation mode.

[0039] At block 304, detection module 305 notifies CCM 304 of the initiation of the cylinder deactivation mode and instructs CCM 304 to deactivate a first engine cylinder 50. For example, the first engine cylinder can be a cylinder number 1 in a four-cylinder ICE, but any random cylinder can be the first engine cylinder. In another example, two or more engine cylinders 50 can be deactivated simultaneously to expedite the faulty injector detection process.

[0040] At block 306, detection module 305 receives information related to an engine speed from engine speed sensor 322. For example, the information can include data relating to the angular velocity (e.g., RPM) of the crankshaft or flywheel of engine system 10. As discussed above, the information can alternatively or additionally include data relating to the pressure level associated with exhaust system 60 or injection system 30 depending on the application.

[0041] At block 308, detection module 305 calculates a contribution value of a corresponding deactivated cylinder (or cylinders when two or more cylinders are deactivated simultaneously) with respect to the engine speed. In various embodiments, the contribution value can be calculated with respect to the pressure level associated with exhaust system 60 or injection system 30 to suit the application.

[0042] At block 310, when at least two contribution values have been calculated for comparison, control proceeds to block 312. Otherwise, control proceeds to block 314. For example, detection module 305 instructs CCM 304 to sequentially deactivate the rest of engine cylinders 50 in engine system 10.

[0043] At block 312, detection module 305 compares the contribution values of engine cylinders 50 for the anomaly. For example, detection module 305 compares at least two

contribution values for an engine speed fluctuation in the flywheel or crankshaft to estimate an engine speed deviation for each cylinder during the cylinder deactivation mode. An acceleration of the engine speed can be indicative of the over-fueling event of fuel injector 34, and a deceleration of the engine speed can be indicative of the under-fueling event of fuel injector 34. In another embodiment, detection module 305 compares at least two contribution values for a pressure level deviation for each cylinder during the cylinder deactivation mode. For example, the pressure level can be associated with exhaust system 60 or injection system 30 depending on the application.

[0044] At block 314, detection module 305 instructs CCM 304 to deactivate a second engine cylinder 50. For example, the second engine cylinder can be a cylinder number 2 in the four-cylinder ICE, but any random cylinder can be the second engine cylinder. In another embodiment, a next group of engine cylinders 50 can be deactivated.

[0045] At block 316, detection module 305 determines whether the deviation estimated for the first engine cylinder is different from the deviation estimated for the second engine cylinder. In one embodiment, when a difference between the contribution values of the first and second engine cylinders 50 is greater than a predetermined threshold, control proceeds to block 318. Otherwise, control proceeds to block 314. In another embodiment, the difference can be determined when the contribution value of the first engine cylinder is a positive value and the contribution value of the second engine cylinder is a negative value. In yet another embodiment, the difference can be determined using a mean (or average) value and/or standard deviation values of contribution values of engine cylinders 50.

[0046] At block 318, detection module 305 generates an alert signal indicative of a fuel injector fault based on the comparison of the contribution values of engine cylinders 50. For example, the alert signal showing that the second engine cylinder is faulty can be displayed on an interactive screen or can be transmitted to other systems, such as fuel injection system 30, associated with engine system 10.

[0047] At block 320, the faulty fuel injector can be replaced by an operator or another suitable mechanical system. Thus, it is advantageous that the method 300 automatically provides an improved technique of accurately detecting the faulty fuel injector using the estimated deviations based on the contribution values of engine cylinders 50 during the cylinder deactivation mode.

[0048] It should be understood that, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements. The scope is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean “one and only one” unless explicitly so stated, but rather “one or more.” Moreover, where a phrase similar to “at least one of A, B, or C” is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B or C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C.

[0049] In the detailed description herein, references to “one embodiment,” “an embodiment,” “an example embodiment,” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art with the benefit of the present disclosure to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

[0050] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112(f), unless the element is expressly recited using the phrase “means for.” As used herein, the terms “comprises,” “comprising,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[0051] Various modifications and additions can be made to the exemplary embodiments discussed without departing from the scope of the presently disclosed subject matter. For example, while the embodiments described above refer to particular features, the scope of this disclosure also includes embodiments having different combinations of features and embodiments that do not include all of the described features. Accordingly, the scope of the subject matter disclosed herein is intended to embrace all such alternatives, modifications, and variations as fall within the scope of the claims, together with all equivalents thereof.

CLAIMS

What is claimed is:

1. A method of detecting a faulty injector of an engine having a plurality of engine cylinders, comprising:
 - initiating a cylinder deactivation mode for operating the engine;
 - deactivating a first engine cylinder of the plurality of engine cylinders operating in the cylinder deactivation mode;
 - receiving information related to an engine speed of the engine;
 - calculating a first contribution value of the first engine cylinder with respect to the engine speed;
 - calculating one or more second contribution values of the rest of the plurality of engine cylinders that are active during the cylinder deactivation mode with respect to the engine speed;
 - comparing the first contribution value and the one or more second contribution values for anomaly; and
 - generating an alert signal indicating the detection of the faulty injector based on the comparison of the first contribution value and the one or more second contribution values for the anomaly.
2. The method of claim 1, wherein calculating the one or more second contribution values comprises deactivating a second engine cylinder of the plurality of engine cylinders and calculating a corresponding contribution value of the second engine cylinder with respect to the engine speed.
3. The method of claim 1, wherein the first contribution value and the one or more second contribution values are calculated with respect to a pressure level associated with an exhaust system.
4. The method of claim 1, wherein the first contribution value and the one or more second contribution values are calculated with respect to a pressure level associated with an injection system.

5. The method of claim 2, wherein comparing the first contribution value and the one or more second contribution values comprises determining a deviation for each of the first and second engine cylinders during the cylinder deactivation mode.

6. The method of claim 5, wherein the deviation for each of the first and second engine cylinders is based on an engine speed.

7. The method of claim 5, wherein the deviation for each of the first and second engine cylinders is based on a pressure level.

8. The method of claim 5, further comprising determining a difference between the deviation for each of the first engine cylinders.

9. The method of claim 8, wherein the difference is based on a predetermined threshold.

10. The method of claim 1, wherein the anomaly is indicative of an over-fueling event or an under-fueling event for the faulty injector.

11. A system of detecting a faulty injector of an engine having a plurality of engine cylinders, comprising:

a controller configured to control the engine, and having a detection module configured to:

- initiate a cylinder deactivation mode for operating the engine;
- deactivate a first engine cylinder of the plurality of engine cylinders operating in the cylinder deactivation mode;
- receive information related to an engine speed of the engine;
- calculate a first contribution value of the first engine cylinder with respect to the engine speed;
- calculate one or more second contribution values of the rest of the plurality of engine cylinders that are active during the cylinder deactivation mode with respect to the engine speed;

compare the first contribution value and the one or more second contribution values for anomaly; and

generate an alert signal indicating the detection of the faulty injector based on the comparison of the first contribution value and the one or more second contribution values for the anomaly.

12. The system of claim 11, wherein the controller configured to calculate the one or more second contribution values is further configured to deactivate a second engine cylinder of the plurality of engine cylinders and calculate a corresponding contribution value of the second engine cylinder with respect to the engine speed.

13. The system of claim 11, wherein the controller is configured to calculate the first contribution value and the one or more second contribution values with respect to a pressure level associated with an exhaust system.

14. The system of claim 11, wherein the controller is configured to calculate the first contribution value and the one or more second contribution values with respect to a pressure level associated with an injection system.

15. The system of claim 12, wherein the controller configured to compare the first contribution value and the one or more second contribution values is further configured to determine a deviation for each of the first and second engine cylinders during the cylinder deactivation mode.

16. The system of claim 15, wherein the deviation for each of the first and second engine cylinders is based on an engine speed.

17. The system of claim 15, wherein the deviation for each of the first and second engine cylinders is based on a pressure level.

18. The system of claim 15, wherein the controller is further configured to determine a difference between the deviation for each of the first engine cylinders

19. The system of claim 18, wherein the difference is based on a predetermined threshold.

20. The system of claim 11, wherein the anomaly is indicative of an over-fueling event or an under-fueling event for the faulty injector.

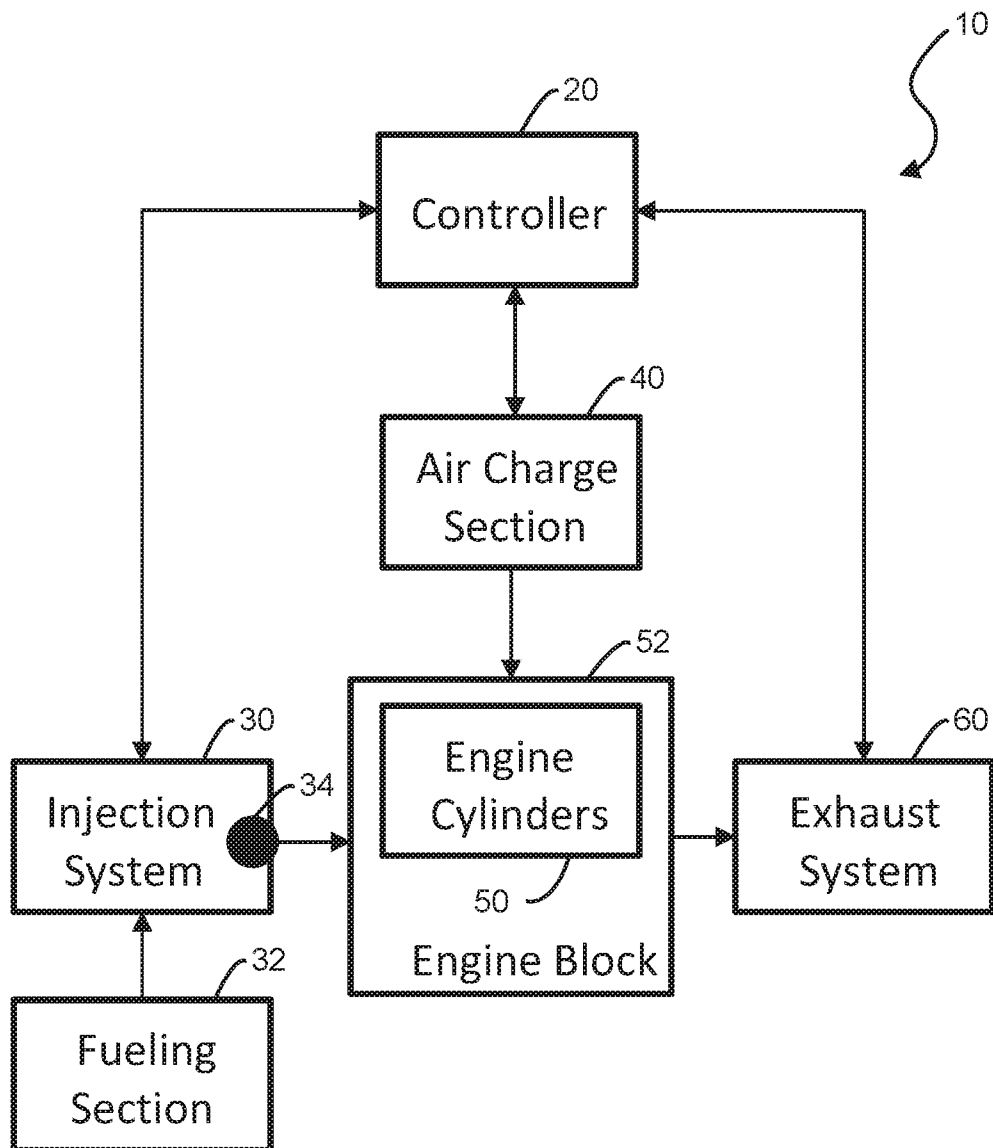


FIG. 1

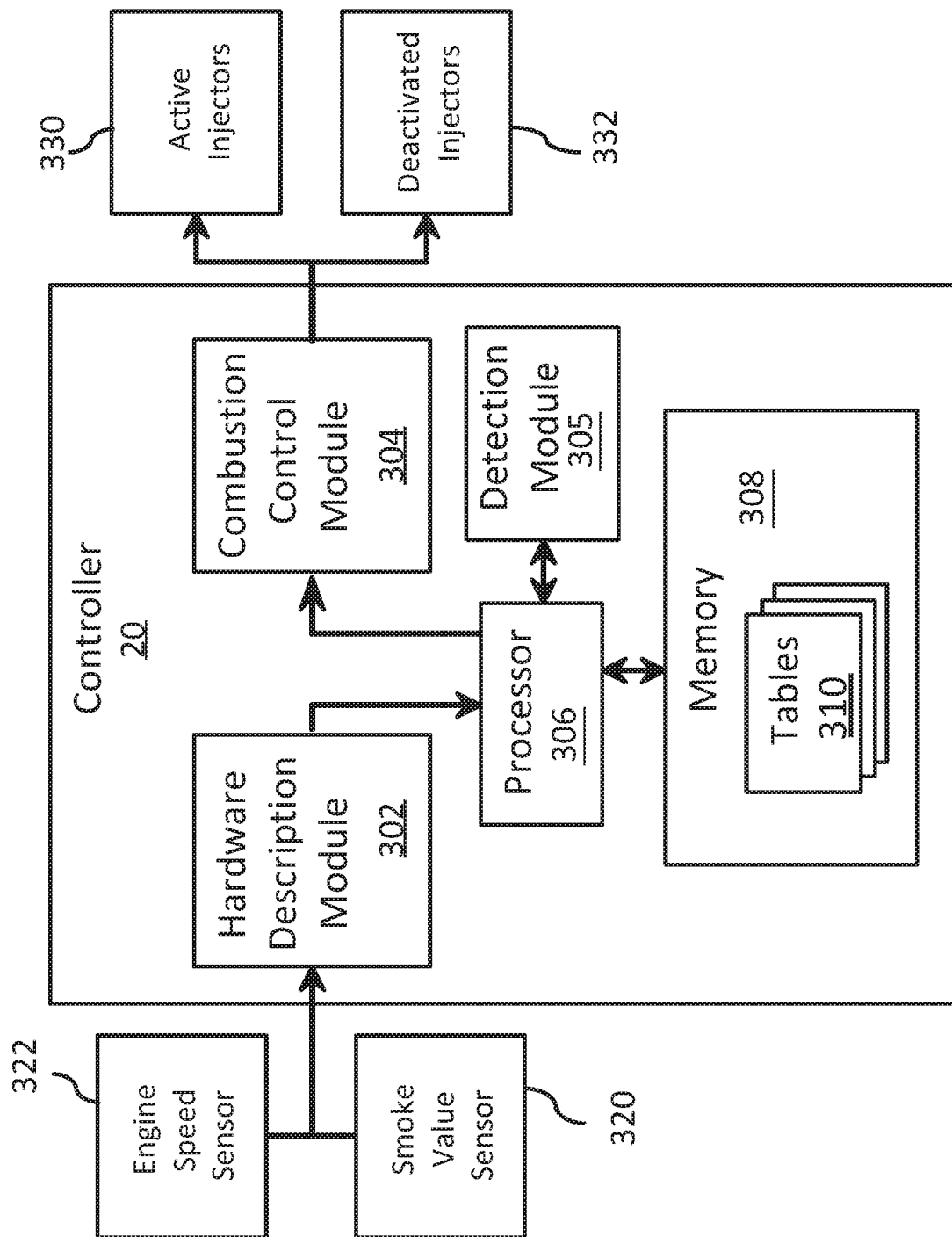


FIG. 2

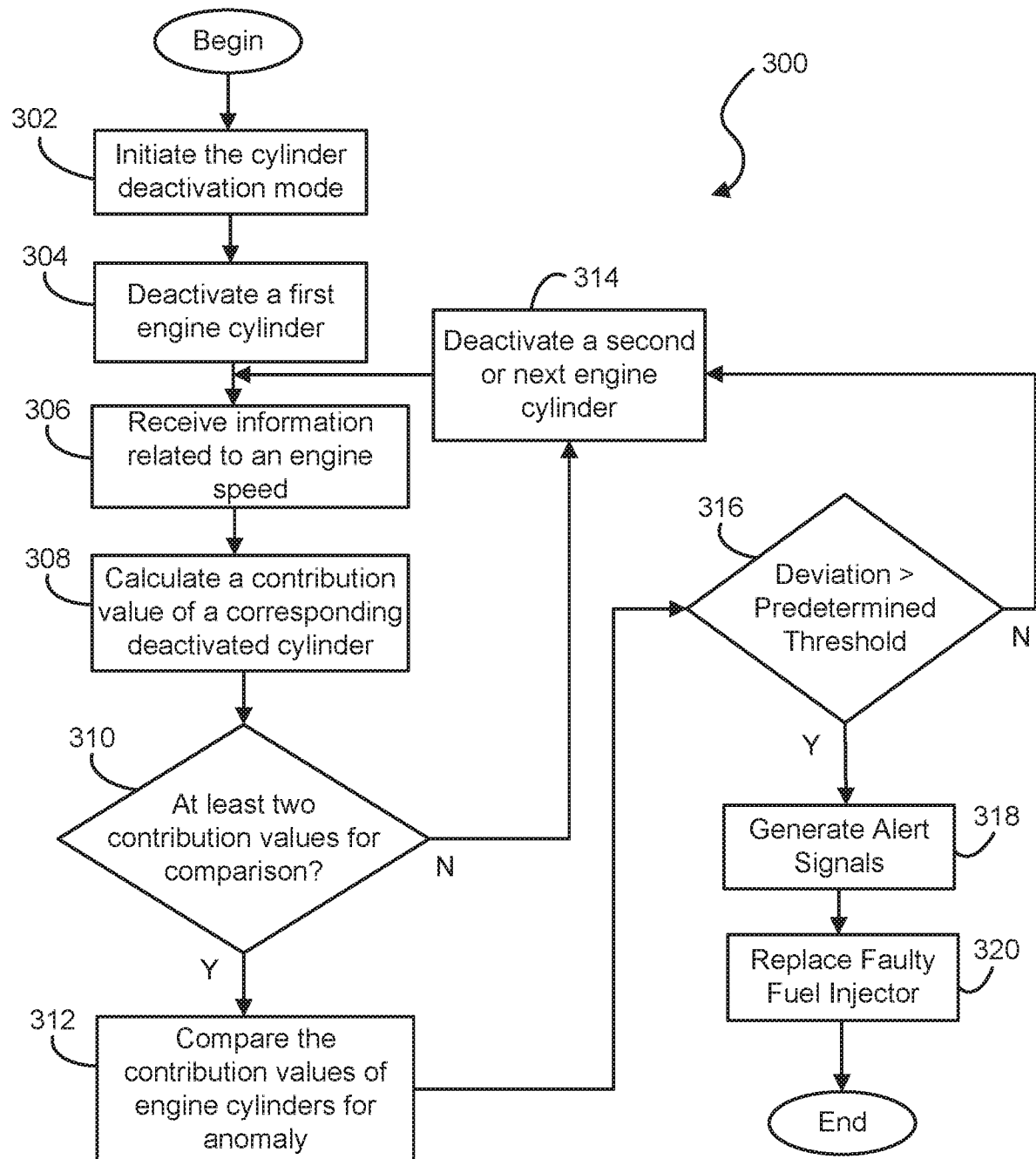


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2019/048714

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F02D 41/22; F02D 13/02; F02D 17/00; F02D 17/02; F02D 41/00; F02D 41/04 (2019.01)

CPC - F02D 41/22; F01N 11/002; F02D 17/00; F02D 17/02; F02D 41/008; F02D 41/0087; F02D 41/1454; F02D 41/3005 (2019.08)

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)

See Search History document

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

USPC - 123/305; 123/435; 701/103 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/0350332 A1 (FORD GLOBAL TECHNOLOGIES, LLC) 07 December 2017 (07.12.2017) entire document	1-20
A	US 2010/0250089 A1 (BUSLEPP et al) 30 September 2010 (30.09.2010) entire document	1-20
A	US 2015/0330319 A1 (CATERPILLAR INC.) 19 November 2015 (19.11.2015) entire document	1-20
A	US 2014/0257674 A1 (GM GLOBAL TECHNOLOGY OPERATIONS LLC) 11 September 2014 (11.09.2014) 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

"E" earlier application or patent but published on or after the international filing date

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"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

15 October 2019

Date of mailing of the international search report

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