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(54) **Title:** AN ECM TO DETERMINE AIR-FUEL RATIO OF AN ENGINE

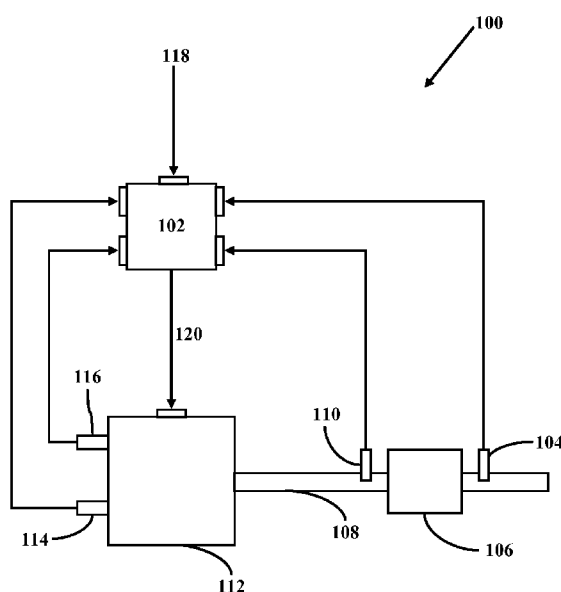


FIG. 1

(57) **Abstract:** The various embodiments herein provide an Electronic Control Module (ECM) 102 to determine Air-Fuel (A/F) ratio of an engine 112. The ECM 102 is adapted to receive signals relating to engine operating parameters comprising at least one exhaust temperature, an engine speed, an engine load, an ignition angle and a relative fuel mass. The ECM 102 then accesses a global model, at least one weighing function and at least one data map from a memory element to determine the A/F ratio. The global model comprises at least two local models. The weighing function for each of the local model is used. The at least one data map comprises empirically derived values corresponding to the engine operating parameters. The ECM 102 processes the received signals of the engine operating parameters through the global model, the at least one weighing function and the data map and determines/predicts the A/F ratio.



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5 **COMPLETE SPECIFICATION****TITLE****AN ECM TO DETERMINE AIR-FUEL RATIO OF AN ENGINE**

10 The following specification describes and ascertains the nature of this invention and the manner in which it is to be performed:

Field of the invention:

15 The present disclosure relates to method and device to determine air-fuel ratio of an internal combustion engine.

Background of the invention:

20 According to a patent literature WO2001000978, a method is disclosed for using a computer for determining an air-to-fuel (A/F) ratio of an internal combustion engine in which information characteristic of the engine relating the A/F ratio of the engine, the exhaust gas temperature of the engine, the speed of the engine and a parameter related to the load of the engine is previously stored in the computer. The method comprises the steps of: measuring the exhaust gas temperature of the engine; measuring the speed of the engine; measuring the parameter related to the load of the engine;
25 computing the A/F ratio based on the previously stored information, the measured exhaust gas temperature, the measured speed and the measured parameter related to the load; and providing an output signal representative of the A/F ratio.

Brief description of the accompanying drawings:

An embodiment of the disclosure is described with reference to the following accompanying drawings,

Fig. 1 illustrates a block diagram of an ECM to determine A/F ratio of an engine, according to an embodiment of the present disclosure, and

5 Fig. 2 illustrates a flow diagram of a method for determining A/F ratio of an engine, according to an embodiment of the present disclosure.

Detailed description of the embodiments:

10 Fig. 1 illustrates a block diagram of an ECM to determine A/F ratio of an engine, according to an embodiment of the present disclosure. The Electronic Control Module (ECM) 102 is provided to determine air-fuel ratio of an Internal Combustion Engine (ICE) 112. The ECM of the present disclosure aims to estimate/determine A/F ratio without using a lambda sensor. The ECM 102 is adapted to receive signals relating to plurality of engine operating parameters comprising at least one exhaust temperature, 15 an engine speed, an engine load, an ignition angle and a relative fuel mass. The ECM 102 then accesses a global model, at least one weighing function and at least one data map from a memory element (not shown) to determine the A/F ratio. The global model comprises at least two local models. In other words, the global model is a combination of at least two independent local models and corresponding weighing functions. The at least one data map comprises empirically derived values (e.g. coefficients) corresponding to the engine operating parameters. The ECM 102 processes the received signals of the engine operating parameters through the global model, a corresponding weighing function and at least one data map and determines/predicts/forecasts the A/F ratio. 20 A real time signal of the engine operating parameters is used for determining the A/F ratio. 25

The global model can be a neural network model such as a Local Linear Model Tree (LoLiMoT), a Local Polynomial Model Tree (POLYMoT), and a combination of LoLiMoT and POLYMoT. The development of the global model is explained in detail in the following paragraphs.

30 The set of engine operating parameters are selected during testing phase of the vehicle. During testing, a vehicle is run for different load conditions and values for different engine parameters are noted. A co-relation matrix is formed and those parameters which are found to have more influence on lambda value are selected. The operating

parameters thus selected comprises but not limited to the exhaust gas temperature, the engine speed, the engine load, the ignition angle and the relative fuel mass.

The ECM 102 is also configurable to take further at least one engine operating parameters selected from a group comprising a throttle angle, a desired A/F ratio, a relative air mass/charge, an engine temperature, a manifold air pressure, a coolant temperature, an exhaust gas pressure and a spark energy. Other operating parameters are allowed to be considered and taken and improve the accuracy further by the ECM 102 at a time. The influence of the selected operating parameters on A/F ratio is known or computed or plotted. Based on the known/ expected response, the global model to determine the A/F ratio is created.

According to an embodiment of the present disclosure, the ECM 102 determines the A/F ratio at an upstream (also referred as pre-cat position) of a catalytic converter 106. The ECM 102 uses at least one of further engine operating parameters selected from a group comprising the relative air charge, the engine temperature, the manifold air pressure, the coolant temperature, the exhaust gas pressure and the spark energy. The term upstream and pre-cat will be used interchangeably hereinafter.

According to yet another embodiment of the present disclosure, the ECM 102 determines the A/F ratio at an downstream (also referred as post-cat) of the catalytic converter 106 by using at least one of further engine operating parameters selected from a group comprising the relative air charge, the engine temperature, the manifold air pressure, the coolant temperature, the exhaust gas pressure, the spark energy, an A/F ratio at an upstream end of the catalytic converter 106, a catalyst efficiency, a rate of change of temperature due to chemical reactions at the catalyst. The A/F ratio is selected from a group comprising an A/F ratio determined without lambda sensor 104 and an A/F ratio measured using a lambda sensor 104. The term downstream and post-cat will be used interchangeably.

The global model is pre-stored in a memory element associated with the ECM 102. The global model establishes a relationship between the plurality of engine operating parameters and the A/F ratio.

As described earlier, the global model is selected from a group comprising a linear model and a non-linear model. For example, the global model is selected from a group comprising a Local Linear Model Tree (LoLiMoT), a Local Polynomial Model Tree (POLYMoT), and a combination of LoLiMoT and POLYMoT. The global model is also allowed to use single local model with a corresponding weighing function. Further, the

global model is also allowed to use just a regression model as well, i.e. only one local model and hence a corresponding weighing function is used.

The global model is processed based on a sum of products of weighted local models. The global model is first built/developed offline. The process of developing global
5 model involves selecting a single model approximately matching the required response data or curve of the lambda sensor. A weighing function is constructed and the first single model is fit using least square estimation process. The weighing function validates the selected single model with respect to the required response curve which signifies the region where the single model is valid. The single model is further checked for different partition techniques. An error in the partition techniques of the selected single
10 model and the required response curve is calculated with the help of the weighing function. The partition technique providing least error (or the best partition technique) is selected and taken forward for further processing. The single model is split/ divided into at least two local models using the partition technique providing least error. The single
15 model undergoes a test based on a convergence factor once split.

The convergence factor is at least one selected from a group comprising number of iterations, the error tolerance, complexity of the model and the like. The iteration of the offline model building continues till the test of convergence is satisfied/ fulfilled. The global model is built using plurality of engine operating parameters and comprises at
20 least one or combination of a Two-Dimensional (2D), Three-Dimensional (3D) or multi dimensional input space.

The present disclosure performs the offline model building using at least one selected from a group comprising a linear model and a polynomial model. Implementing a polynomial model provides a more flexible model where an order of the polynomial is selected in a manner to be fit to each part of the input space. The use of polynomial
25 model provides a mixture of first, second, third and multi-order polynomials.

According to an embodiment of the present disclosure, a device or means to determine air-fuel equivalence ratio (lambda value) is provided. Once the A/F ratio is calculated, the ECM 102 estimates the A/F ratio equivalence ratio (lambda) based on a stoichiometric A/F ratio. The ECM 102 divides the determined A/F ratio by the stoichiometric
30 A/F ratio. The device is the ECM 102.

According to an embodiment of the present disclosure, a system 100 to determine Air-Fuel (A/F) ratio of an Internal Combustion Engine (ICE) 112 is provided. The system 100 comprises means/sensors to measure engine operating parameters comprising an

exhaust temperature, an engine speed, an engine load, an ignition angle and a relative fuel mass. The system 100 further comprises the ECM 102 in communication with the means to measure the engine operating parameters. The ECM 102 determines the A/F ratio which is used to control or enhance the combustion process in the engine 112.

5 The at least one device to provide input signals for respective operating parameters is selected from a group comprising a engine speed sensor 116, a Manifold Absolute Pressure (MAP) sensor, a mass air flow sensor, a engine load sensor 118, at least one temperature sensor 110, an oxygen/lambda sensor 104, a relative fuel mass sensing means 114, a controller/ processor for selecting fuel injection quantity based on a map and the like.

10 According to an embodiment of the present disclosure, at least one temperature sensor 110 and a lambda sensor 104 is provided before and after a catalytic converter 106 in an exhaust path/line/pipe 108 in various combinations. The different combination of arranging the at least temperature sensor 110 and the lambda sensor 104 are possible for two-wheeler, three-wheeler, four-wheeler and other type of vehicles. The combinations comprises but not limited to a temperature sensor 110 at pre-cat and lambda sensor 104 at post-cat position, a lambda sensor 104 at pre-cat and temperature sensor 110 at post-cat location. In another combination a temperature sensor 110 at both pre-cat and post-cat positions are provided. The lambda sensor 104 is selected from a group comprising universal type and a two step type based on requirement.

20 The input signals from the temperature sensor 110 and other engine operating parameters are used and processed to determine the A/F ratio before the catalyst i.e. pre-cat position.

25 Based on the determined A/F ratio and other catalyst related parameters comprising catalyst efficiency, heat released due to chemical reactions at the catalyst and the like, an A/F ratio after the catalyst i.e. post-cat position is determined.

30 In the combination where a temperature sensor 110 before and a temperature sensor 110 after the catalyst are provided, the input signals from the two sensors along with the other appropriate engine operating parameters are used to determine the A/F ratio before and after the catalyst.

In the combination where a lambda sensor 104 before the catalytic converter 106 and a temperature sensor 110 after the catalytic converter 106 are provided, the lambda sen-

sensor 104 directly provides the A/F ratio, and the A/F ratio is used with the values of temperature sensor 110 and other suitable engine operating parameters to determine A/F ratio after the catalyst.

The ECM 102 controls/adjusts the ignition or combustion process through a control signal 120 for injectors, throttle and the like. The lambda or the A/F ratio determined from the model is used in the fuel mixture adaptation. The lambda controller will operate the engine always at $\lambda=1$. The deviation in the lambda that results in a deviation in the fuel mixture is corrected in the fuel path via mixture adaptation. The injection time is corrected in all operating modes and engine speed-load ranges.

Fig. 2 illustrates a flow diagram of a method for determining A/F ratio for the engine, according to an embodiment of the present disclosure. The step 202 comprises receiving a set of engine operating parameters comprising an exhaust gas temperature, an engine speed, an engine load, an ignition angle and a relative fuel mass from respective sensing means. The sensing means comprises but not limited to a temperature sensor 110 for the exhaust gas, speed sensor 116 for engine speed, Manifold Air Pressure (MAP) sensor and the like. The step 204 comprises accessing a global model comprising at least two local models, at least two weighing functions and at least one data map, from a memory element. The at least one data map comprises empirically derived values corresponding to said engine operating parameters. The step 206 comprises determining an A/F ratio based on the received set of engine operating parameters by processing the global model, the weighing function and the at least one data map.

The set of engine operating parameters further comprises at least one selected from a group comprising a throttle angle, a desired A/F ratio, a relative air charge, an engine temperature, manifold air pressure, coolant temperature, exhaust gas pressure and spark energy.

The sensing means are in communication with the ECM 102 through a wired or wireless connection. The real time input signals or measured/ calculated values are feature scaled/ normalized to bring all inputs values to a common range. The feature scaling is done as various engine operating parameters with different units and different types of values are used. The modified input values of the engine operating parameters are used to process the at least two local models and the corresponding weighing functions. While processing the value of the at least two local models, at least one data map is used to use various pre-stored coefficients or constants as per the respective

engine operating parameters. An output value of the each of the local models is calculated and stored in the memory element.

The method further comprises calculating a closeness of each local model to the required model using the at least two weighing function and values from the at least data map. The at least one data map is used for computing the corresponding weighing functions. The result provides a value (hereinafter referred as weight) indicating how well is the particular local model matches to the required/expected local model. The result is stored for each local model in the memory element. The weights for each local model is calculated and stored.

A total of all the weights is calculated and stored separately. Now the output value of each local model is multiplied with the respective weights. The multiplication provides the contribution of each local model in determining the A/F ratio. The sum/ addition of all the contributions from each of the local models determine the A/F ratio. The determined A/F ratio is said to be a forecasted or predicted or estimated A/F ratio.

The A/F ratio is determined in at least one site/location in an exhaust path 108 of a vehicle. In one embodiment the site is an upstream of the catalytic converter 106 i.e. before a catalyst of a catalytic converter 106. In another embodiment, the site is a downstream of the catalytic converter 106 i.e. after the catalyst of the catalytic converter 106. The A/F ratio is determined after the catalyst, assists in On-Board Diagnostics (OBD) of the catalyst.

In accordance to an embodiment, the global model is a regression model, and the A/F ratio is directly calculated by inserting the real time operating parameters values in the regression model.

According to an embodiment of the present disclosure, estimation of the A/F ratio is cost effective as no lambda sensor or oxygen sensor is used. The present disclosure is applicable to existing vehicles by using sensors inputs already existing in the vehicle. By adding a temperature sensor in the exhaust line, the estimation of A/F ratio is made more accurate in existing vehicles. The A/F ratio is also possible to be calculated for different fuels comprising gasoline, Compressed Natural Gas (CNG), Piped Natural Gas (PNG), ethanol, diesel, flex-fuel and the like.

It should be understood that embodiments explained in the description above are only illustrative and do not limit the scope of this invention. Many such embodiments and

other modifications and changes in the embodiment explained in the description are envisaged. The scope of the invention is only limited by the scope of the claims.

5 **We claim:**

1. A method for determining Air-Fuel (A/F) ratio of an Internal Combustion Engine (ICE) (112), the method comprising the steps of:
 - 10 a. receiving a set of engine operating parameters comprising an exhaust gas temperature, an engine speed, an engine load, an ignition angle and a relative fuel mass from respective sensing means;
 - b. accessing a global model comprising at least two local models, at least two weighing functions and at least one data map, from a memory element, said at least one data map comprises empirically derived values corresponding to said engine operating parameters;
 - 15 c. determining an A/F ratio based on the received set of engine operating parameters by processing said global model, said weighing function and said at least one data map.
2. The method as claimed in claim 1, wherein said set of engine operating parameters further comprises at least one selected from a group comprising a throttle angle, a desired A/F ratio, a relative air charge, an engine temperature, a manifold air pressure, a coolant temperature, a exhaust gas pressure and a spark energy.
- 20 3. The method as claimed in claim 1, wherein said set of engine operating parameters and said at least one data map are used for computing said at least two weighing functions and said at least two local models.
- 25 4. The method as claimed in claim 1, wherein determining said A/F ratio comprises multiplying an output of said at least two weighing functions by an output of respective local models, followed by adding said multiplied results.
- 30 5. The method as claimed in claim 1, wherein said A/F ratio is determined for at least one selected from a group comprising an upstream of a catalytic converter (106) and a downstream of a catalytic converter (106).

6. An Electronic Control Module (ECM) (102) to determine Air-Fuel (A/F) ratio of an Internal Combustion Engine (ICE) (112), said ECM (102) is adapted to:
receive a set of engine operating parameters comprising an exhaust gas temperature, an engine speed, an engine load, an ignition angle and a relative fuel mass from respective sensing means,
access a global model comprising at least two local models, a respective weighing function, and at least one data map, all from a memory element; said at least one data map comprises empirically derived values corresponding to a set of engine operating parameters and
determine an A/F ratio based on the received set of engine operating parameters using said global model, said weighing function and said at least one data map.
7. The ECM (102) as claimed in claim 6, wherein said A/F ratio is determined at an upstream of a catalytic converter (106) by using at least one of further engine operating parameters selected from a group comprising a throttle angle, a desired A/F ratio, a relative air charge, an engine temperature, a manifold air pressure, a coolant temperature, an exhaust gas pressure and a spark energy.
8. The ECM (102) as claimed in claim 6, wherein said A/F ratio is determined at a downstream of a catalytic converter (106) by using at least one of further engine operating parameters selected from a group comprising a relative air charge, an engine temperature, a manifold air pressure, a coolant temperature, an exhaust gas pressure, a spark energy, an A/F ratio corresponding to upstream of said catalytic converter (106), a catalyst efficiency, a rate of change of temperature due to chemical reactions at said catalyst converter (106).
9. The ECM (102) as claimed in claim 6, wherein at least one of said at least two local models are selected from a group comprising a linear model and a non-linear model.
10. The ECM (102) as claimed in claim 6, wherein said global model is selected from a group comprising a Local Linear Model Tree (LoLiMoT), a Local Polynomial Model Tree (POLYMoT), and a combination of LoLiMoT and POLYMoT.

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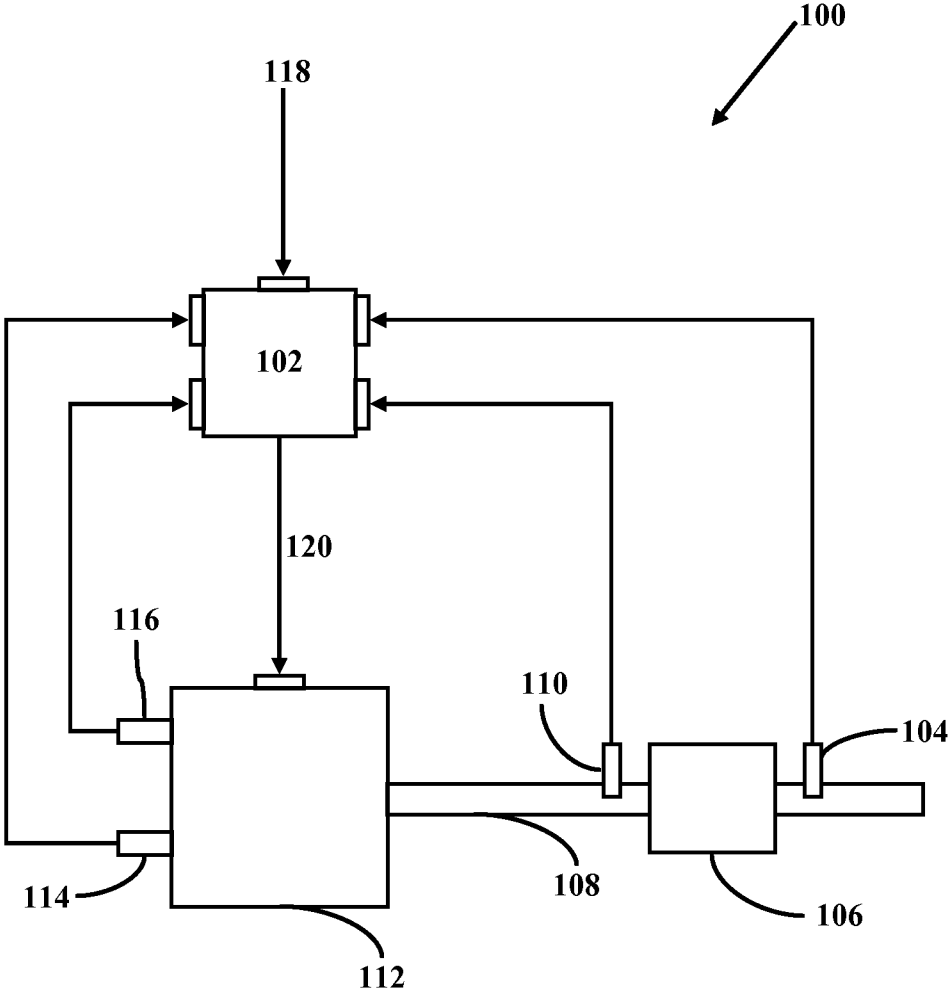


FIG. 1

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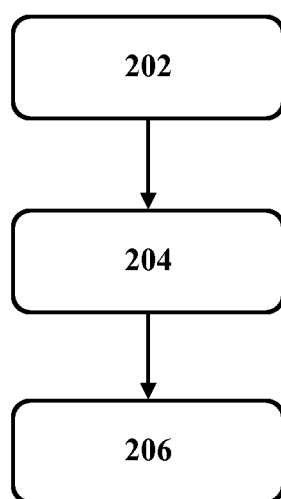


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/062171

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/14 F02D41/24
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 962 871 A2 (YAMAHA MOTOR CO LTD [JP]) 8 December 1999 (1999-12-08) paragraphs [0001], [0014] - [0015], [0019], [0025] - [0028], [0047] - [0048], [0051] - [0055], [0060] - [0061]; figures 1, 26 paragraphs [0076], [0111] - [0113], [0122]	1-10
Y	US 5 915 368 A (ISHIDA AKIRA [JP] ET AL) 29 June 1999 (1999-06-29) column 5, line 9 - line 16 column 24, line 30 - line 48 figures 2, 15 ----- -/--	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/062171

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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