An engine emissions diagnostic is disclosed that utilizes parameters correlating to catalyst temperature to identify when an indication of degraded performance may be generated.
Engine start condition present?

- YES
  - Time Elapsed?
    - NO
    - YES
      - Calculate reference catalyst temperature estimate: ext_cmd_wavg_ref
    - Calculate current catalyst temperature estimate: ext_cmd_wavg
  - Calculate the delta reference catalyst temperature estimate: Delta_Ref
    - Delta_Ref = ext_cmd_wavg_ref(end) - ext_cmd_wavg_ref(beg)
  - Calculate the delta current catalyst temperature estimate: Delta_CMD
    - Delta_CMD = ext_cmd_wavg(end) - ext_cmd_wavg(beg)
  - Calculate catalyst delta ratio: CDR
    - CDR = (Delta_Ref - Delta_CMD) / Delta_Ref

Is CDR above threshold?

- NO
- YES
  - Set service code

Fig. 2
Fig. 3
COLD START EMISSION REDUCTION MONITORING SYSTEM AND METHOD

BACKGROUND AND SUMMARY

[0001] Vehicles may be required to meet certain emission thresholds. As such, some vehicles may use emission control devices, such as catalytic converters, to reduce engine emissions. These devices may provide various levels of emission reduction depending on exhaust temperature. As such, engine operation may be adjusted during an engine start to increase temperature of the device to thereby reduce emissions by achieving earlier catalyst light-off, for example.

[0002] However, the various factors can affect performance of the above adjustments to increase catalyst temperature. For example, degradation of components may result in less airflow than desired, for example, which may reduce exhaust gas heat. Further, engine speed control operation may result in adjustment of spark timing to such a degree that spark retard is sufficiently reduced or eliminated thus resulting in reduced exhaust gas temperature and delayed catalyst light-off.

[0003] As such, in one example, the above conditions causing reduced catalyst light-off performance via reduced catalyst temperature may be detected and utilized to indicate that vehicle emission control performance has degraded.

DESCRIPTION OF THE FIGURES

[0004] FIG. 1 shows a schematic engine diagram;
[0005] FIG. 2 shows an example cold start emissions reduction monitoring routine; and
[0006] FIG. 3 shows an example graph plotting the catalyst delta ratio against the engine coolant temperature at start.

DETAILED DESCRIPTION

[0007] Internal combustion engine 10 comprising a plurality of cylinders, one cylinder of which is shown in FIG. 1, is controlled by electronic engine controller 12. Engine 10 includes combustion chamber 30 and cylinder walls 32 with piston 36 positioned therein and connected to crankshaft 13. Combustion chamber 30 communicates with intake manifold 44 and exhaust manifold 48 via respective intake valve 52 and exhaust valve 54. Exhaust gas oxygen sensor 16 is coupled to exhaust manifold 48 of engine 10 upstream of catalytic converter 20.

[0008] Intake manifold 44 communicates with throttle body 64 via throttle plate 66. Throttle plate 66 is controlled by electric motor 67, which receives a signal from ETC driver 69. ETC driver 69 receives control signal (DC) from controller 12. Intake manifold 44 is also shown having fuel injector 68 coupled thereto for delivering fuel in proportion to the pulse width of signal (fsw) from controller 12. Fuel is delivered to fuel injector 68 by a conventional fuel system (not shown) including a fuel tank, fuel pump, and fuel rail (not shown).

[0009] Engine 10 further includes conventional distributorless ignition system 88 to provide ignition spark to combustion chamber 30 via spark plug 92 in response to controller 12. In the embodiment described herein, controller 12 is a conventional microcomputer including: microprocessor unit 102, input/output ports 104, electronic memory chip 106, which is an electronically programmable memory in this particular example, random access memory 108, and a conventional data bus. The controller may further include a keep alive memory (not shown) for storing adaptive parameters.

[0010] Controller 12 receives various signals from sensors coupled to engine 10, in addition to those signals previously discussed, including: measurements of induced mass air flow (MAF) from mass air flow sensor 110 coupled to throttle body 64; engine coolant temperature (ECT) from temperature sensor 112 coupled to cooling jacket 114; a measurement of throttle position (TP) from throttle position sensor 117 coupled to throttle plate 66; a measurement of turbine speed (Wt) from turbine speed sensor 119, where turbine speed measures the speed of a torque converter output shaft, and a profile ignition pickup signal (PIP) from Hall effect sensor 118 coupled to crankshaft 13 indicating an engine speed (N). Alternatively, turbine speed may be determined from vehicle speed and gear ratio.

[0011] Controller 12 may include various control routines, such as cold start rapid catalyst heating routines that adjust various engine and/or vehicle operating parameters to more rapidly raise exhaust gas temperature. For example, ignition timing of one or more cylinders may be retarded from peak torque timing during cold starting operating to increase exhaust gas heat generation. Further, engine idle speed may be temporarily elevated after a cold start to further increase exhaust gas heat generation. Still other actions may be taken, such as air-fuel ratio adjustments, valve timing adjustments, fuel injection timing adjustments, and the like. In one particular embodiment, engine idle speed, spark timing, and engine airflow, may be adjusted during a cold start to increase exhaust gas temperature. In another embodiment, intake valve advance and/or retard may be used, along with spark retard and fuel injection timing and amount variations. For example, the controller may adjust a variable valve timing system to increase positive valve overlap (e.g., via an intake only variable valve timing unit) of at least one cylinder during a cold start, and then adjust a fuel injection amount and/or timing and/or spark timing.

[0012] However, other control routines may be present which may limit or vary the above exhaust heat generation adjustments. For example, detection of low fuel quality, such as hesitation fuel, may reduce or eliminate spark retard (in order to maintain combustion and minimum engine speed). As another example, flow blockages or plugs, may limit airflow increases. As still another example, variable valve unit degradation may limit or affect valve timing adjustments or positive overlap generation. As such, diagnostic routines may be used to detect such system overrides and the corresponding effects on exhaust gas temperature and/or catalyst light off during at least the first 15 seconds of vehicle operation from a cold start under selected conditions, such as standard air temperatures near 70 degrees F. and barometric pressure near sea level.

[0013] Continuing with FIG. 1, accelerator pedal 130 is shown communicating with the driver's foot 132. Accelerator pedal position (PP) is measured by pedal position sensor 134 and sent to controller 12.

[0014] In an alternative embodiment, where an electronically controlled throttle is not used, an air bypass valve (not shown) can be installed to allow a controlled amount of air to bypass throttle plate 62. In this alternative embodiment, the air bypass valve (not shown) receives a control signal (not shown) from controller 12. In another alternative
embodiment, where a mass air flow sensor is not used, inducted mass air flow may be determined using a variety of computational methods.

[0015] In an exemplary embodiment, electronic engine controller 12 may further include an on-board diagnostic (OBD) system (not shown). The OBD system may detect operating component degradation through various diagnostic routines. In some instances, if a routine detects degradation, the routine may set a diagnostic trouble code (alternatively referred to as a service code) in the electronic engine controller. Many routines within the on-board diagnostics system may detect emission related degradations in a range of operating condition of the engine.

[0016] One embodiment advantageously implements a routine to monitor hydrocarbon emissions during various operating conditions, such as during engine cold start conditions. Such a monitoring routine may detect, whether various cold start emissions reduction (CSER) engine control strategies are effective in heating a catalyst to a desired light-off temperature and reducing hydrocarbon emissions. Specifically, the routine may determine if particular ignition spark retard and/or elevated idle speed strategies are effectively reducing cold start emissions. However, it should be appreciated that in some embodiments the routine may demonstrate the effectiveness of other CSER control strategies as well.

[0017] Referring to FIG. 2, an exemplary cold start emissions reduction (CSER) monitoring routine is shown. Specifically, routine 200 monitors catalyst temperature via a catalyst temperature warm-up index calculation. Furthermore the monitoring system may make a degradation determination regarding CSER related components based on whether actual emissions exceed a predetermined threshold when compared to reference emissions standards. The determined degradation may result in setting a CSER service code in the electronic engine controller. Additionally, in some embodiments the degradation determination may result in a change in operating parameter.

[0018] Referring back to FIG. 2, the routine begins at 210 where it is determined if the engine is in a start condition. In one embodiment, the CSER monitor routine may be configured to monitor emissions conditions for fifteen seconds following the start of the engine. Thus, the determination made at 210 may judge whether or not fifteen seconds have elapsed since the start of the engine. In some embodiments, the CSER monitor routine may further be limited to running only when the engine is started and the transmission is in a neutral position. As such, the engine may be judged to be in a start condition only when the transmission is in neutral and less than fifteen seconds have elapsed since the start of the engine.

[0019] It should be appreciated that in some embodiment, the CSER monitor routine may run for a desired longer or shorter amount of time, and/or may run during driving conditions as well.

[0020] Continuing with 210, if it is determined that the engine is not in a start condition, the routine ends, otherwise the routine moves to 220. In the illustrated embodiment, the routine may be configured to make diagnostic calculations at predetermined intervals during the CSER monitoring time period, for example, a calculation cycle may be carried out every one hundred milliseconds. In some embodiments, the diagnostic interval may be adjusted to desired longer or shorter lengths based on a desired diagnostic resolution.

[0021] Continuing with 220, if it is determined that the predetermined amount of time has not elapsed, the routine loops until it is determined that the predetermined amount of time has elapsed. Once the predetermined amount of time has elapsed the routine moves to 230.

[0022] At 230, the routine may calculate a reference catalyst temperature estimate (ext_cmd_wavg_ref). The reference catalyst temperature estimate may represent the temperature of the catalyst based on performance as if there are no hardware problems or unintended software algorithms. In other words, the reference catalyst temperature estimate may represent the temperature of the catalyst during fully functioning conditions. The reference catalyst temperature estimate may be calculated from several operating parameters including, a desired idle rpm (dsdpm) which may be increased during CSER conditions to heat the catalyst; an estimated airflow (am_ref) based on the above desired engine speed (dsdrpm (am_ref)); and the spark timing (spk_lold_cld). In some embodiments the airflow estimation may be made based on a subset of an idle speed control open loop airflow calculation. Further, the reference temperature may be a required temperature needed to achieve a given emissions level for the current engine starting conditions, which may include engine coolant temperature, barometric pressure, air temperature, or combinations thereof. As such, the reference temperature may be a function of these and other parameters.

[0023] Once the reference catalyst temperature estimate has been calculated the routine moves to 240, where the current catalyst temperature estimate (ext_cmd_wavg) may be calculated. The current catalyst temperature estimate may be calculated from several measured or estimated operating parameters including, engine speed (N); spark estimate (saltot); and the observed airmeter estimate (load). In some embodiments, the current catalyst temperature estimate calculation may represent the actual temperature of the catalyst during a start condition of the engine.

[0024] It should be appreciated that the above described input operating parameters are purely exemplary, and in some embodiments other operating parameters may be utilized as inputs for measurements, derivations, and calculations of the exemplary routine.

[0025] Next at 250, the delta reference catalyst temperature estimate (Delta_Ref) may be made based on the change in reference temperature estimation from the beginning of a calculation cycle to the end of a calculation cycle. The delta reference catalyst temperature estimate may indicate the expected catalyst temperature change according to CSER control strategies. Specifically, the delta reference catalyst temperature estimate (Delta_Ref) may be calculated by subtracting the reference catalyst temperature estimate (ext_cmd_wavg_ref(beg)) calculated at the beginning of the calculation cycle from the reference catalyst temperature estimate (ext_cmd_wavg_ref(end)) calculated at the end of the calculation cycle.

[0026] Next at 260, the delta current catalyst temperature estimate (Delta_CMD) may be made based on the change in actual temperature estimation from the beginning of a calculation cycle to the end of a calculation cycle. The delta current catalyst temperature estimate may indicate the actual catalyst temperature change according to CSER control strategies. Specifically, the delta current catalyst temperature estimate (Delta_CMD) may be calculated by subtracting the current catalyst temperature estimate (ext_cmd_wavg_ref
(beg)) calculated at the beginning of the calculation cycle from the current catalyst temperature estimate (ext_cmd_wavg_ref(end)) calculated at the end of the calculation cycle.

[0027] Now referring to 270, the temperature warm-up index calculation may be made. A catalyst delta ratio (CDR) may be calculated by subtracting the delta current catalyst temperature estimate (Delta_CMD) from the delta reference catalyst temperature estimate (Delta_Ref). The difference of two estimates may be further divided by the delta reference catalyst temperature estimate (Delta_Ref) to produce the catalyst delta ratio. In some embodiments, the routine may include a normalization step which may create a catalyst delta ratio ranging from zero to one. Moreover, the normalized catalyst delta ratio calculation may indicate the percent of heating loss in the catalyst between the reference estimate and the actual estimate. For example, a catalyst delta ratio of ‘0.5’ may indicate that the catalytic temperature may have achieved only 50% of expected temperature value.

[0028] Continuing to 280, the calculated catalyst delta ratio can be compared to a predetermined threshold value. In the illustrated embodiment, the threshold value may correspond to one and a half times the expected emission value. Further, the degradation threshold may be determined based on a function of the engine coolant temperature at start. Thus, by plotting the catalyst delta ratio against the engine coolant temperature at start, it can be determined whether the catalyst delta ratio is above the threshold. If it is determined that the catalyst delta ratio is below the threshold value the routine loops back to the beginning of the routine for another cycle of calculations. If it is determined that the catalyst delta ratio is above the threshold, the routine moves to 290.

[0029] At 290, a service code may be set in the electronic engine controller. In some embodiments, the service code may be related to CSER, for example, the code may state “cold start engine exhaust temperature out of range”. Furthermore, in some embodiments, setting the service code may result in a “check engine” light to illuminate and/or other diagnostic routines to be initiated. Once the service code has been set, the routine ends.

[0030] The routine shown in FIG. 2 is just one example of a cold start emission reduction engine monitoring strategy. In some embodiments the routine may include more or less diagnostic modes than shown in FIG. 2.

[0031] It should also be appreciated that the example control/diagnostic routines described herein are dependant upon the configuration of the vehicle control system. Note that the example control and estimation routines included herein can be used with various engine and/or vehicle propulsion system configurations. The specific routines described herein may represent one or more of any number of processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various steps, acts, or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Likewise, the order of processing is not necessarily required to achieve the features and advantages of the example embodiments described herein, but is provided for ease of illustration and description. One or more of the illustrated steps, acts, or functions may be repeatedly performed depending on the particular strategy being used.

Further, the described steps may graphically represent code to be programmed into the computer readable storage medium in controller 12.

[0032] FIG. 3 shows an exemplary graph of catalyst delta ratio calculations plotted against the engine coolant temperature at start during a cold start condition according to the above described monitoring routine. The example graph shows results compiled over multiple tests. As shown, the plots determined by the monitoring routine to be above the threshold, are plotted as circles and may be judged to be degradations. Furthermore, the plots determined by the monitoring routine to be below the threshold, are plotted as squares and may be judged to fall within acceptable operating conditions.

[0033] The results illustrated in the example graph demonstrate the accurate and robust nature of the monitoring routine. For example, the appropriation of the threshold value within the routine may allow for clear determinations of whether or not a CSER engine strategy may be functioning effectively. It should be noted that in embodiments where engines are equipped with electronic throttle control, degradation determinations may occur less frequently because the electronically controlled throttle may have a large dynamic range of operation, resulting in more airflow and faster catalyst temperature increase.

[0034] Further, it will be appreciated that the configurations and routines disclosed herein are exemplary in nature, and that these specific embodiments are not to be considered in a limiting sense, because numerous variations are possible. For example, the above technology can be applied to V-6, I-4, I-6, V-12, opposed 4, and other engine types.

[0035] The subject matter of the present disclosure includes all novel and nonobvious combinations and sub-combinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

[0036] The following claims particularly point out certain combinations and sub-combinations regarded as novel and nonobvious. These claims may refer to “an” element or “a first” element or the equivalent thereof. Such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and sub-combinations of the disclosed features, functions, elements, and/or properties may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

1. A method for controlling a vehicle having an engine, the engine having an exhaust with an emission control device, comprising:
   - during an engine start, at least temporarily adjusting an operating parameter of the engine to increase exhaust mass flow or temperature when needed to more rapidly heat the emission control device;
   - estimating temperature of the emission control device during said engine start; and
   - comparing said estimated temperature to a reference catalyst temperature required to achieve an emission threshold.

2. The method of claim 1 wherein said reference catalyst temperature is based on a desired engine idle speed.
3. The method of claim 2 wherein said reference catalyst temperature is further based on an estimated airflow based on the desired engine speed.

4. The method of claim 3 wherein said reference catalyst temperature is based on an expected spark value for current conditions.

5. The method of claim 4 wherein actual spark timing is adjusted based on fuel quality.

6. The method of claim 1 wherein said emission threshold is based on engine coolant temperature at start.

7. A method for controlling a vehicle having an engine, the engine having an exhaust with an emission control device, comprising:
   during an engine start, at least temporarily adjusting at least engine airflow and spark timing to increase exhaust mass flow and temperature when needed to more rapidly heat the emission control device;
   overriding at least one of said engine airflow and spark timing adjustments to compensate for an operating condition; and
   setting a diagnostic indication when said override has caused temperature of the emission control device to be lower than desired to meet an emission level.

8. A method for controlling a vehicle having an engine, the engine having an exhaust with an emission control device, comprising:
   during an engine cold start, at least temporarily adjusting at least engine airflow and spark timing to increase exhaust mass flow and temperature when needed to more rapidly heat the emission control device;
   overriding at least one of said engine airflow and spark timing adjustments to compensate for fuel quality effects on combustion; and
   setting a diagnostic indication when said override has caused temperature of the emission control device to be lower than desired to meet an emission level.

9. The method of claim 8 wherein said override compensates for hesitation fuel.

10. The method of claim 8 wherein said override compensates for engine speed falling below a selected engine speed profile during said start.

11. The method of claim 8 wherein said diagnostic indication sets a code in a controller of the vehicle.

12. The method of claim 8 wherein said emission level is based on engine coolant temperature at start.

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