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(54) **Sensor activation monitor**

(57) The present invention relates to a method and on-board diagnostic system for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine. It is determined if entry conditions are met. Changes in an electrical signal output by the sensor are detected. A maximum value of the signal is detected. The detected signal changes are accumulated. It is determined if the accumulation is above a predetermined threshold within a first time period following start-up. It is determined if the maximum value is above a predetermined reference value within a second time period following start-up. If at least one of the determinations is positive, a functioning sensor is indicated and if both determinations are negative, a malfunctioning sensor is indicated.

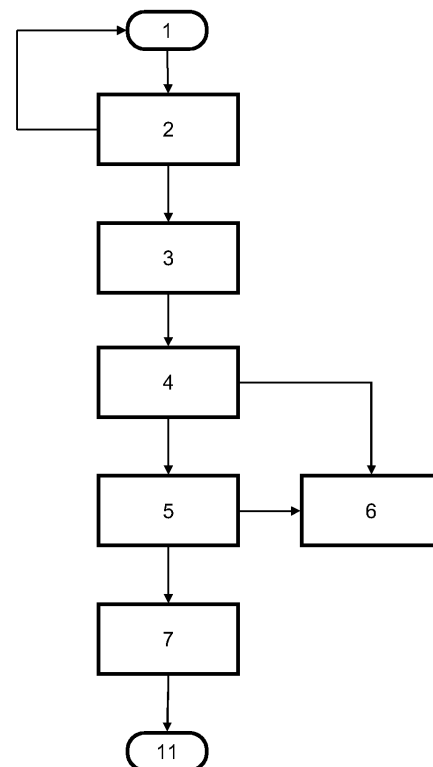


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention is related to a method for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine in accordance with the preamble of claim 1.

[0002] The present invention further relates to an on-board diagnostic system for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine in accordance with the preamble of claim 6.

BACKGROUND OF THE INVENTION

[0003] Emission control is becoming an increasingly important issue in automotive vehicles having internal combustion engines. Sensors in an associated exhaust after treatment system are used to verify proper operation of the exhaust after treatment system as well as providing input to engine management systems, for operating the associated engine in an appropriate way to reduce emissions there from. One such sensor commonly used is the so called binary oxygen sensor.

[0004] A binary oxygen sensor must have a certain temperature to work correctly. An aged or malfunctioning sensor may not be timely activated after engine start, but possibly activated after a longer time period than normal, causing unwanted emissions. The binary oxygen sensor may also comprise a sensor heater, used to heat the sensor in order to bring it to its operating temperature faster. In the same way, an aged or malfunctioning sensor heater may cause unwanted emissions.

[0005] Some previous attempts to monitor oxygen sensors in exhaust after treatment systems have been based on the utilization of non intrusive monitoring of the sensor output voltage and summing voltage trace segments over a specified period, referencing this data against a threshold to determine if the sensor meets its performance requirement specifications.

[0006] One such previous attempt is illustrated by US 5 801 295, which describes an on-board diagnostic test for a heated exhaust gas oxygen sensor which includes sensing the output of the oxygen sensor and summing the output over a specified period to determine the length of the trace of the sensor voltage versus time. Such length over a given time period indicates the activity of the sensor. This data is compared to a threshold to determine if the exhaust gas oxygen sensor meets certain performance requirements.

[0007] However, US 5 801 295 provides monitoring of a heated exhaust gas oxygen sensor during normal operating conditions, i.e. when the engine is at operating temperature and during favorable operation thereof. Fre-

quency of switching is used as an indication of the sensitivity, robustness and age of the sensor. US 5 801 295 provides no monitoring of timely sensor activation following engine start.

SUMMARY OF THE INVENTION

[0008] An object of the present invention is to provide an improved method for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine, through which method a malfunctioning sensor may be detected such that the risk of unwanted emissions may be eliminated or at least reduced.

[0009] According to a first aspect of the present invention this object is achieved in accordance with the characterizing portion of claim 1, which specifies that it comprises the steps of: determining if entry conditions are met; detecting changes in an electrical signal output by the sensor; detecting a maximum value of the signal; accumulating the detected signal changes; determining if the accumulation is above a predetermined threshold within a first time period following start-up; determining if the maximum value is above a predetermined reference value within a second time period following start-up; if at least one of the determinations are positive, indicating a functioning sensor and if both determinations are negative, indicating a malfunctioning sensor.

[0010] A second object of the present invention is to provide an improved on-board diagnostic system for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine, through which method a malfunctioning sensor may be detected such that the risk of unwanted emissions may be eliminated or at least reduced.

[0011] According to a second aspect of the present invention this object is achieved in accordance with the characterizing portion of claim 6, which specifies that that it comprises: means for determining if entry conditions are met; means for detecting changes in an electrical signal output by the sensor; means for detecting a maximum value of the signal; means for accumulating the detected signal changes; means for determining if the accumulation is above a predetermined threshold within a first time period following start-up; means for determining if the maximum value is above a predetermined reference value within a second time period following start-up; means for, if at least one of the determinations are positive, indicating a functioning sensor and if both determinations are negative, indicating a malfunctioning sensor.

[0012] Further embodiments are listed in the dependent claims.

[0013] It will be appreciated that features of the invention are susceptible to being combined in any combina-

tion without departing from the scope of the invention as defined by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] By way of example only, embodiments of the present invention will now be described with reference to the accompanying drawings wherein:

Figure 1 is a flow chart illustrating a method in accordance with a first embodiment of the present invention;

Figure 2 is a flow chart illustrating a method in accordance with a second embodiment of the present invention.

[0015] Still other objects and features of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein. The same reference numerals will be used for illustrating corresponding features in the different drawings.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] In a preferred first embodiment of the present invention, as illustrated by the flow chart of FIG. 1, the method starts at block 1.

[0017] For verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine it is firstly determined in block 2 if entry conditions are met. As an entry condition is performed at least one of a determination that: an electric sensor heater is energized; the ambient temperature is above a certain level; the ambient atmospheric pressure is above a certain level, the engine number of revolutions is above a certain level; the coolant temperature of the engine is within a certain range; the battery voltage is above a certain level; fuel is not cut-off. If entry conditions are met the method proceeds to block 3, if not the method loops back to the start block 1.

[0018] In block 3, changes in an electrical signal output by the sensor are detected, and a maximum value of the signal is detected. Furthermore the detected signal changes are accumulated. Thereafter the method proceeds to block 4.

[0019] In block 4 it is determined if the accumulation

is above a predetermined threshold within a first time period following start-up, and in block 5 it is determined if the maximum value is above a predetermined reference value within a second time period following start-up. If at least one of these determinations 4, 5 is positive, a functioning sensor is indicated in block 6 and if both determinations are negative, a malfunctioning sensor is indicated in block 7. Thereafter the method is terminated by end block 11.

[0020] In a further embodiment, as illustrated by the flow chart of FIG. 2, if both of the above determinations are negative the method is continued from block 7 to block 8 and the determinations are repeated for a respective third and fourth time period following start-up, which third and fourth time period are longer than the corresponding first and second time periods. If at least one of the repeated determinations is positive, a functioning sensor having a malfunctioning sensor heater is indicated in block 9. This as a positive determination will indicate that the sensor is responding although after a longer time period as heating thereof without a functioning heater will require more time. Thus, it is hereby possible to discriminate which of sensor and heater that is malfunctioning. If both additional determinations are negative, a malfunctioning sensor is indicated in block 10. Thereafter the method is terminated by end block 11.

[0021] The first, second, third and fourth time periods may be chosen as respective predetermined time periods or alternatively be determined as a function of an accumulation of an amount of an engine parameter. Examples of such accumulations that may be used for establishing the time periods are: an amount of engine revolutions; an amount of airflow; an amount of load; an amount of lambda; an amount of temperature; an amount of exhaust gas energy. The third and fourth time period should be longer than the corresponding first and second time periods in order to allow a determination of a functioning sensor having a malfunctioning sensor heater, through the sensor responding after a longer time period than if properly heated.

[0022] The above method is preferably implemented in an on-board diagnostic system for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine.

[0023] It is envisaged that such an on-board diagnostic system comprises means for determining if entry conditions are met. Integral to the means for determining if entry conditions are met are provided means for performing as an entry condition at least one of a determination that: an electric sensor heater is energized; the ambient temperature is above a certain level; the ambient atmospheric pressure is above a certain level, the engine number of revolutions is above a certain level; the coolant temperature of the engine is within a certain range; the battery voltage is above a certain level; fuel is not cut-off.

[0024] Further are provided means for detecting

changes in an electrical signal output by the sensor; means for detecting a maximum value of the signal and means for accumulating the detected signal changes.

[0025] Additional means are provided for determining if the accumulation is above a predetermined threshold within a first time period following start-up, and for determining if the maximum value is above a predetermined reference value within a second time period following start-up.

[0026] Yet further means are provided for, if at least one of the determinations are positive, indicating a functioning sensor and if both determinations are negative, indicating a malfunctioning sensor.

[0027] In a further embodiment of the on-board diagnostic system are provided means for, if both determinations are negative, repeating the determinations for a respective third and fourth time period following start-up, which third and fourth time period are longer than the corresponding first and second time periods, and means for, if at least one of the repeated determinations are positive, indicating a functioning sensor having a malfunctioning sensor heater and if both additional determinations are negative, indicating a malfunctioning sensor. A positive determination will indicate that the sensor is responding although after a longer time period as heating thereof without a functioning heater will require more time. Thus, it is hereby possible to discriminate which of sensor and heater that is malfunctioning.

[0028] At least one of the first, second, third and fourth time periods are respective predetermined time periods or alternatively are functions of an accumulation of an amount of an engine parameter. Examples of such accumulations that may be used for establishing the time periods are: an amount of engine revolutions; an amount of airflow; an amount of load; an amount of lambda; an amount of temperature; an amount of exhaust gas energy. The third and fourth time period should be longer than the corresponding first and second time periods in order to allow a determination of a functioning sensor having a malfunctioning sensor heater, through the sensor responding after a longer time period than if properly heated.

[0029] In accordance with the present invention is also envisaged an automotive vehicle, which comprises an on-board diagnostic system as described above.

[0030] Modifications to embodiments of the invention described in the foregoing are possible without departing from the scope of the invention as defined by the accompanying claims.

[0031] Expressions such as "including", "comprising", "incorporating", "consisting of", "have", "is" used to describe and claim the present invention are intended to be construed in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural and vice versa.

[0032] Numerals included within parentheses in the accompanying claims are intended to assist understand-

ing of the claims and should not be construed in any way to limit subject matter claimed by these claims.

[0033] Thus, while there have been shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art. For example, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

Claims

1. Method for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine, **characterised in that** it comprises the steps of:

determining if entry conditions are met;
detecting changes in an electrical signal output by the sensor;
detecting a maximum value of the signal;
accumulating the detected signal changes;
determining if the accumulation is above a predetermined threshold within a first time period following start-up;
determining if the maximum value is above a predetermined reference value within a second time period following start-up;
if at least one of the determinations are positive, indicating a functioning sensor and if both determinations are negative, indicating a malfunctioning sensor.

2. Method according to claim 1, **characterised in that** it further comprises the steps of:

if both determinations are negative, repeating the determinations for a respective third and fourth time period following start-up;
if at least one of the repeated determinations are positive, indicating a functioning sensor having a malfunctioning sensor heater and if both additional determinations are negative, indicating

a malfunctioning sensor.

3. Method according to claim 2, **characterised in that** at least one of the first, second, third and fourth time periods are chosen as respective predetermined time periods. 5

4. Method according to any one of claims 2 to 3, **characterised in that** at least one of the first, second, third and fourth time periods are determined as a function of an accumulation of an amount of an engine parameter. 10

5. Method according to any one of claims 1 to 4, **characterised in that** it further comprises the steps of: 15

in the step of determining if entry conditions are met, performing as an entry condition at least one of a determination that: an electric sensor heater is energized; the ambient temperature is above a certain level; the ambient atmospheric pressure is above a certain level, the engine number of revolutions is above a certain level; the coolant temperature of the engine is within a certain range; the battery voltage is above a certain level; fuel is not cut-off. 20 25

6. On-board diagnostic system for verifying timely activation of a heated exhaust gas binary oxygen sensor arranged in an exhaust after-treatment system of a vehicle following start-up of an associated internal combustion engine, **characterised in that** it comprises: 30

means for determining if entry conditions are met; 35

means for detecting changes in an electrical signal output by the sensor;

means for detecting a maximum value of the signal; 40

means for accumulating the detected signal changes;

means for determining if the accumulation is above a predetermined threshold within a first time period following start-up; 45

means for determining if the maximum value is above a predetermined reference value within a second time period following start-up;

means for, if at least one of the determinations are positive, indicating a functioning sensor and if both determinations are negative, indicating a malfunctioning sensor. 50

7. On-board diagnostic system according to claim 6, **characterised in that** it further comprises: 55

means for, if both determinations are negative, repeating the determinations for a respective

third and fourth time period following start-up; means for, if at least one of the repeated determinations are positive, indicating a functioning sensor having a malfunctioning sensor heater and if both additional determinations are negative, indicating a malfunctioning sensor.

8. On-board diagnostic system according to claim 7, **characterised in that** at least one of the first, second, third and fourth time periods are respective predetermined time periods.

9. On-board diagnostic system according to any one of claims 7 to 8, **characterised in that** at least one of the first, second, third and fourth time periods are functions of an accumulation of an amount of an engine parameter.

10. On-board diagnostic system according to any one of claims 6 to 9, **characterised in that** it further comprises:

integral to the means for determining if entry conditions are met, means for performing as an entry condition at least one of a determination that: an electric sensor heater is energized; the ambient temperature is above a certain level; the ambient atmospheric pressure is above a certain level, the engine number of revolutions is above a certain level; the coolant temperature of the engine is within a certain range; the battery voltage is above a certain level; fuel is not cut-off.

11. An automotive vehicle **characterised in that** it comprises an on-board diagnostic system according to any one of claims 6 to 10.

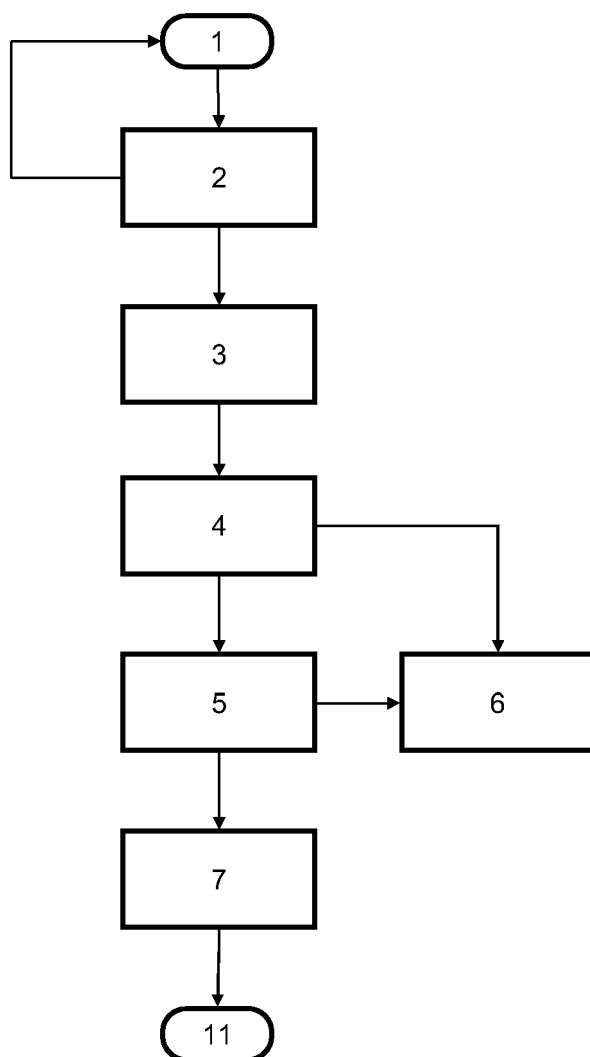


Fig. 1

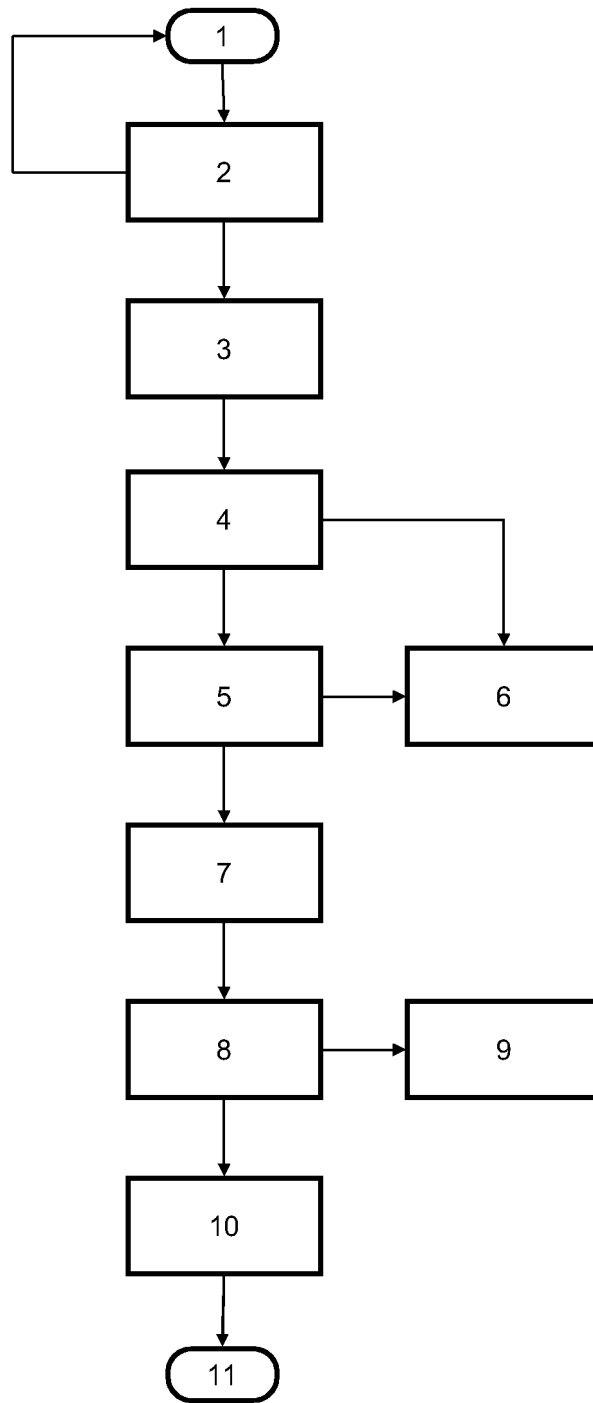


Fig. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 07 10 2404

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Place of search Munich		Date of completion of the search 25 July 2007	Examiner Wettemann, Mark
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EUROPEAN SEARCH REPORT

Application Number
EP 07 10 2404

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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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