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(54) Title: METHOD FOR FUEL INJECTION

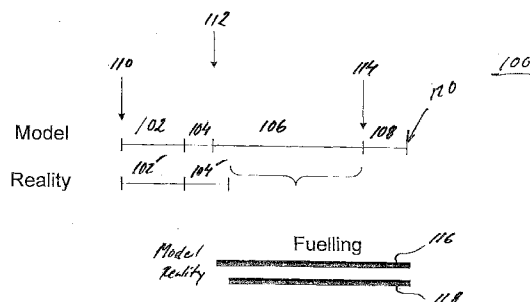


Fig. 1

(57) Abstract: xx The invention relates to a method for controlling fuel injection in an internal combustion engine provided in a vehicle, comprising the steps of: providing means for detecting start of combustion (SOC), determining an injection start delay period being a time period from an injection start pulse to SOC, comparing said determined injection start delay period with a stored reference value of said injection start delay period, establishing that a change of fuel has taken place if the difference between said determined injection start delay period and said reference value is greater than a predetermined value.

DESCRIPTION

Method for fuel injection

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TECHNICAL FIELD

The invention relates to a method for controlling fuel injection for an internal combustion engine according to the preamble of the independent claim.

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BACKGROUND OF THE INVENTION

Present regulatory conditions in the automotive market have led to an increasing demand to improve fuel economy and reduce emissions in present vehicles.

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These regulatory conditions must be balanced with the demands of a consumer for high performance and quick response for a vehicle.

20

A diesel engine has an efficiency of up to about 52% and is thus the best converter of fossil energy. Alternative fuels such as natural gas, hydrogen, propane and ethanol are starting to enter the market in the transportation sector. This is due to a number of factors, including lower price, reduced tailpipe emissions, and the security of the fuel supply in comparison to gasoline and diesel fuel. Furthermore, natural gas and propane reduce greenhouse gas emissions by about 25% compared to gasoline in automotive applications, while ethanol can reduce greenhouse gas emissions by about 30-65% depending on the process used to produce ethanol. Similarly, hydrogen fuelled vehicles can reduce greenhouse gas emissions by about 60-80%.

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Different kind of fuels may have different viscosity and energy content. In a vehicle accepting a plurality of different fuels, a so called flexifuel engine, there is a need to determine what kind of fuel is injected into a combustion chamber of the internal combustion engine. One way of determining the fuel is to use a fuel quality sensor. Said sensor may be of capacitive or dielectric nature which is well known in the art

or other types of sensors which directly or indirectly measures and determines the kind of fuel in the tank.

A disadvantage of using such sensors is that they are expensive.

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SUMMARY OF THE INVENTION

It is an object of the invention to provide a method for determining fuel without using an additional fuel sensor

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The objects are achieved by the features of the independent claims. The other claims and the description disclose advantageous embodiments of the invention.

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In a first aspect of the invention it is provided a method for controlling fuel injection in an internal combustion engine provided in a vehicle. Said method comprising the steps of: providing means for detecting start of combustion (SOC), determining an injection start delay period being a time period from an injection start pulse to SOC, comparing said determined injection start delay period with a stored reference value of said injection start delay period, establishing that a change of fuel has taken place if the difference between said determined injection start delay period and said reference value is greater than a predetermined value.

20

An advantage with this method is that it needs no additional hardware

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In an alternative embodiment according to the invention said method may be used while engine braking or coasting the vehicle. An advantage with this embodiment is that the drivability of the vehicle is affected very little for not saying nothing.

30

In still another embodiment of the present invention the kind of fuel may be determined by comparing the determined injection start delay period with stored values of injection start delay periods for different kind of fuels or blends of different fuels.

An advantage with this method is that it only requires additional software to an existing engine in order to determine which kind of fuel is to be injected to the engine.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The present invention together with the above-mentioned and other objects and advantages may best be understood from the following detailed description of the embodiment(s), but not restricted to the embodiments, wherein is shown
10 schematically:

Fig. 1 and 2 depicts schematically operating parameters of a fuel injector for an internal combustion engine.

15 DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

In the drawings, equal or similar elements are referred to by equal reference numerals. The drawings are merely schematic representations, not intended to portray specific parameters of the invention. Moreover, the drawings are intended
20 to depict only typical embodiments of the invention and therefore should not be considered as limiting the scope of the invention.

Fig. 1 depicts schematically operating parameters of a fuel injector for an internal combustion engine. A fuel injector is used for injecting fuel into a combustion
25 chamber of an internal combustion engine. A valve in a form of a needle may be operated electrically for starting and stopping said injection of fuel. Electrically operated fuel injectors have been known since over half a century and are well known for a person skilled in the art.

30 In figure 1 it is depicted different factors which may affect the timing of fuel into the combustion chamber and injected amount of said fuel. A logical pulse for starting fuel injection is denoted by 110. A delay in the fuel injector is denoted by 102, 104. Actual fuel injection is denoted by 106, 108.

Said delay in the fuel injector may be divided into an electric delay 102 and a hydraulic delay 104. The electric delay 102 is related to the time it takes from the logical pulse 110 until a coil in said injector for operating said needle to become active. This delay is typically constant for a specific injector and may differ very little between equal injectors. This delay may however be very different for different injectors (different brands and different models). This electrical delay is typically in the range of μs .

The hydraulic delay 104 is related to the compressible fuel, i.e., the time it takes to compress the particular fluid which is going to be injected into the combustion chamber. This delay is different for different fluids. This hydraulic delay is typically in the range of μs .

The electrical delay 102 plus the hydraulic delay may be denoted injection start delay period.

The actual fuel injection may be divided in two phases. A first phase 106 is characterized by said active logical pulse 110 for starting fuel injection is on. A second phase 108 is characterized by said active logical pulse 110 for starting fuel injection is off. The second phase 108 has to do with the electrical delay, which is related to the time it takes from a logical pulse 114 to stop fuel injection until a coil in said injector for operating said needle to become passive. The second phase is typically in the range of μs and the first phase is typically in the range of μs to ms .

In figure 1 fuelling is expected, according to a model, to take place between 112 and 120.

This model may more or less correspond to the reality, which may depend of the kind of fuel which is injected by said injector. In figure 1 a fictitious reality is compared with the model. Said fictitious reality has the same electrical delay since it is the same injector but a different hydraulic delay. This difference in hydraulic delay depends in the viscosity of the fuel. Different fuels and blends of different fuels have specific viscosities, which result in different hydraulic delays. Diesel,

biofuels and DME have different viscosities. Diesel of different qualities and different manufacturing methods may also differ in viscosity. Different fuels also have different energy content. Establishing the actual hydraulic delay may be an indication of the energy content of the particular fuel in the fuel tank which information in turn may be used for optimizing the performance of the engine by altering different parameters such as timing, amount of fuel, fuel pressure, charge pressure, amount of EGR, etc. In figure 1 the hydraulic delay is longer than the model, which means that the actual time period for fuel injection is shorter than the model.

The particular value of the hydraulic delay may be established according to different methods. One method is to close the injector to one cylinder of the engine. This may be done at any time, such at idle, coasting, engine braking or normal use of the engine. However, if one is closing one injector for one cylinder during idle or normal use of the engine said engine will start to vibrate due to the fact that one cylinder is killed. Establishing the particular value of the hydraulic delay during engine braking may affect the performance of the engine very little for not saying nothing at all.

The electrical delay is more or less constant through out the life time of an injector. Shutting off the electricity at a time period equal to the electrical delay after the logical pulse for starting fuel injection should therefore not result in fuel injection into a particular combustion chamber. As a first attempt to establish the hydraulic delay said electrical delay may be used to see if any fuel is injected. As a second attempt said electrical delay plus Δt is used. As a third attempt said electrical delay plus $2x\Delta t$ is used. Indication of injected fuel may be done by looking at the acceleration of the fly wheel. When no fuel is injected into a particular cylinder the flywheel is rotating in a predetermined way. When fuel is starting to be injected (start of combustion) into said initially closed cylinder, this may be indicated by an acceleration of the flywheel at a particular position. Using fine steps of Δt , the start of injection may be establish with high accuracy. The hydraulic delay is calculated by subtracting the electrical delay from the electrical delay + $N*\Delta t$, where N is the number of Δt used until injection is detected.

Other means instead of said flywheel detector, which measures the acceleration of the flywheel for indication of starting of combustion, may be a pressure sensor in the combustion chamber, a temperature sensor in the exhaust manifold, a
5 temperature sensor in the combustion chamber, a vibration sensor attached to the engine, an exhaust gas particle sensor etc a flow sensor in the exhaust system, a torque sensor on the crank shaft, etc. A difference in pressure, temperature, frequency, particle content torque and/or flow may be an indication of a start of combustion and a means for establishing the hydraulic delay according to the
10 method as disclosed above.

Said determined injection start delay period may be compared with a stored reference value of said injection start delay period. Said stored reference values of said injection start delay period may represent different kind of fuels and different
15 blends of different fuels.

If a change of fuel has taken place it may be established if the difference between said determined injection start delay period and said reference value is greater than a predetermined value. A slow change of injection start delay period may be
20 caused by a worn injector. However, a rapid change of injection start delay period may be an indication of a change of fluid to be injected into the combustion chamber. Typically, this rapid change of injection start delay period takes place between two consecutive measurement of said injection start delay period.

25 An adjustment of at least one parameter in the group of: fuel injection period; fuel timing; fuel pressure, in dependence of the result of said comparison of the determined injection start delay period with said stored reference value of said injection start delay period for maintaining the power of the engine.

30 Said fuel injection period may be extended if said determined injection start delay period is longer than said stored reference value of said injection start delay period.

Said fuel injection period may be reduced if said determined injection start delay period is shorter than said stored reference value of said injection start delay period.

- 5 Said stored reference value of said injection start delay period may be a previously determined injection start delay period, alternatively said stored reference value of said injection start delay period may be made when an injector is new.

- 10 Said determined injection start delay periods may be stored in a FIFO list. Two consecutive determined injection start delay periods may be compared for establishing a change in fuel. If two consecutive determined injection start delay periods differing by more than a predetermined period of time a change of fuel may have taken place. The injection start delay period may be established at a first appropriate time, which may be the first engine braking occasion, after the
15 engine has been started.

- The kind of fuel may be determined by comparing the determined injection start delay period with stored values of injection start delay periods for different kind of fuels or different blends of fuels.

- 20 Said injection start delay period may be determined while the vehicle is coasting and/or engine braking or at an engine load less than a predetermined value.

- 25 If the hydraulic delay is changed one may alter the fuel injection pressure. A higher viscosity may lead to a lower fuel injection pressure and vice versa.

- The establishing if a change of fuel has taken place may be done each time the tank in a vehicle has been refilled partly or fully. The method may be used within a predetermined driving period after said refilling of fuel, for instance 2 minutes, 5
30 minutes or 10 minutes. The new blend of fuels have a specific injection delay start period which may be analysed and compared with stored data in order to establish the current mixture of fuels. Once the mixture has been determined different engine parameters may be optimised for said mixture in order to maintain the power and/or the emission level from the engine.

A computer program may comprise program code means for performing at least the open loop experiment when said program is run on a computer.

- 5 A computer program product may comprise program code means stored on a computer readable medium for performing at least the open loop experiment when said program product is run on a computer.

- 10 The invention should not be deemed to be limited to the embodiments described above, but rather a number of further variants and modifications are conceivable within the scope of the following patent claims.

C L A I M S

1. A method for controlling fuel injection in an internal combustion engine
5 provided in a vehicle, comprising the steps of:
 - a. providing means for detecting start of combustion (SOC),
 - b. determining an injection start delay period being a time period from an injection start pulse to SOC,
 - c. comparing said determined injection start delay period with a stored
10 reference value of said injection start delay period,
 - d. establishing that a change of fuel has taken place if the difference between said determined injection start delay period and said reference value is greater than a predetermined value.
- 15 2. The method according to claim 1 further comprising the step of:
 - d. adjusting at least one parameter in the group of: fuel injection period; fuel timing; fuel pressure, in dependence of the result of said comparison of the determined injection start delay period with said stored reference value of said injection start delay period for
20 maintaining the power and emission of the engine.
3. The method according to claim 2, wherein said fuel injection period is extended if said determined injection start delay period is longer than said stored reference value of said injection start delay period.
25
4. The method according to claim 2, wherein said injection period is reduced if said determined injection start delay period is shorter than said stored reference value of said injection start delay period.
- 30 5. The method according to claim 1, wherein said stored reference value of said injection start delay period is a previously determined injection start delay period.

6. The method according to claim 1, wherein said stored reference value of said injection start delay period is made when an injector is new.

7. The method according to claim 4, further comprising the step of:

- 5 e. storing said determined injection start delay periods in a FIFO list,
 f. comparing two consecutive determined injection start delay periods,
 g. establishing a change in fuel if two consecutive determined injection start delay periods differing by more than a predetermined period of time.

10

8. The method according to claim 7, further comprising the step of:

- h. determining the kind of fuel by comparing the determined injection start delay period with stored values of injection start delay periods for different kind of fuels.

15

9. The method according to claim 1, wherein said injection start delay period is determined while the vehicle is coasting and/or engine braking or at an engine load less than a predetermined value.

20

10. A computer program comprising program code means for performing all the steps of any one of the claims 1-9 when said program is run on a computer.

11. A computer program product comprising program code means stored on a computer readable medium for performing all steps of anyone of the claims
25 1-9 when said program product is run on a computer.

12. A use of the method according to any one of claim 1-9 within a predetermined driving period after a tank of said vehicle has been refilled with fuel.

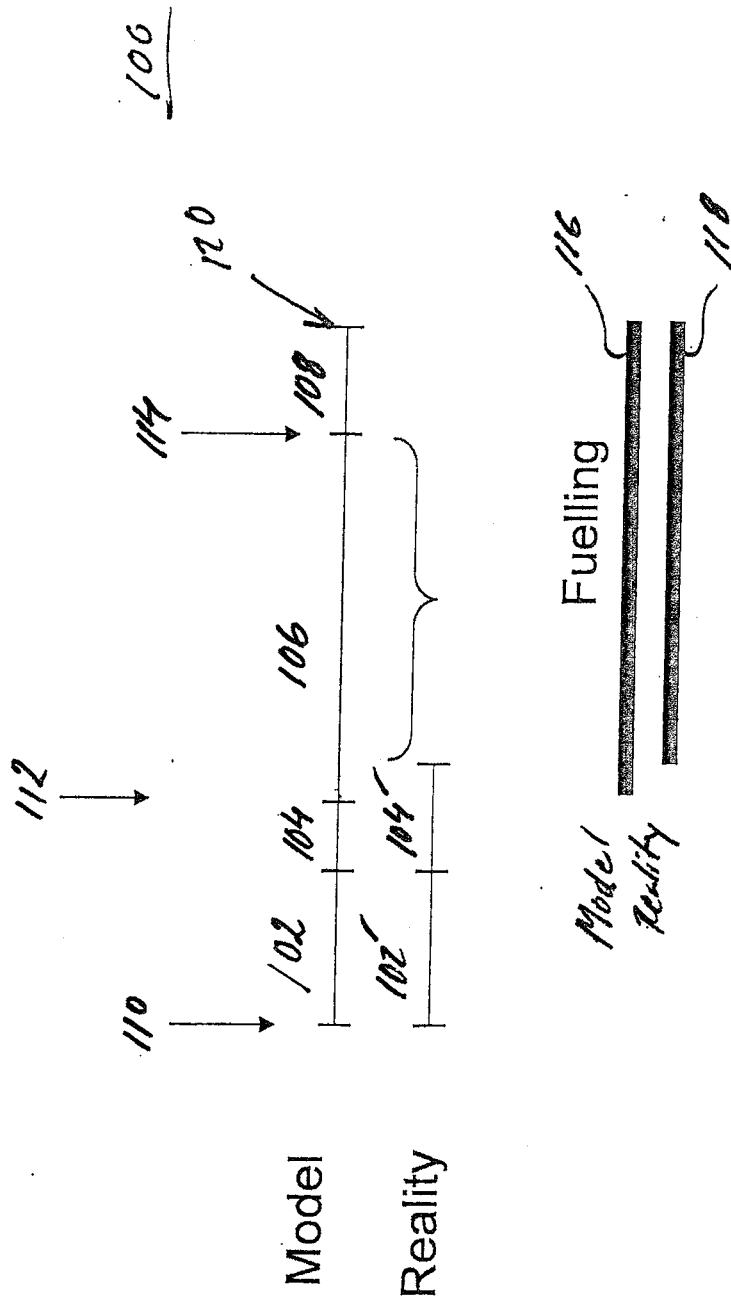
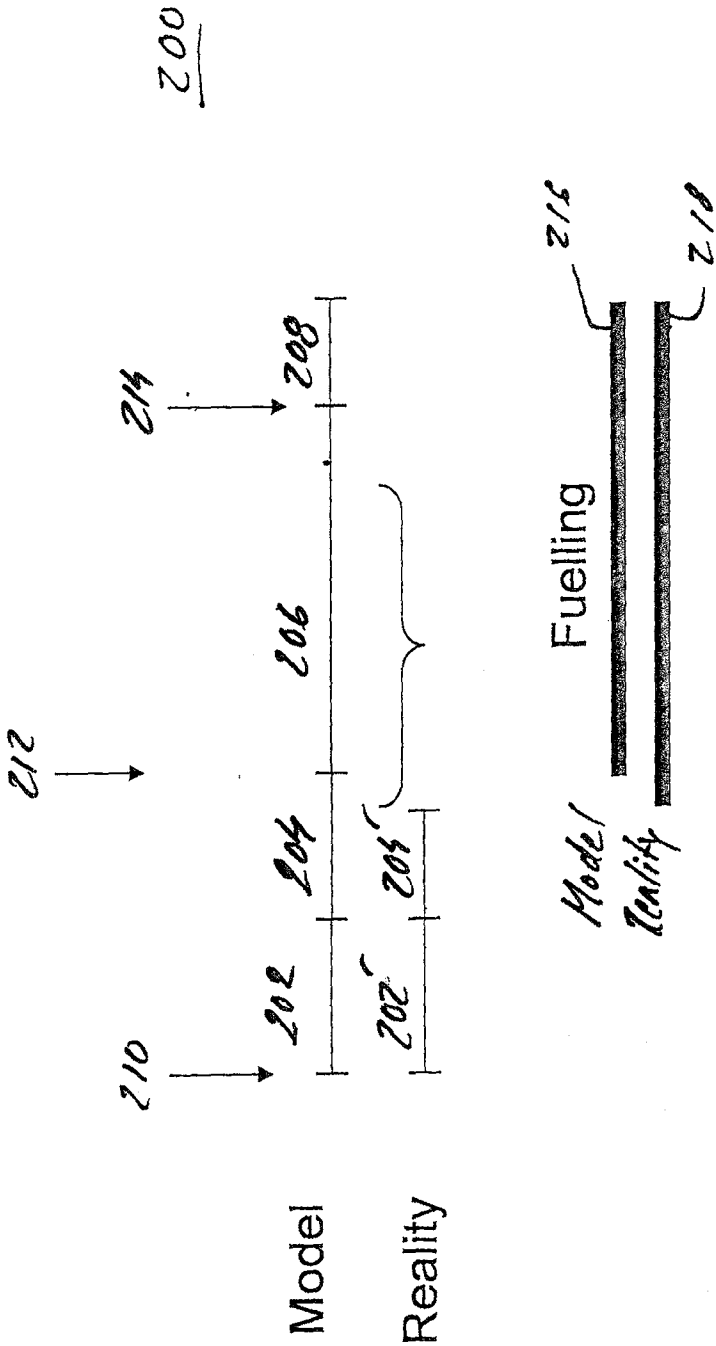


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2010/000206

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F02D, F02P

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20070079647 A1 (AOYAMA), 12 April 2007 (12.04.2007), abstract, paragraphs (0002),(0011), (0018),(0019),(0061),(0078)-(0081) --	1-12
X	US 20050247285 A1 (NAGAI ET AL), 10 November 2005 (10.11.2005), abstract, paragraphs (0004),(0006), (0008),(0055),(0056),(0065),(0084) --	1-12
A	WO 2004048761 A1 (RICARDO CONSULTING ENGINEERS LIMITED), 10 June 2004 (10.06.2004), page 12, line 16 - line 25, claim 10 --	1

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2010/000206

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5706780 A (SHIRAKAWA), 13 January 1998 (13.01.1998), column 1, line 16 - line 19; column 2, line 23 - line 29, claim 1, abstract --	1
A	US 20070204682 A1 (SUNWOO ET AL), 6 Sept 2007 (06.09.2007), figure 1, paragraphs (0006)-(0010) --	1
A	US 20100132435 A1 (DORING), 3 June 2010 (03.06.2010), abstract, paragraphs (0002),(0003) --	1-12
E	WO 20100134150 A1 (TOYOTA JIDOSHA KABUS HIKI KAISHA), 25 November 2010 (25.11.2010), abstract -- -----	1-12

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2010/000206

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WO	20100134150	A1	25/11/2010	NONE		