(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 327 756 B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
21.09.2005 Bulletin 2005/38

(51) Int Cl.[7]: **F01N 11/00**, F02D 41/14

(21) Application number: **03100003.7**

(22) Date of filing: **06.01.2003**

(54) **A system and method for detecting an air leak in the exhaust system of an internal combustion engine**

Verfahren und Vorrichtung zur Erkennung einer Luftleckage im Abgassystem einer Brennkraftmaschine

Méthode et système de détection d'une fuite d'air dans le système d'échappement d'un moteur à combustion interne

(84) Designated Contracting States:
DE GB

(30) Priority: **11.01.2002 US 44602**

(43) Date of publication of application:
16.07.2003 Bulletin 2003/29

(73) Proprietor: **Ford Global Technologies, Inc.**
Michigan 48126 (US)

(72) Inventors:
- **Ponagai, Edward**
  Dearborn Heights, MI 48127 (US)
- **Danhoff, Gary, Lee**
  MI 48239, Redford (US)
- **Hussini, Ghassan**
  MI 48127, Dearborn Hieghts (US)
- **Raad, Ghassan, K.**
  MI 48331, Farmington Hills (US)
- **Kluzner, Michael, Igor**
  MI 48237, Oak Park (US)
- **Berger, Raymond, Henry**
  MI 48188, Canton (US)
- **Jergert, Robert, Joseph**
  MI 48130, Dexter (US)

(74) Representative: **Messulam, Alec Moses et al**
A. Messulam & Co. Ltd.,
43-45 High Road
Bushey Heath,
Bushey,
Herts WD23 1EE (GB)

(56) References cited:
EP-A- 0 719 931
EP-A- 1 114 922
US-A- 5 351 526
US-A- 5 372 036

EP 1 327 756 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The invention relates to a system and method for detecting an air leak in an exhaust system coupled to an engine.

[0002] To meet current emission regulations, automotive vehicles must regulate the air-fuel ratio supplied to the vehicles' engine cylinders to achieve maximum efficiency of exhaust gas catalysts. For this purpose, it is known to control the air-fuel ratio of an internal combustion engine using an exhaust gas oxygen sensor positioned in the exhaust stream from the engine.

[0003] The exhaust gas sensor provides feedback data to an electronic controller that calculates desired air-fuel ratio values over time to achieve optimum efficiency of the catalyst in the exhaust system.

[0004] When an air leak occurs in an exhaust system upstream of an exhaust gas sensor, atmospheric air may be inducted into the exhaust system during idle or deceleration operating conditions. As a result, the exhaust gas sensor may indicate a lean air-fuel ratio even though a combusted air-fuel mixture in an engine cylinder was not a lean mixture. An electronic engine controller utilizing the inaccurate air-fuel ratio measurement may not be able to maintain an optimal air-fuel ratio for optimal catalyst efficiency. Thus, air leaks in the exhaust system may result in increased emissions and decreased fuel economy.

[0005] It is known from, for example, US Patent number 5,372,036 to provide an engine control system that detects air leaks in an exhaust system by measuring the number of switch transitions in an output signal of an oxygen sensor disposed upstream of an emission catalyst. However, the known system relies only on the instantaneous oxygen sensor signals and not on any other engine air-fuel control parameters. Thus, the known system may incorrectly indicate air leaks in the exhaust system during relatively short transient operation of the oxygen sensor when no air leak actually exists.

[0006] It is further known from EP-A-0719931 to provide a system for detecting leaks in an exhaust system during low speed, low load operating conditions by using at least one air/fuel correction factor and a measurement of whether an Oxygen sensor determines the mixture to be rich or rear.

[0007] It is an object of this invention to provide a more accurate system and method for detecting an air leak in an exhaust system coupled to an engine.

[0008] According to a first aspect of the invention there is provided a system for detecting an air leak within an exhaust system communicating with an engine including an intake manifold communicating with at least one combustion chamber of the engine, the system comprising a first sensor generating a first signal indicative of one of a mass air flow and a pressure in the intake manifold, a second sensor generating a second signal indicative of an engine speed, a third sensor generating a third signal indicative of an air-fuel ratio in exhaust gases from the engine and a controller operably connected to the first, second and third sensors wherein the controller is configured to determine when the engine is operating in a low speed, low load mode and when operating in such a mode is further configured to determine when an air leak is present in the exhaust system based on the third signal and at least one air-fuel correction value characterised in that the low speed and low load mode is one of an idle operating mode and a deceleration operating mode and the controller is operable to determine when the engine is operating in one of the two modes based on the first and second signals and that the system is further operable to indicate the air leak is detected in the exhaust system when the third signal indicates a lean air-fuel ratio, a first short term air-fuel correction value which compensates for fuelling errors detected by the third sensor corresponds to a rich air-fuel ratio and a second long term air-fuel correction value which is based on at least one stored value in a table indexed with reference to one of engine speed and load or air charge temperature corresponds to a rich air-fuel ratio. The third sensor may be an exhaust gas oxygen sensor.

[0009] According to a second aspect of the invention there is provided a method for detecting an air leak within an exhaust system communicating with an engine including an intake manifold communicating with at least one combustion chamber of the engine wherein the method comprises measuring an exhaust gas constituent in exhaust gases from the engine when the engine is operating in a low speed, low load mode and determining when an air leak is present in the exhaust system based on the measured exhaust gas constituent and at least one air-fuel correction value characterised in that that the low speed, low load mode is an idle operating mode and the step of determining when an air leak is present includes indicating the air leak is detected in the exhaust system when the measured exhaust gas constituent indicates a lean air-fuel ratio, a first short term air-fuel correction value which compensates for fuelling errors as detected by the third sensor corresponds to a rich air-fuel ratio and a second long term air-fuel correction value which is based on at least one stored value in a table indexed with reference to one of engine speed and load or air charge temperature corresponds to a rich air-fuel ratio. The exhaust gas constituent may be oxygen. The first air-fuel correction value may be determined based on a measured oxygen concentration in the exhaust gases.

[0010] The method may further comprise indicating that there is an air leak in the intake manifold when the measured exhaust gas constituent indicates a lean air-fuel ratio, the second value exceeds a respective predetermined threshold, the third value is less than a predetermined threshold.

[0011] According to a third aspect of the invention there is provided an article of manufacture comprising a computer storage medium having a computer program encoded therein for detecting an air leak within an exhaust system communicating with an engine including an intake manifold communicating with at least one combustion chamber of the.engine the computer storage medium including code for determining a first value indicative of a lean air-fuel ratio in exhaust gases from the engine and code for determining at least one air-fuel correction value for the engine characterised in that the computer storage medium further comprises code for determining a second value indicative of a first short term air-fuel correction value which compensates for engine fuelling errors, code for determining a third value indicative of a second long term air-fuel correction value for the engine which is based upon at least one stored value in a table indexed by engine speed and load or air charge temperature, code for determining a fourth value when the second value exceeds a respective predetermined threshold and the third value is less than a predetermined threshold and code for determining a fifth value when a predetermined period of time has been exceeded and code for summing the first, second, third, fourth and fifth values to obtain a total value and code for indicating that an air leak is present in the exhaust when the total value is equal to a predetermined leak detection value.

[0012] The computer medium may further include code for indicating that an air leak is present in the intake manifold when the total value is equal to a second predetermined leak detection value.

[0013] The engine may be provided with a positive crankcase ventilation system and the computer medium may further include code for indicating that an air leak is present in the positive crankcase ventilation system when the total value is equal to a third predetermined leak detection value.

[0014] The invention will now be described by way of example with reference to the accompanying drawing of which:-

Figure 1 is block diagram of an automotive vehicle having an engine and an engine control system;

Figures 2A-2D are schematics of signals used to determine when an air leak in an engine intake manifold is detected;

Figures 3A-3D are schematics of signals used to determine when an air leak proximate a PCV valve in an engine is detected;

Figures 4A-4D are schematics of signals used to determine when an air leak in an exhaust system coupled to an engine is detected; and

Figure 5 is a flowchart of a method for detecting an air leak within an engine or an exhaust system.

[0015] Referring now to the drawings, like reference numerals are used to identify identical components in the various views and Fig. 1 shows an automotive motor vehicle 10 having an internal combustion engine 12 and an engine control system 14.

[0016] The engine 12 has a plurality of cylinders, however only one cylinder is shown for clarity of illustration. The engine 12 has a combustion chamber 30, cylinder walls 32, a piston 34, a crankshaft 35, a spark plug 36, an intake manifold 38, an exhaust manifold 40, an intake valve 42, an exhaust valve 44, a throttle body 46, a throttle plate 48, a fuel injector 50, and a catalytic converter 52.

[0017] The combustion chamber 30 communicates with intake manifold 38 and exhaust manifold 40 via respective intake and exhaust valves 42, 44. A piston 34 is positioned within combustion chamber 30 between cylinder walls 32 and is connected to crankshaft 35. Ignition of an air-fuel mixture within combustion chamber 30 is controlled via spark plug 36 which delivers ignition spark responsive to a signal from distributorless ignition system 54.

[0018] Intake manifold 38 communicates with throttle body 46 via throttle plate 48. Throttle plate 48 is controlled by electric motor 55 which receives a signal from ETC driver 56. ETC driver 56 receives a control signal (DC) from a controller 58. Intake manifold 38 is also shown having fuel injector 50 coupled thereto for delivering fuel in proportion to the pulse width of signals (FPW) from controller 58. Fuel is delivered to fuel injector 50 by a conventional fuel system (not shown) including a fuel tank, fuel pump, and fuel rail (now shown).

[0019] Although port fuel injection is shown, direct fuel injection could be utilized instead of port fuel injection.

[0020] The intake manifold 38 also communicates with a crankcase 59 via a positive crankcase (PCV) valve 61. When valve 61 is open, unburned fuel and exhaust gases trapped in crankcase 59 are inducted into intake manifold 38. As will be discussed in more detail below, if an air leak occurs near PCV valve 61 in conduit 63, additional atmospheric air may be inducted directly into manifold 38 which can affect closed-loop air-fuel control. Similarly, if PCV valve 61 becomes disconnected from conduit 63, additional air may be inducted into manifold 38 affecting closed-loop air-fuel control.

[0021] The exhaust manifold 40 communicates with catalyst 52 which as shown is a three-way catalytic converter. The "exhaust system" includes the components downstream of the engine cylinder and includes exhaust manifold 40 and catalyst 52. The catalyst 52 reduces exhaust gas constituents such as nitrous oxides (NOx) and oxidizes carbon monoxide (CO) and hydrocarbons (HC).

[0022] As illustrated, an exhaust gas sensor 60 is disposed upstream of catalyst 52 and a second exhaust gas sensor 64 is disposed downstream of catalyst 52. The exhaust gas sensors 60, 64 may comprise one of an EGO sensor, a HEGO sensor, or a UEGO sensor.

[0023] The sensor 60 generates a signal FEGO indicative of an air to fuel ratio in exhaust gases upstream of catalyst 52. Sensor 64 may generate signal REGO indicative of an air/fuel ratio in exhaust gases downstream of catalyst 52. As will be discussed in greater detail below, if an air leak occurs upstream of exhaust gas sensor 60, atmospheric air will be inducted directly into exhaust manifold 40 which can cause the signal FEGO to indicate a lean air-fuel ratio, even though a lean air-fuel mixture was not combusted in the engine cylinder. As such, the air leak can affect closed-loop air-fuel control of engine 12.

[0024] Control system 14 is provided to control the operation of engine 12 and to implement a method for detecting an air leak within engine 12 or the exhaust system. Control system 14 includes distributorless ignition system 54, an electric motor 55 for controlling throttle plate 48, an ETC driver 56, exhaust gas sensors 60, 64, a mass air flow sensor 68, a temperature sensor 70, a throttle position sensor 72, a torque sensor 74, an engine speed sensor 76, a pedal position sensor 78, an accelerator pedal 80, and controller 58.

[0025] Mass air flow sensor 68 generates a signal indicating the inducted mass air flow (AM) that is transmitted to controller 58. Sensor 68 may be coupled to the throttle body 46 or intake manifold 38. As discussed above, if an air leak occurs downstream of sensor 68, the inducted air flow into the engine cylinder will be greater than the measured air flow (AM). In an alternate embodiment (not shown), sensor 68 could be replaced by a pressure sensor measuring a pressure in throttle body 46 or intake manifold 38 where the air flow (AM) is calculated based on the measured pressure.

[0026] Temperature sensor 70 generates a signal indicating the engine coolant temperature (ECT) received by controller 58. Sensor 70 may be coupled to cooling jacket 71 in cylinder wall 32.

[0027] Throttle position sensor 72 generates a signal indicating a throttle position (TP) of throttle plate 48 received by controller 58 for closed-loop control of plate 48.

[0028] Torque sensor 74 generates a signal (TQ) that may indicate one of following torque values: (i) an engine crankshaft torque, ii) a transmission torque, such as for example, a torque converter turbine torque or a transmission output shaft torque, or (iii) an axle torque.

[0029] Engine speed sensor 76 may comprise a Hall Effect sensor that generates a signal (N) indicating an engine speed. Sensor 76 may be coupled to crankshaft 35 and transmits signal (N) to controller 58.

[0030] Vehicle speed sensor 79 is conventional in the art and may be operably connected to a vehicle wheel (not shown) or to a drive train (not shown) of vehicle 10. Sensor 79 generates a signal (S) indicative of vehicle speed that is transmitted to controller 58.

[0031] Accelerator pedal 80 is shown communicating with a driver's foot 82. Pedal position sensor 78 generates a signal indicating acceleration pedal position (PP) that is transmitted to controller 58.

[0032] The controller 58 is provided to implement the method for detecting an air leak within engine 12 or the exhaust system in accordance with the present invention. The controller 58 includes a microprocessor 84 communicating with various computer-readable storage media. The computer readable storage media preferably include non-volatile and volatile storage in a read-only memory (ROM) 86 and a random-access memory (RAM) 88. The computer readable media may be implemented using any of a number of known memory devices such as PROMs, EPROMs, EEPROMs, flash memory or any other electric, magnetic, optical or combination memory device capable of storing data, some of which represent executable instructions, used by microprocessor 84 in controlling engine 12. Microprocessor 84 communicates with various sensors and actuators (discussed above) via an input/output (I/O) interface 90. Of course, the present invention could utilize more than one physical controller to provide engine/vehicle control depending upon the particular application.

[0033] Before discussing the method for detecting an air leak in accordance with the present invention, the signals utilized by the method will be discussed. Referring to Figure 2A, the signal FEGO generated by exhaust gas sensor 60 is illustrated. As discussed above, the signal FEGO is indicative of an air-fuel ratio measured in exhaust gases from engine 12.

[0034] Referring to Figure 2B, the engine speed (N) over time is illustrated.

[0035] Referring to Figure 2C, the a short term air-fuel ratio correction value LAMBSE is utilized to adjusted the fuel delivery the engine cylinders to adjust the fuel delivery to compensate for rich or lean fuelling errors as detect by exhaust gas sensor 60. LAMBSE is generally a proportional-integral value of output signal FEGO generated by sensor 60. LAMBSE is an average value of unity when engine 12 is operating at stoichiometric and there are not steady-state air/fuel errors or offsets. For typical engine operation, LAMBSE ranges from 0.75-1.25.

[0036] Referring to Figure 2D, a long term air fuel ratio adaptive correction value, KAMRF is illustrated. The value KAMRF may be determined based on at least one stored value in a table indexed by engine speed and load, or air charge temperature. The correction values LAMBSE and KAMRF are utilized in adjusting fuel delivery to engine 12 as follows:

$$Fuel\_flow = AM * KAMRF / (14.65 * LAMBSE)$$

[0037] It should be understood, however, alternate and/or additional air-fuel correction values could be utilized. For example, an air-fuel correction value based on signal REGO indicative of an air/fuel ratio downstream of catalyst 52 could be utilized to calculate the Fuel_flow.

[0038] Referring to Figures 2A-2D, signals generated when an air leak is detected in intake manifold 38 are illustrated. It should be noted that air leaks in intake manifold 38 are detected when engine 12 is operating in idle operating mode. As shown, at time T=620 seconds for example, the engine speed (N) is at an idle speed.

[0039] Thereafter, signal FEGO indicates a lean air-fuel ratio for an extended amount of time (e.g., time T=620-645 seconds). In response, controller 58 begins to adjust LAMBSE toward a richer air-fuel value and KAMRF toward a richer air-fuel value. At time T=645 seconds, for example, when controller 58 determines that (i) signal FEGO indicates a lean air-fuel ratio, (ii) engine speed is at an idle speed, (iii) LAMBSE corresponds to a rich air-fuel ratio, and (iv) KAMRF corresponds to a rich air-fuel ratio---controller 58 indicates that an air leak was detected in intake manifold 58.

[0040] Referring to Figures 3A-3D, signals generated when an air leak is detected proximate to PCV valve 61 are illustrated. It should be noted that air leaks proximate PCV valve 61 are detected when engine 12 is operating in idle operating mode. As shown, at time T=617 seconds for example, the engine speed (N) is at an idle speed.

[0041] Thereafter, signal FEGO indicates lean air-fuel ratio for an extended amount of time (e.g., time T=618-645 seconds). In response, controller 58 begins to adjust LAMBSE toward a relatively large rich air-fuel value and adjusts KAMRF toward a relatively large rich air-fuel value.

[0042] At time T=645 seconds, when controller 58 determines that (i) HEGO indicates a lean air-fuel ratio, (ii) engine speed (N) is at an idle speed, (iii) LAMBSE corresponds to a relatively large rich air-fuel ratio, and (iv) KAMRF corresponds to a relatively large rich air-fuel ratio---controller 58 indicates that an air leak was detected proximate PCV valve 61. It should be noted that the air leak could occur if PCV valve 61 was not connected to conduit 63 or a hole formed in conduit 63.

[0043] Referring to Figures 4A-4D, signals generated when an air leak is detected proximate the exhaust system coupled to engine 12 are illustrated. It should be noted that air leaks in the exhaust system are detected after a decelerating operating mode in a subsequent idle operating mode of engine 12.

[0044] As shown, between times T=615-620 seconds, engine 12 is in a deceleration operating mode and after time T=620 seconds enters an idle speed operating mode. Further, signal FEGO indicates a lean air-fuel ratio for an extended amount of time (e.g., time T=620-645 seconds). In response, controller 58 begins to adjust LAMBSE toward a rich air-fuel value and adjusts KAMRF toward a rich air-fuel value. At time T=645 seconds, when controller 58 determines that (i) HEGO indicates a lean air-fuel ratio, (ii) engine speed (N) is at an idle speed (after decelerating), (iii) LAMBSE corresponds to a rich air-fuel ratio, and (iv) KAMRF corresponds to a rich air-fuel ratio controller 58 indicates that an air leak was detected in the exhaust system of engine 12. In particular, controller 58 indicates that an air leak occurred upstream of exhaust gas sensor 60 or proximate sensor 60.

[0045] Referring to Figure 5, a method 92 for detecting an air leak within engine 12 or an exhaust system coupled to engine 12 will now be explained. For purposed of simplicity, the method 92 is described with reference to a vehicle 10 having a single intake manifold 38 and a single exhaust system. However, the method 92 can also be utilized with vehicles having dual intake manifolds or dual exhaust systems by simply duplicating the steps of method 92 for each respective intake manifold or exhaust system.

[0046] At step 94, a determination is made as to whether initial vehicle operating conditions are met for detecting air leaks. In particular, controller 58 determines whether the engine coolant temperature (ECT), the air charge temperature (ACT), and catalyst temperature are above predetermined respective thresholds. If the foregoing conditions are met and the value of step 94 equals "Yes", the step 96 is performed. Otherwise, the method is exited.

[0047] At step 96, the weighting values X1, X2, X3, X4, X5 are initialized to zero.

[0048] At step 98, the timers TMR1 and TMR2 are stopped and reset. The timer TMR1 will be utilized to determine an amount of time that engine 12 is in a deceleration operating mode. The timer TMR2 will be utilized to determine an amount of time that engine 12 is in an idle operating mode.

[0049] Next at step 100, a determination is made as to whether engine 12 is operating in a deceleration operating mode. Controller 58 may access an engine speed/load table using engine speed (N) and air flow rate (AM) to determine whether engine 12 is operating in deceleration mode. If the value of step 100 equals "Yes", the method advances to step 102. Otherwise, the method re-executes step 100.

[0050] At step 102, a determination is made as to whether signal FEGO is less than a predetermined voltage V_1. Voltage V_1 represents a voltage corresponding to a lean air-fuel ratio, such as 0.4 Volts dc when sensor 60 comprises a HEGO sensor. If the value of step 102 equals "Yes", the method advances to step 104. Otherwise, the method advances to step 112 explained below.

[0051] At step 104, timer TMR1 is either started or continues to be incremented. TMR1 will be incremented as long as engine 12 is in the deceleration operating mode.

[0052] Next at step 106, a determination is made as to whether timer TMR1 is greater than a threshold time $T_{THRESHOLD1}$. The time $T_{THRESHOLD1}$ may be equal to 10 seconds for example. If the value of step 106 equals "No", the method returns to step 100. Otherwise, the method advances to step 108 which sets value X1 according to the following equation:

$$X1 = 1$$

[0053] Next at step 110, the timer TMR1 is stopped and the method advances to step 112.

[0054] At step 112, a determination is made as to whether engine 12 is operating in an idle operating mode. Controller 58 may access an engine speed/load table using engine speed (N) and air flow rate (AM) to determine whether engine 12 is operating in idle mode. If the value of step 112 equals "Yes", the method advances to step 114. Otherwise, the method returns to step 112 waiting for engine 12 to enter idle mode.

[0055] At step 114, a determination is made as to whether signal FEGO is less than predetermined voltage V_1 which represents a voltage corresponding to a lean air-fuel ratio. If the value of step 114 equals "Yes", the method advances to step 116. Otherwise, the method returns to step 96 to thereafter wait for another deceleration operating mode.

[0056] At step 116, timer TMR2 is either started or continues to be incremented. TMR2 will be incremented as long as engine 12 is in the idle operating mode.

[0057] Next at step 118, a determination is made as to whether the value KAMRF corresponds to a rich air-fuel ratio. If the value of step 118 equals "Yes", the step 120 sets the value X2 according to the following equation:

$$X2 = 2$$

and the method advances to step 122. Otherwise, if the value of step 118 equals "No, the method also advances to step 122.

[0058] At step 122, a determination is made as to whether the value LAMBSE corresponds to a rich air-fuel ratio. If the value of step 122 equals "Yes", the step 124 set the value X3 using the following equation:

$$X3 = 3$$

and advances to step 126. Otherwise, if the value of step 122 equals "No, the method also advances to step 126.

[0059] Next, step 126 determines whether (i) value KAMRF is greater than a threshold value C1 and (ii) value LAMBSE is less than a threshold value C2. The value C1 corresponds to a relatively rich air-fuel ratio (for KAMRF) and may have a value of 1.2 for example. The value C2 corresponds to a relatively large rich air-fuel ratio (for LAMBSE) and may have a value of 0.8 for example. If the value of step 126 equals "Yes", the step 128 sets the value X4 using the following equation:

$$X4 = 4$$

and the method advances to step 130. Otherwise, if the value of step 126 equals "No", the method also advances to step 130.

[0060] At step 130, a determination is made as to whether timer TMR2 is greater than a threshold time $T_{THRESHOLD2}$. The time $T_{THRESHOLD2}$ is empirically determined and may be equal to 20 seconds for example. If the value of step 130 equals "Yes", the method advances to step 132. Otherwise, the method returns to step 112.

[0061] At step 132, the value X5 is set using the following equation:

$$X5 = 5$$

[0062] Next at step 134, the timer TMR2 is stopped and the method advances to step 136.

[0063] At step 136, a value TOTAL_SUM is calculated utilizing the following equation:

$$TOTAL\_SUM = X1 + X2 + X3 + X4 + X5$$

[0064] Next at step 138, a determination is made as to whether the value TOTAL_SUM is equal to the value 14. If the value of step 138 equals "Yes", the step 140 indicates that an air leak was detected proximate to PCV valve 61 and the method is ended. Otherwise, the step 142 is performed.

[0065] At step 142, a determination is made as to whether the value TOTAL_SUM is equal to the value 11. If the value of step 142 equals "Yes", the step 144 indicates that an air leak was detected in the exhaust system of vehicle 10 and the method is ended. Otherwise, the step 146 is performed.

[0066] At step 146, a determination is made as to whether the value TOTAL_SUM is equal to the value 10. If the value of step 146 equals "Yes", the step 148 indicates that an air leak was detected in intake manifold 38 of engine 12 and the method is ended. Otherwise, if the value of step 146 equals "No", the method is also ended.

[0067] The system 14 and method for detecting air leaks in an exhaust system provides a substantial advantage over conventional systems and methods. In particular, the system and method can accurately detect air leaks in an exhaust system by considering additional engine air-fuel control parameters as compared to known systems which only use an oxygen sensor signal. In particular, the system utilizes air-fuel correction value LAMBSE and air-fuel correction value KAMRF along with an exhaust gas sensor output signal to detect when the air leak occurs.

[0068] It will be appreciated by those skilled in the art that the invention has been described by example with reference to certain embodiments but that the invention is not limited to the specific embodiments described herein and various modified embodiments could be constructed without departing from the scope of the appended claims.

Claims

1. A system (14) for detecting an air leak within an exhaust system (40, 52) communicating with an engine (12) including an intake manifold (38) communicating with at least one combustion chamber (30) of the engine (12), the system (14) comprising a first sensor (68) generating a first signal indicative of one of a mass air flow and a pressure in the intake manifold, a second sensor (76) generating a second signal indicative of an engine speed, a third sensor (60) generating a third signal indicative of an air-fuel ratio in exhaust gases from the engine (12) and a controller (58) operably connected to the first, second and third sensors (68, 76 and 60) wherein the controller (58) is configured to determine when the engine (12) is operating in a low speed, low load mode and when operating in such a mode is further configured to determine when an air leak is present in the exhaust system (40, 52) based on the third signal and at least one air-fuel correction value **characterised in that** the low speed and low load mode is one of an idle operating mode and a deceleration operating mode and the controller (58) is operable to determine when the engine is operating in one of the two modes based on the first and second signals and that the system is further operable to indicate the air leak is detected in the exhaust system (40, 52) when the third signal indicates a lean air-fuel ratio, a first short term air-fuel correction value which compensates for fuelling errors detected by the third sensor (60) corresponds to a rich air-fuel ratio and a second long term air-fuel correction value which is based on at least one stored value in a table indexed with reference to one of engine speed and load or air charge temperature corresponds to a rich air-fuel ratio.

2. A system as claimed in claim 1 wherein the third sensor is an exhaust gas oxygen sensor (60).

3. A method for detecting an air leak within an exhaust system (40, 52) communicating with an engine (12) including an intake manifold (38) communicating with at least one combustion chamber (30) of the engine (12) wherein the method comprises measuring an exhaust gas constituent in exhaust gases from the engine (12) when the engine (12) is operating in a low speed, low load mode and determining when an air leak is present in the exhaust system (40, 52) based on the measured exhaust gas constituent and at least one air-fuel correction value **characterised in that** the low speed, low load mode is an idle operating mode and the step of determining when an air leak is present includes indicating the air leak is detected in the exhaust system (40, 52) when the measured exhaust gas constituent indicates a lean air-fuel ratio, a first short term air-fuel correction value which compensates for fuelling errors as detected by the third sensor (60) corresponds to a rich air-fuel ratio and a second long term air-fuel correction value which is based on at least one stored value in a table indexed with reference to one of engine speed and load or air charge temperature corresponds to a rich air-fuel ratio.

4. A method as claimed in claim 3 wherein the exhaust gas constituent is oxygen.

5. A method as claimed in claim 3 or in claim 4 wherein the first short term air-fuel correction value is determined based on a measured oxygen concentration in the exhaust gases.

6. A method as claimed in any of claims 3 to 5 wherein the method further comprises indicating that there is an air leak in the intake manifold when the measured exhaust gas constituent indicates a lean air-fuel ratio, the second value exceeds a respective predetermined threshold and the third value is less than a predetermined threshold.

7. An article of manufacture (58) comprising a computer storage medium (84, 86, 88) having a computer program encoded therein for detecting an air leak within an exhaust system (40, 52) communicating with an engine (12) including an intake manifold (38) communicating with at least one combustion chamber (30) of the engine (12), the computer storage medium (84, 86, 88) including code for determining a first value indicative of a lean air-fuel ratio in exhaust gases from the engine (12) and code for determining at least one air-fuel correction value for the engine **characterised in that** the computer storage medium further comprises code for determining a second value indicative of a first short term air-fuel correction value which compensates for engine fuelling errors, code for determining a third value indicative of a second long term air-fuel correction value for the engine which is based upon at least one stored value in a table indexed by engine speed and load or air charge temperature, code for determining a fourth value when the second value exceeds a respective predetermined threshold and the third value is less than a predetermined threshold and code for determining a fifth value when a predetermined period of time has been exceeded and code for summing the first, second, third, fourth and fifth values to obtain a total value and code for indicating that an air leak is present in the exhaust

when the total value is equal to a predetermined leak detection value.

8. An article of manufacture (58) as claimed in claim 7 wherein the computer medium further includes code for indicating that an air leak is present in the intake manifold (38) when the total value is equal to a second predetermined leak detection value.

9. An article of manufacture (58) as claimed in claim 7 or in claim 8 in which the engine is provided with a positive crankcase ventilation system (61, 63) and the computer medium further includes code for indicating that an air leak is present in the positive crankcase ventilation system (61, 63) when the total value is equal to a third predetermined leak detection value.

Patentansprüche

1. System (14) zum Erfassen eines Luftlecks innerhalb eines Abgassystems (40, 52), das mit einem Motor (12) verbunden ist, umfassend einen Einlassrohrverzweiger (38), der mit mindestens einer Brennkammer (30) des Motors (12) kommuniziert, wobei das System (14) einen ersten Sensor (68) umfasst, der ein erstes Signal erzeugt, das entweder einen Luftmassestrom oder einen Druck in dem Einlassrohrverzweiger angibt, einen zweiten Sensor (76), der ein zweites Signal erzeugt, das eine Motordrehzahl angibt, einen dritten Sensor (60), der ein drittes Signal erzeugt, das ein Luft-Kraftstoffgemischverhältnis in Verbrennungsgasen des Motors (12) anzeigt, und einen Controller (58), der betrieblich mit dem ersten, zweiten und dritten Sensor (68, 76 und 60) verbunden ist, wobei der Controller (58) konfiguriert ist, um zu bestimmen, ob der Motor (12) mit einer niedrigen Drehzahl, einem Niederlastbetrieb läuft, und, wenn er in einem solchen Betrieb läuft, ferner konfiguriert ist, um auf der Grundlage des dritten Signals und mindestens eines Luft-Kraftstoffkorrekturwerts zu bestimmen, ob ein Luftleck in dem Abgassystem (40, 52), gegenwärtig ist, **dadurch gekennzeichnet, dass** der Betrieb mit niedriger Drehzahl und Niederlastbetrieb entweder ein Leerlaufbetrieb oder ein Bremsbetrieb ist, und dass der Controller (58) betrieben werden kann, um zu bestimmen, ob der Motor in einer der zwei Betriebsarten läuft, die auf dem ersten und zweiten Signal basieren, und dass das System ferner betrieben werden kann, um anzuzeigen, dass das Luftleck in dem Abgassystem (40, 52) erfasst wird, wenn das dritte Signal ein mageres Luft-Kraftstoffverhältnis anzeigt, wobei ein erster kurzfristiger Luft-Kraftstoffkorrekturwert, der die Kraftstoffzuführfehler ausgleicht, die von dem dritten Sensor (60) erfasst werden, einem reichhaltigen Luft-Kraftstoffverhältnis entspricht, und ein zweiter langfristiger Luft-Kraftstoffkorrekturwert, der auf mindestens einem Wert basiert, der in einer Tabelle gespeichert ist, die unter Bezugnahme entweder auf die Motordrehzahl oder Last- oder Luftlasttemperatur indexiert ist, einem reichhaltigen Luft-Kraftstoffverhältnis entspricht.

2. System nach Anspruch 1, wobei der dritte Sensor ein Abgassauerstoffsensor (60) ist.

3. Verfahren zum Erfassen eines Luftlecks innerhalb eines Abgassystems (40, 52), das mit einem Motor (12) kommuniziert, umfassend einen Einlassrohrverzweiger (38), der mit mindestens einer Brennkammer (30) des Motors (12) kommuniziert, wobei das Verfahren das Messen eines Abgasbestandteils in den Abgasen des Motors (12) umfasst, wenn der Motor (12) in einer Betriebsart mit niedriger Drehzahl und niedriger Last läuft, und das Bestimmen auf der Grundlage des gemessenen Abgasbestandteils und mindestens eines Luft-Kraftstoffkorrekturwerts, ob ein Luftleck in dem Abgassystem (40, 52) gegenwärtig ist, **dadurch gekennzeichnet, dass** die Betriebsart mit niedriger Drehzahl und niedriger Last ein Leerlaufbetrieb ist, und dass der Schritt des Bestimmens, wenn ein Luftleck gegenwärtig ist, das Angeben des Erfassens des Luftlecks in dem Abgassystem (40, 52) umfasst, wenn der gemessene Abgasbestandteil ein mageres Luft-Kraftstoffverhältnis anzeigt, wobei ein erster kurzfristiger Luft-Kraftstoffkorrekturwert, der für Kraftstoffzuführungsfehler ausgleicht, die vom dritten Sensor (60) erfasst werden, einem reichhaltigen Luft-Kraftstoffgemisch entspricht, und wobei ein zweiter langfristiger Luft-Kraftstoffkorrekturwert, der auf mindestens einem Wert basiert, der in einer Tabelle gespeichert ist, die unter Bezugnahme auf entweder die Motordrehzahl oder die Last oder Luftlasttemperatur indexiert ist, einem reichhaltigen Luft-Kraftstoffverhältnis entspricht.

4. Verfahren nach Anspruch 3, wobei der Abgasbestandteil Sauerstoff ist.

5. Verfahren nach Anspruch 3 oder 4, wobei der erste kurzfristige Luft-Kraftstoffkorrekturwert auf der Grundlage einer in den Abgasen gemessenen Sauerstoffkonzentration bestimmt wird.

6. Verfahren nach einem der Ansprüche 3 bis 5, wobei das Verfahren ferner das Anzeigen umfasst, dass sich in dem Einlassrohrverzweiger ein Luftleck befindet, wenn der gemessene Abgasbestandteil ein mageres Luft-Kraftstoffverhältnis anzeigt, der zweite Wert einen jeweiligen vorausbestimmten Schwellenwert überschreitet und der dritte Wert kleiner ist als ein vorausbestimmter Schwellenwert.

7. Produkt (58), das ein Computerspeichermittel (84, 86, 88) umfasst, das ein codiertes Computerprogramm enthält, um ein Luftleck innerhalb eines Abgassystems (40, 52) zu erfassen, das mit einem Motor (12) kommuniziert, der einen Einlassrohrverteiler (38) umfasst, der mit mindestens einer Brennkammer (30) des Motors (12) kommuniziert, wobei das Computerspeichermittel (84, 86, 88) einen Code zum Bestimmen eines ersten Werts umfasst, der ein mageres Luft-Kraftstoffverhältnis in den Abgasen des Motors (12) anzeigt, und einen Code zum Bestimmen mindestens eines Luft-Kraftstoffkorrekturwerts für den Motor, **dadurch gekennzeichnet, dass** das Computerspeichermittel ferner einen Code umfasst, um einen zweiten Wert zu bestimmen, der einen ersten kurzfristigen Luft-Kraftstoffkorrekturwert, der Motorkraftstoffzuführungsfehler ausgleicht, anzeigt, einen Code zum Bestimmen eines dritten Werts, der einen zweiten langfristigen Luft-Kraftstofflcorrekturwert für den Motor anzeigt, der auf mindestens einem in einer Tabelle gespeicherten Wert basiert, die nach Motordrehzahl und Last oder Luftlasttemperatur indexiert ist, einen Code zum Bestimmen eines vierten Werts, wenn der zweite Wert einen jeweiligen vorausbestimmten Schwellenwert überschreitet und der dritte Wert kleiner ist als ein vorausbestimmter Schwellenwert, und einen Code zum Bestimmen eines fünften Werts, wenn eine vorausbestimmte Zeitspanne überschritten wurde, und einen Code zum Summieren des ersten, zweiten, dritten, vierten und fünften Werts, um einen Gesamtwert zu erzielen, und einen Code, um anzuzeigen, dass ein Luftleck in dem Abgassystem gegenwärtig ist, wenn der Gesamtwert gleich einem vorausbestimmten Leckerfassungswert ist.

8. Produkt (58) nach Anspruch 7, wobei das Computerspeichermittel ferner einen Code umfasst, um anzuzeigen, dass ein Luftleck in dem Einlassrohrverteiler (38) gegenwärtig ist, wenn der Gesamtwert gleich einem zweiten vorausbestimmten Lekkerfassungswert ist.

9. Produkt (58) nach Anspruch 7 oder Anspruch 8, wobei der Motor mit einem Kurbelgehäuse-Fremdbelüftungssystem (61, 63) versehen ist, und das Computerspeichermittel ferner einen Code umfasst, um anzuzeigen, dass ein Luftleck in dem Kurbelgehäuse-Fremdbelüftungssystem (61, 63) gegenwärtig ist, wenn der Gesamtwert gleich einem dritten vorausbestimmten Leckerfassungswert ist.

Revendications

1. Système (14) pour détecter une fuite d'air à l'intérieur d'un système d'échappement (40, 52) communiquant avec un moteur (12) comprenant un collecteur d'admission (38) communiquant avec au moins une chambre de combustion (30) du moteur (12), le système (14) comprenant un premier capteur (68) générant un premier signal indiquant un élément parmi un débit massique d'air et une pression dans le collecteur d'admission, un deuxième capteur (76) générant un deuxième signal indiquant une vitesse ou régime de moteur, un troisième capteur (60) générant un troisième signal indiquant un mélange air-carburant dans les gaz d'échappement provenant du moteur (12) et une l'unité de contrôle (58) connectée de manière opérationnelle aux premier, deuxième et troisième capteurs (68, 76 et 60), dans laquelle l'unité de contrôle (58) est configurée de manière à déterminer lorsque le moteur (12) fonctionne à un mode de basse vitesse, à faible charge, et lorsqu'il fonctionne avec ce mode, elle est en outre configurée pour déterminer lorsqu'une fuite d'air est présente dans le système d'échappement (40, 52) sur la base du troisième signal et au moins une valeur de correction du mélange air-carburant, **caractérisé en ce que** le mode de basse vitesse et à faible charge est un mode parmi le mode de fonctionnement au ralenti et le mode de fonctionnement de décélération et l'unité de contrôle (58) peut être actionnée pour déterminer lorsque le moteur fonctionne dans l'un des deux modes sur la base des premier et deuxième signaux et **en ce que** le système peut être en outre actionné pour indiquer que la fuite d'air est détectée dans le système d'échappement (40, 52) lorsque le troisième signal indique un mélange air-carburant pauvre, une première valeur de correction à court terme du mélange air-carburant, qui compense les erreurs d'alimentation en carburant détectées par le troisième capteur (60), correspond à un mélange air-carburant riche et une deuxième valeur de correction à long terme du mélange air-carburant, qui s'appuie sur au moins une valeur stockée dans un tableau indexé faisant référence à un élément parmi la vitesse et la charge du moteur ou la température de la charge d'air, correspond à un mélange air-carburant riche.

2. Système selon la revendication 1, dans lequel le troisième capteur est un capteur de l'oxygène des gaz d'échappement (60).

3. Procédé pour détecter une fuite d'air à l'intérieur d'un système d'échappement (40, 52) communiquant avec un moteur, comprenant un collecteur d'admission (38) communiquant avec au moins une chambre de combustion (30) du moteur (12), dans lequel le procédé comprend la mesure d'un constituant des gaz d'échappement dans des gaz d'échappement provenant du moteur (12) lorsque le moteur (12) fonctionne en un mode de basse vitesse et à faible charge et la détermination du moment auquel une fuite d'air est présente dans le système d'échappement (40, 52) sur la base du constituant mesuré des gaz d'échappement et d'au moins une valeur de correction du mélange air-carburant, **caractérisé en ce que** le mode de basse vitesse et à faible charge est un mode de fonctionnement au ralenti et l'étape de détermination du moment auquel une fuite d'air est présente comprend l'indication selon laquelle la fuite d'air est détectée dans le système d'échappement (40, 52) lorsque le constituant mesuré des gaz d'échappement indique un mélange air-carburant pauvre, une première valeur de correction à court terme du mélange air-carburant, qui compense les erreurs d'alimentation en carburant telles que détectées par le troisième capteur (60), correspond à un mélange air-carburant riche et une deuxième valeur de correction à long terme du mélange air-carburant, qui s'appuie sur au moins une valeur stockée dans un tableau indexé faisant référence à un élément parmi la vitesse et la charge du moteur ou la température de la charge d'air, correspond à un mélange air-carburant riche.

4. Procédé selon la revendication 3, dans lequel le composant des gaz d'échappement est de l'oxygène.

5. Procédé selon la revendication 3 ou la revendication 4, dans lequel la première valeur de correction à court terme du mélange air-carburant est déterminée sur la base d'une concentration mesurée d'oxygène dans les gaz d'échappement.

6. Procédé selon l'une quelconque des revendications 3 à 5, dans lequel le procédé comprend en outre l'indication qu'il y a une fuite d'air dans le collecteur d'admission lorsque le constituant mesuré des gaz d'échappement indique un mélange air-carburant pauvre, la deuxième valeur dépasse un seuil respectif prédéterminé et la troisième valeur est inférieure à un seuil prédéterminé.

7. Article de fabrication (58) comprenant un support de stockage informatique (84, 86, 88) ayant un programme informatique codé à l'intérieur pour détecter une fuite d'air à l'intérieur d'un système d'échappement (40, 52) communiquant avec un moteur (12) comprenant un collecteur d'admission (38) communicant avec au moins une chambre de combustion (30) du moteur (12), le support de stockage informatique (84, 86, 88) comprenant un code pour déterminer une première valeur indiquant un mélange air-carburant pauvre dans les gaz d'échappement provenant du moteur (12) et un code pour déterminer au moins une valeur de correction du mélange air-carburant pour le moteur, **caractérisé en ce que** le support de stockage informatique comprend en outre un code pour déterminer une deuxième valeur indiquant une première valeur de correction à court terme du mélange air-carburant qui compense les erreurs d'alimentation en carburant du moteur, un code pour déterminer une troisième valeur indiquant une deuxième valeur de correction à long terme du mélange air-carburant pour le moteur, qui s'appuie sur au moins une valeur stockée dans un tableau indexé par la vitesse et la charge du moteur ou la température de charge de l'air, un code pour déterminer une quatrième valeur lorsque la deuxième valeur dépasse un seuil prédéterminé respectif et la troisième valeur est inférieure à un seuil prédéterminé et un code pour déterminer une cinquième valeur lorsqu'une période de temps prédéterminée a été dépassée et un code pour additionner les première, deuxième, troisième, quatrième et cinquième valeurs pour obtenir une valeur totale et un code pour indiquer qu'une fuite d'air est présente dans les gaz d'échappement lorsque la valeur totale est égale à une valeur de détection de fuite prédéterminée.

8. Article de fabrication (58) selon la revendication 7, dans lequel le support informatique comprend en outre un code pour indiquer qu'une fuite d'air est présente dans le collecteur d'admission (38) lorsque la valeur totale est égale à une deuxième valeur de détection de fuite prédéterminée.

9. Article de fabrication (58) selon la revendication 7 ou la revendication 8, dans lequel le moteur est doté d'un système de soupape de recyclage des gaz de carter (61, 63) et le support informatique comprend en outre un code pour indiquer qu'une fuite d'air est présente dans le système de soupape de recyclage des gaz de carter (61, 63) lorsque la valeur totale est égale à une troisième valeur de détection de fuite prédéterminée.

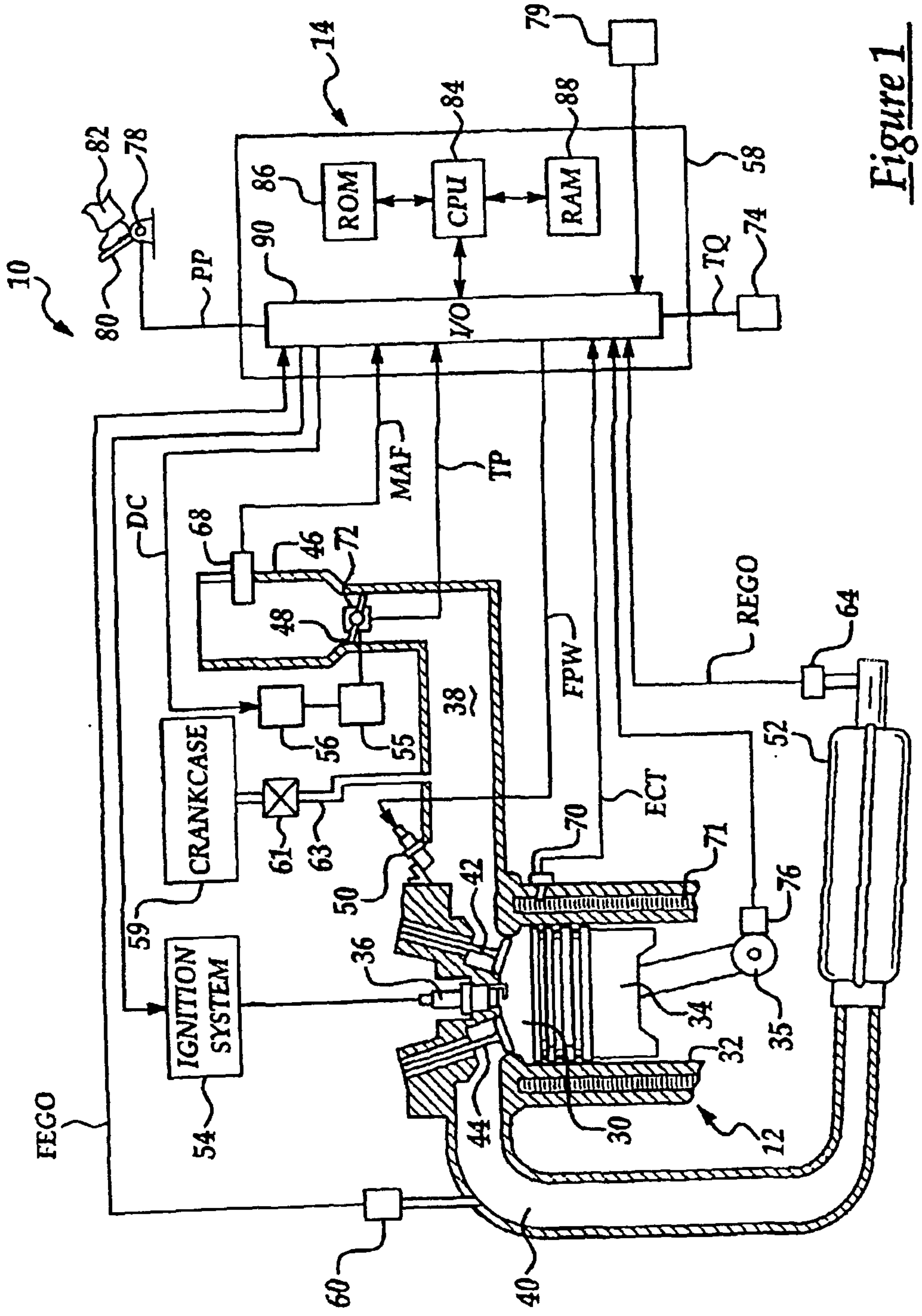

10
80
82
78
PP
90
86
ROM
84
CPU
88
RAM
14
79
58
I/O
TQ
74
FEGO
IGNITION SYSTEM
54
DC
CRANKCASE
59
68
46
72
48
MAF
TP
56
55
38
61
63
50
42
36
44
30
32
34
35
12
70
71
76
ECT
FPW
REGO
64
52
60
40

Figure 1

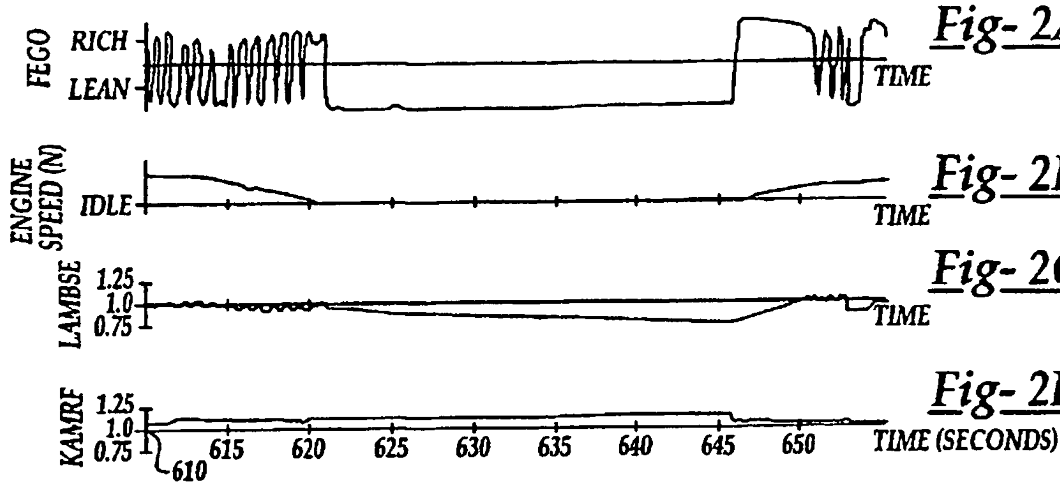


Fig- 2A

Fig- 2B

Fig- 2C

Fig- 2D

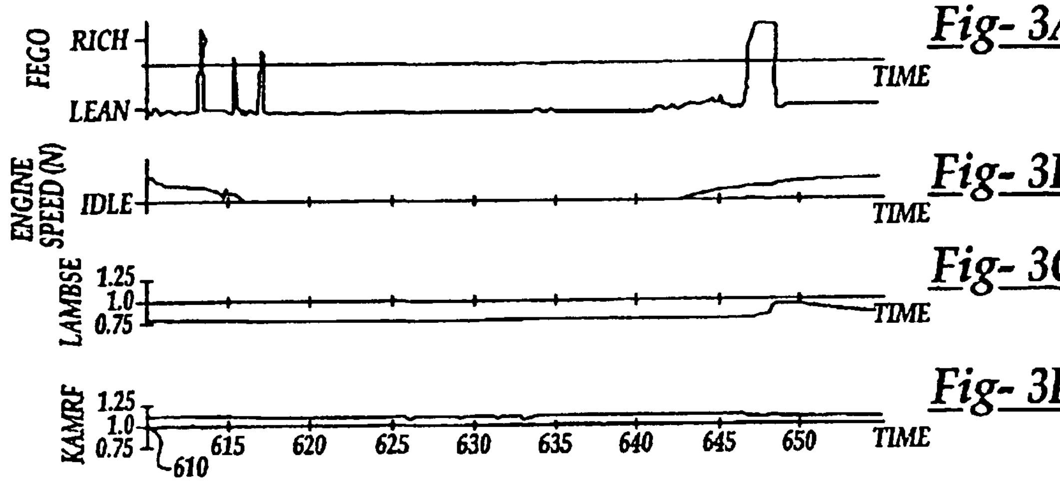


Fig- 3A

Fig- 3B

Fig- 3C

Fig- 3D

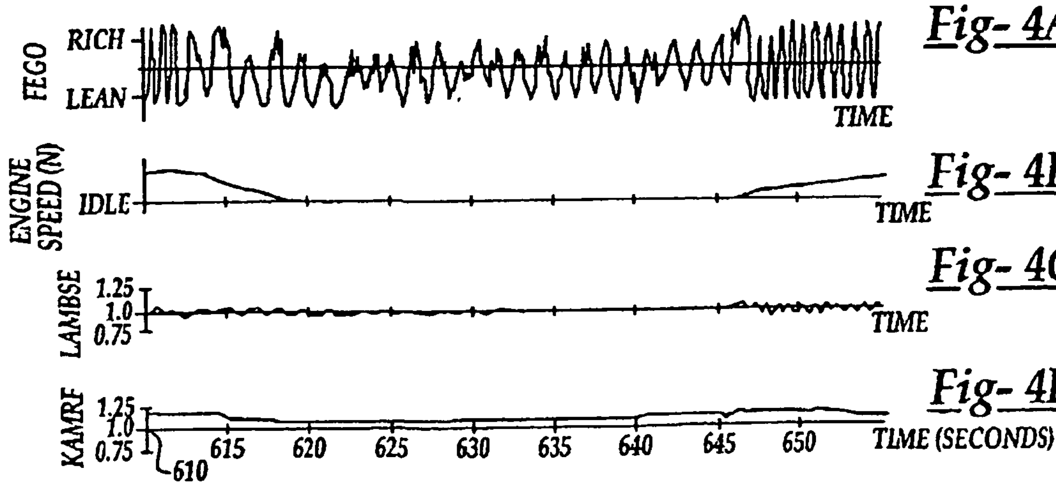
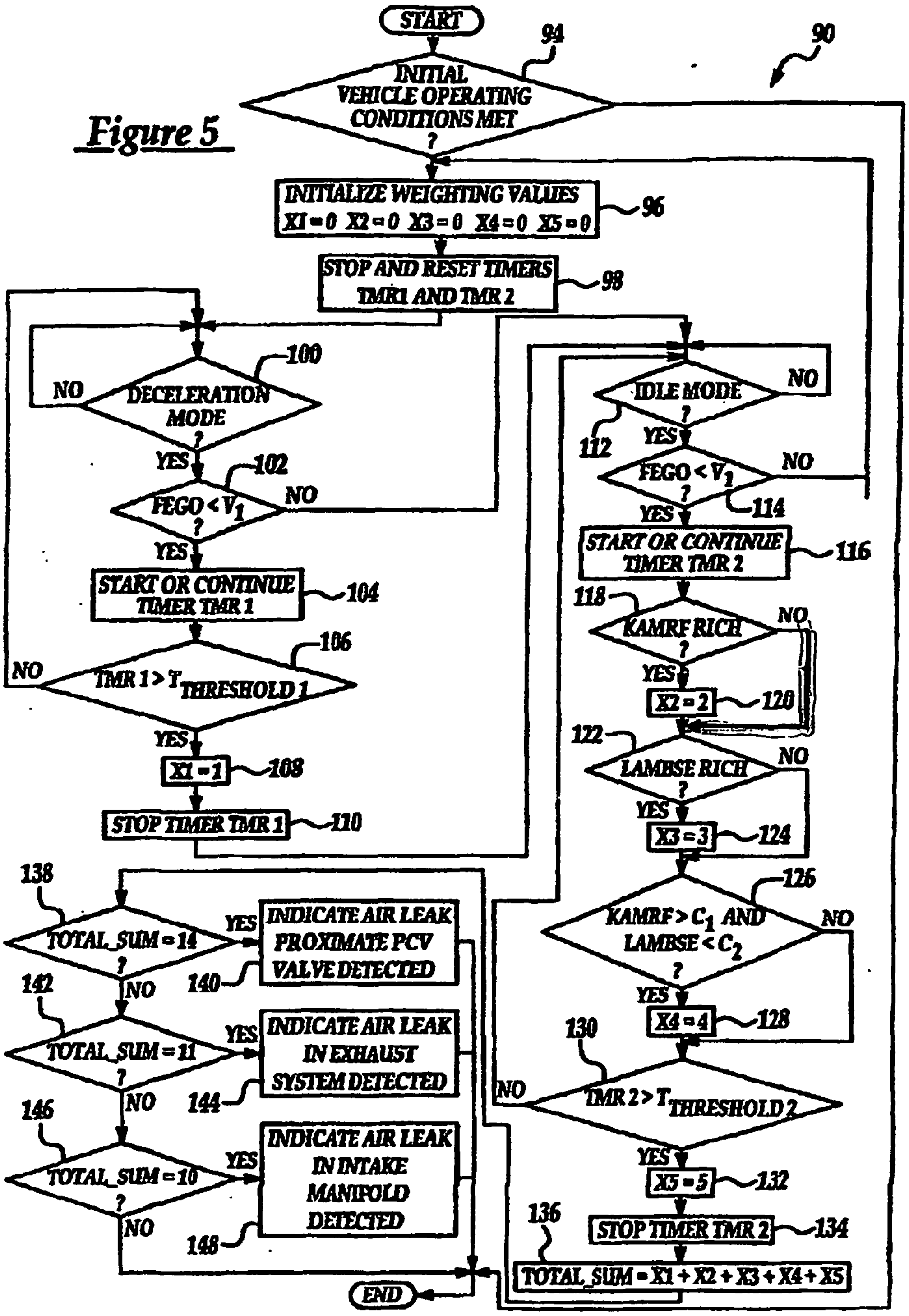


Fig- 4A

Fig- 4B

Fig- 4C

Fig- 4D


START
INITIAL VEHICLE OPERATING CONDITIONS MET ?
94
90
INITIALIZE WEIGHTING VALUES X1=0 X2=0 X3=0 X4=0 X5=0
96
STOP AND RESET TIMERS TMR1 AND TMR 2
98
DECELERATION MODE ?
100
NO
YES
FEGO < V1 ?
102
START OR CONTINUE TIMER TMR 1
104
TMR 1 > T THRESHOLD 1
106
X1=1
108
STOP TIMER TMR 1
110
IDLE MODE ?
112
FEGO < V1 ?
114
START OR CONTINUE TIMER TMR 2
116
KAMRF RICH ?
118
X2=2
120
LAMBSE RICH ?
122
X3=3
124
KAMRF > C1 AND LAMBSE < C2 ?
126
X4=4
128
TMR 2 > T THRESHOLD 2
130
X5=5
132
STOP TIMER TMR 2
134
TOTAL_SUM = X1 + X2 + X3 + X4 + X5
136
TOTAL_SUM = 14 ?
138
INDICATE AIR LEAK PROXIMATE PCV VALVE DETECTED
140
TOTAL_SUM = 11 ?
142
INDICATE AIR LEAK IN EXHAUST SYSTEM DETECTED
144
TOTAL_SUM = 10 ?
146
INDICATE AIR LEAK IN INTAKE MANIFOLD DETECTED
148
END
Figure 5