

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
20 November 2008 (20.11.2008)

PCT

(10) International Publication Number
WO 2008/140403 A1

(51) International Patent Classification:

F02M 65/00 (2006.01) **G01M 15/11** (2006.01)
F02D 41/14 (2006.01)

(21) International Application Number:

PCT/SE2008/050519

(22) International Filing Date: 7 May 2008 (07.05.2008)

(25) Filing Language: Swedish

(26) Publication Language: English

(30) Priority Data:

0701121-6 9 May 2007 (09.05.2007) SE

(71) Applicant (for all designated States except US): **SCANIA CV AB (publ)** [SE/SE]; S-151 87 Södertälje (SE).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **VÖLCKER, Björn** [SE/SE]; Folkparksvägen 182, S-126 39 Hägersten (SE).

(74) Agent: **GARDEMARK, Niklas**; Scania CV AB, UTY/Patents, S-151 87 Södertälje (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

(54) Title: METHOD AND COMPUTER PROGRAM PRODUCT FOR IDENTIFYING A MALFUNCTIONING CYLINDER OF A MULTI-CYLINDER COMBUSTION ENGINE

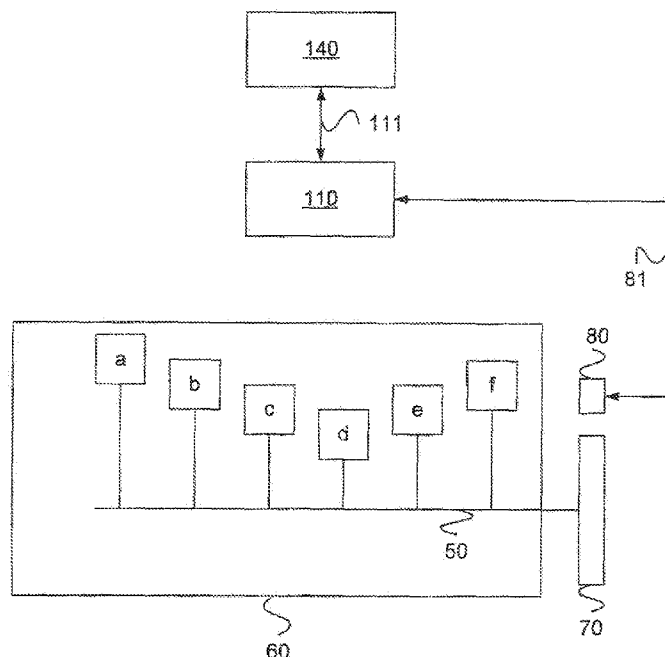


Fig. 1b

(57) Abstract: The present invention relates to a method for identifying a malfunctioning fuel injector (150a, 150b, 150c, 150d, 150e, 150f) associated with an individual cylinder (Ca, Cb, Cc, Cd, Ce, Cf) of a multicylinder combustion engine (60). The method comprises the step of generating a first data set (r(t)) comprising engine-speed values (rl-r20; rl-r120) corresponding to at least one cylinder of said engine. The method also comprises the step of processing said first data set (r(t)) so as to generate a second data set (s(t)) depending upon said first data set (r(t)). The method further comprises the steps of processing said second data set (s(t)) so as to establish a detection value (d(t)), and comparing said detection value (d(t)) with a predetermined threshold value (K), and identifying at least one malfunctioning fuel injector depending upon said comparison, and weighting of said second data set by means of a weight vector during the step of establishing the detection value.

Method and computer program product for identifying a malfunctioning cylinder of a multi-cylinder combustion engine

Technical field

5

The present invention relates to a method for identifying a malfunctioning fuel injector of a cylinder of a multi-cylinder combustion engine. The invention also relates to a computer program product comprising computer program code for implementing a method according to the invention. The invention also relates to a computer. The invention further relates to a platform having a computer.

10

Background of the invention

When a multi-cylinder combustion engine fails to deliver its rated power, this may be due to the malfunctioning of any of the cylinders of the engine. In the case of a diesel engine, the malfunctioning of a cylinder may be due to overfuelling caused by a faulty fuel injector or to excessive fuel pressure within a fuel supply system of the engine.

15

20

US 5095742 discloses a method for diagnosis of faulty ignition in individual cylinders by calculating power loss. According to the method of US 5095742 accelerations of the engine speed are measured. Subsequently an acceleration value of a measurement associated with a particular cylinder of the engine is compared with a median acceleration and the resulting difference is used for a normalized calculation of power loss.

25

Today, there exists a need to identify a malfunctioning of a cylinder out of a plurality of properly functioning cylinders of an engine.

Summary of the invention

An object of the invention is to provide a new and advantageous manner of identifying a malfunctioning fuel injector associated with an individual cylinder of a multicylinder combustion engine.

An object of the invention according to an aspect of the invention is to provide an improved method for diagnosing a multi-cylinder combustion engine.

According to the invention, these objects are achieved by a method for identifying a malfunctioning fuel injector associated with an individual cylinder of a multicylinder combustion engine, comprising the steps of:

- generating a first data set comprising engine-speed values corresponding to at least one cylinder of said engine;

- processing said first data set so as to generate a second data set depending upon said first data set;

- processing said second data set so as to establish a detection value;

- comparing said detection value with a predetermined threshold value;

- identifying at least one malfunctioning fuel injector based upon said comparison;

- in which said step of establishing a detection value may involve weighting of said second data set by means of a weight vector. By this an erroneous detection of a malfunctioning fuel injector is reduced.

An advantage of the present invention is that the derivative of the engine speed values does not need to be taken into consideration. This thus means that the torque of the crank shaft also does not need to be taken into consideration. An advantage is that the noise reduction is improved.

An advantage of the present invention is also that the number of erroneous detections is reduced.

The present invention further provides an improved ability to early detect a malfunctioning cylinder of a multi-cylinder engine, which is highly desirable, not least for the operators of the vehicle, such as a driver of a heavy vehicle.

- 5 A beneficial contribution of the invention is that a cost effective solution to the above stated problems is achieved. Existing vehicles may easily be upgraded with relevant software so as to achieve the positive effects of the present invention.

10 Yet another beneficial contribution of the invention is that the method for identifying a malfunctioning cylinder of a multi-cylinder engine is robust.

Yet another beneficial contribution of the invention is that an erroneous detection of a malfunctioning fuel injector is reduced.

- 15 The step of processing said first data set may involve establishing the median value of a chosen number of said engine-speed values. It is an advantage in comparison to using the mean value, as false calculations are diminished in this case. Alternatively other calculation procedures may be used, such as calculating the cylinder wise mean engine speed by measuring the time from marker #1 to #21.

20

The weight vector may comprise elements, the sum of which is substantially zero (0). The advantage with this is that under normal conditions, when the average engine speed is close to constant, the weighting is close to zero.

- 25 The step of establishing said detection value may involve normalizing said detection value. It should be pointed out that the normalization preferably is performed in relation to idle engine speed. This makes the algorithm average speed independent.

30 Said second data set may constitute a set of elements, each element correlates to an individual cylinder.

The method may comprise the step of resetting said first data set after each engine cycle. Advantageously effects from earlier time instants will not affect the performance.

- 5 The method may comprise the step of periodically upgrading the second data set.

The step of identifying at least one malfunctioning fuel injector may be established in dependence of the upgrade of the second data set.

- 10 The step of identifying at least one malfunctioning fuel injector may be established in dependence of a predetermined validation time. Validation makes detection more robust to false alarms.

- 15 The method may be performed on-line, i.e. in real time during operation of the engine. Thus, possible malfunction may be detected at an early stage. This facilitates for the operator to shut off the injector or attend to the problem by replacing the malfunctioning fuel injector.

- 20 Additional objects, advantages and novel features of the present invention will become apparent to those skilled in the art from the following details, as well as by practice of the invention. While the invention is described below, it should be understood that the invention is not limited to the specific details disclosed. A person skilled in the art having access to the teachings herein will recognise additional applications, modifications and embodiments in other fields, which are
25 within the scope of the invention.

Brief description of the drawings

- 30 For a more complete understanding of the present invention and further objects and advantages thereof, reference is now made to the examples shown in the accompanying drawings, in which:

Figure 1a schematically illustrates a fuel injection system for a combustion engine according to an aspect of the present invention;

5 Figure 1b schematically illustrates a combustion engine and a control unit according to an aspect of the present invention;

Figure 2 schematically illustrates a side view of the fuel injection system for a combustion engine shown in Figure 1 according to an aspect of the present
10 invention;

Figure 3a schematically illustrates a graph according to an aspect of the present invention;

15 Figure 3b schematically illustrates a graph according to an aspect of the present invention;

Figure 4 schematically illustrates a flow chart depicting a method for identifying a malfunctioning cylinder/fuel injector according to an aspect of the present
20 invention; and

Figure 5 schematically illustrates an electronic control unit according to an aspect of the invention.

25 **Detailed description of the drawings**

With reference to Figure 1a, a sub-system of a platform 10 is shown. The platform 10 is preferably a ground vehicle, such as a truck or lorry. It should be noted that the platform 10 alternatively can be a water craft or underwater craft, e.g. a ship or
30 submarine. Alternatively the platform 10 can be a power plant.

Hereinafter the term “link” refers to a communication link which may be a physical connector, such as an optoelectronic communication wire, or a non-physical connector such as a wireless connection, for example a radio or microwave link. Further, hereinafter the term malfunctioning primarily refers to a too high fuel injection, i.e. the amount of fuel supplied to the cylinder is considerably higher than a desired amount. This kind of malfunction may lead to cylinder/engine breakdown.

Fig. 1a shows a fuel injection system for a combustion engine 60 (shown fig. 1b) in the form of a schematically represented diesel engine having six cylinders. The fuel injection system and the diesel engine are with advantage fitted to heavy vehicle, such as truck, lorry or bus, for propelling the vehicle. The fuel injection system is a so-called Common Rail system and comprises a fuel line for supply of fuel from a fuel tank 115 to the cylinders of the diesel engine. A fuel pump 116 is arranged in the fuel line to convey fuel from the fuel tank via a filter 117 to a high-pressure pump 118. The high pressure pump 118 is adapted to pressurize the fuel so that it enters at high pressure an accumulator tank 120 which takes the form of a so-called Common Rail. The high fuel pressure in the accumulator tank 120 constitutes a power source making it possible for fuel to be injected at high pressure into the respective cylinders of the diesel engine. The fuel in the accumulator tank 120 is intended to be distributed to all the cylinders of the combustion engine 60.

To control the injection of fuel, injection means 150a-150f is arranged in each of the connections between the accumulator tank 120 and the respective cylinders of the diesel engine. When an injection means is in an open state, it injects fuel at high pressure into the cylinder concerned. Thus, fuel from the accumulator tank 120 is injected into the combustion spaces of the respective cylinder by means of the injection means which is in the form of electronic injectors which injectors can open and close very quickly. A control unit in the form of an electronic control unit 110 (ECU) is adapted to control the operation of the fuel pump 116, the high pressure pump 118 and the injection means 150a, 150b, 150c, 150d, 150e, and 150f. A

pressure sensor 122 is fitted in the accumulator tank 120 to detect the prevailing pressure therein and to send to the control unit 110 a signal S122 conveying information about the pressure values detected. On the basis of knowing the pressure in the accumulator tank, the electronic control unit 110 controls the on-time or opening times of each individual electronic injector so that the calculated amount of fuel is supplied with good accuracy to the combustion spaces of the respective cylinders.

In this description, the term “on-time” refers to the opening time of an injector, i.e. the duration of the time period during which the injector is kept open in order to inject fuel into the associated cylinder in connection with a single stroke of the engine. The quantity of fuel injected into a cylinder in connection with a stroke of the engine depends on the length of the on-time and the pressure of the fuel supplied to the injector.

Here, the inventive method is initiated and controlled by means of the electronic control unit 110. Alternatively, the inventive method is initiated and controlled by means of an external PC 112. The external computer may be directly connected to the electronic control unit 110 via a link 114, but may also be indirectly connected to the electronic control unit 110 in any suitable manner, such as through an internal vehicle internal network. The communication between the external computer and the engine control unit may be partly or entirely wireless. The inventive method could also be initiated and controlled by the electronic control unit 110 itself or by another electronic control unit comprised in an internal vehicle network, such as an electronic gear box control unit.

Figure 1b shows the engine having six cylinders, each cylinder Ca, Cb, Cc, Cd, Ce, and Cf (not shown) being provided with a piston a, b, c, d, e, f, respectively. It should be noted that the invention is applicable to any multicylinder combustion engine with an arbitrary number of cylinders. The six pistons are attached to a crank shaft 50. The crank shaft 50 is attached to a fly wheel 70 being arranged to rotate

with the same speed as the crank shaft 50. A sensor unit 80 is provided at a close proximity to the fly wheel 70. The sensor unit 70 is arranged to measure engine speed by detecting time points corresponding to detections of markers equidistantly provided on the fly wheel 70 as depicted in greater detail below. The sensor unit 80 is arranged for communication with the electronic control unit 110 via a link 81. The sensor unit 80 is arranged to continuously transmit detected discrete time points. Alternatively, the sensor unit 80 is arranged to on a regular basis send signals comprising a plurality of detected discrete time points.

Thus, the electronic control unit is arranged to receive sensed engine data in the form of e.g. a toothed fly wheel signal (TF-signal). The TF-signal is received on a data communications port from the engine-speed sensor unit 80 which senses rotation of the engine's toothed fly wheel 70. The engine-speed sensor 80 may be e.g. an inductive type sensor or a Hall-effect sensor. Of course there may be more than one engine-speed sensor unit and other positions for measuring engine speed, such as measuring the engine's camshaft speed and the speed of a generator connected to the engine.

The electronic control unit 110 is arranged to perform a diagnosis test depending upon transmitted discrete time points from the sensor unit 80, so as to determine if one or more injectors associated with a unique cylinder of the engine is malfunctioning.

Figure 2 schematically illustrates a side view of the fly wheel of the engine. There is also shown the engine-speed sensor unit 80 arranged for communication with the electronic control unit 110 via the link 81.

The flywheel 60 is provided with 60 markers denoted #1, #2, ... , #60, such as teeth or holes. However, since there are four strokes in an engine cycle two turns of the flywheel results in each marker being calculated twice and therefore 120 markers are sensed by the engine-speed sensor unit 80 during an engine cycle. The

measurements are denoted #1, #2, ... , #120, wherein #1 and #61, #2 and #62 etc. corresponds to the same marker. The engine-speed sensor unit 80 is arranged to detect a time point corresponding to a marker passing by a predetermined location, e.g. a location schematically indicated at marker #60 (and #120).

5

A person skilled in the art thus realizes that two turns of the flywheel 70 correspond to one engine cycle, which in turn corresponds to two turns of the crankshaft 50. It should be noted that the invention is suitable for various types of flywheels having an arbitrary number of markers.

10

The electronic control unit 110 is arranged to calculate an engine-speed value $r_i(t)$ corresponding to each of the teeth i of the flywheel 70, wherein i is an integer in the interval 1-120,. The calculation of the respective engine-speed value is performed depending upon received time point data, which data is communicated by the engine-speed sensor unit.

15

Alternatively, the engine-speed sensor unit 80 is arranged to calculate an engine-speed value $r_i(t)$, wherein i is an integer in the interval 1-120, corresponding to each of the teeth of the flywheel 70 and to continuously transmit these values to the electronic control unit 110.

20

An engine-speed vector $r(t)$ is generated, wherein

$$r(t)=[r_1(t), r_2(t), \dots, r_{120}(t)]^T$$

25

wherein T is the transpose.

The electronic control unit is further arranged to generate a more dense vector $s(t)$. The vector $s(t)$ includes median values of predetermined groups of engine-speed elements of the engine-speed value vector $r(t)$. In this example, a median value of the first 20 engine-speed elements $r_1(t), r_2(t), \dots, r_{20}(t)$ is generated, denoted $s_1(t)$.

30

Similarly, the second element $s_2(t)$ consists of a median value of the sensed engine-speed elements $r_{21}(t), r_{22}(t), \dots, r_{40}(t)$, etc.

$r_i(t)$ is related to a marker # i , among the 120 markers.

5

Thus,

$s(t)=[s_1(t), s_2(t), \dots, s_6(t)]^T$, wherein

$s_1(t)=\text{median}(r_1(t), r_2(t), \dots, r_{20}(t))$

$s_2(t)=\text{median}(r_{21}(t), r_{22}(t), \dots, r_{40}(t))$

10

...

$s_6(t)=\text{median}(r_{101}(t), r_{102}(t), \dots, r_{120}(t))$

It should be noted that the engine-speed elements $r_1(t), r_2(t), \dots, r_{20}(t)$ corresponds to sensed measurements of the first cylinder Ca as depicted with reference to Figure

15

1b.

Alternatively the engine-speed elements corresponding to different cylinders of the engine may be overlapping. For example, $r_1(t), r_2(t), \dots, r_{25}(t)$ may be corresponding to the first cylinder Ca and $r_{21}(t), r_{22}(t), \dots, r_{45}(t)$ may be corresponding to the second cylinder Cb.

20

Accordingly, $s_2(t)$ corresponds to the median value of the engine-speed elements $r_{21}(t), r_{22}(t), \dots, r_{40}(t)$, etc.

25

Hereby a comparison value $d(t)$ is introduced. The comparison value $d(t)$ is defined as:

$$d(t) = \frac{K \sum_{i=0}^5 w(i) s_i(t)}{\sum_{i=0}^5 s_i^2(t)} = \frac{K w^T s(t)}{\|s(t)\|^2}$$

wherein w^T is a weight vector of the same range as $s(t)$. One way of determining w^T is depicted below with reference to Example 1. K is a predetermined constant value. According to an embodiment K corresponds to the idle engine speed. For example the idle engine speed is 500 rpm. By choosing an idle speed of 500 rpm the method according to the present invention becomes more robust regarding variation of the engine speed.

$d(t) > \kappa$, where κ is a predetermined numerical value. The value of κ may be preset and stored in a memory of the electronic control unit 110. The value of κ can e.g. be about 0,01.

It should also be noted that:

$-1 < \kappa < 1$, where proper working injectors and cylinders are corresponding to a value close to 1.

According to a preferred embodiment of the invention the vector $s(t)=[s_1(t), s_2(t), \dots, s_6(t)]^T$ is shifted every 20th engine-speed value.

Let t_{20} be the time it takes to collect 20 new speed samples, e.g. $\{r_{21}, r_{22}, \dots, r_{40}\}$, then the vector $s(t)$ is shifted as $s(t+t_{20})=[s_2(t+t_{20}), \dots, s_6(t+t_{20}), s_1(t+t_{20})]^T$.

Example 1. Determine the weight vector w

The weight vector w is a pre-calculated design parameter, which could be optimized as stated below.

$$w = \arg \max_w \min_{i \neq 0} \sum_n (s_n(t) - s_n(t-i))^T w \quad w^T w \leq 1$$

meaning that a preferred vector w is determined by maximizing the expression:

$\frac{w^T s_i(t)}{\|s(t)\|}$ is maximized

while minimizing the expression:

- 5 $\frac{w^T s_j(t)}{\|s(t)\|}$, where $i \neq j$, and where the index i represents the malfunctioning cylinder/fuel injector. Thus, the weight vector w is a design parameter which is predetermined by an experimental procedure. The beforehand determined weight vector w is stored in a memory of the electronic control unit 110.
- 10 A vector w determined in this way contribute with the positive advantage that an easier identification procedure of a malfunctioning cylinder/injector is achieved. This is clearly shown in the graph depicted with reference to Figure 3. Thus, by choosing a weight vector w , as depicted in this example, a value difference between a (highest) value $d_i(t)$, corresponding to a malfunctioning cylinder/injector, and
- 15 another (second highest) value $d_j(t)$, is increased. It should be noted that $i \neq j$ and that index i refers to the malfunctioning fuel injector. Further, the index j refers to any properly functioning fuel injector.

20 According to one example of weight parameter w , the sum of the elements of w is equal to zero (0), which provides the advantage that in a case wherein an average engine speed signal is constant, i.e. when the engine runs without a malfunctioning fuel injector, for the respective cylinders the detection signal $d(t)$ will be equal to zero (0). Also, the boundary condition implying that the weight vector w should have a norm which is equal to one (1) will be fulfilled.

25

End of Example 1

Figure 3a is an example graph wherein comparison values $d(t)$ corresponding to the six cylinders 1, 2, ..., 6 is shown. In this particular example there is shown that the

second cylinder Cb has a highest comparison value $d(t)$. This indicates that the injector 150b may be injecting an excessive amount of fuel to the second cylinder Cb.

5 There is also illustrated that a level difference between the comparison value $d(t)$ corresponding to the indicated malfunctioning cylinder/fuel injector Cb/150b and a second highest comparison value, which in this example corresponds to the fourth cylinder/fuel injector Cd/150d, is $L1-L2$. The difference between a highest level $L1$ and a second highest level $L2$ is denoted ϕ . Thus, $\phi=L1-L2$. A suitably chosen
10 weight vector w contributes to generate a significant difference value ϕ , which in turn facilitates identification of a malfunctioning cylinder/fuel injector.

Figure 3b is an example graph associated with the example illustrated with reference to Figure 3a. The graph depicts that engine speed is increased during the
15 power stroke of the second cylinder Cb.

Figure 4 schematically illustrates in greater detail a method for identifying a malfunctioning fuel injector associated with an individual cylinder of a multicylinder combustion engine.

20

The method comprises a first step s410. The step s410 comprises the step of generating a first data set $r(t)$ comprising engine-speed values r_1-r_{20} ; r_1-r_{120} corresponding to at least one cylinder of said engine. According to a first embodiment the engine speed values are generated in real time, sequentially. As an
25 alternative to generating engine speed values sequentially, engine speed values corresponding to one cylinder, e.g. r_1-r_{20} , corresponding to the first cylinder, are generated substantially at the same time in a batch. After the method step s410 a subsequent step s415 is performed.

30 The step s415 comprises the step of processing said first data set. After the step s415 a subsequent step s420 is performed.

The step s420 comprises the step of generating a second data set $s(t)$ depending upon said first data set $r(t)$. According to an embodiment of the present invention the processing of the first data set according to step s415 involves the process of
5 determining the median value of the first data set so as to generate said second data set. After the step s420 a subsequent step s425 is performed.

The step s425 comprises the step of processing said second data set $s(t)$. After the method step s425 a subsequent step s430 is performed.

10 The step s430 comprises the step of establishing a detection value $d(t)$. According to an embodiment of the present invention the processing of the second data set according to step s425 involves the process of establishing a detection value. After the step s430 a subsequent step s435 is performed.

15 The step s435 comprises the step of comparing said detection value $d(t)$ with a predetermined threshold value κ . According to an embodiment of the present invention the comparison process involves determining whether the detection value is greater than or equal to the threshold value. After the step s435 a subsequent step
20 s440 is performed.

The step s440 comprises the step of identifying at least one malfunctioning fuel injector depending upon said comparison. If the detection value is greater than the threshold value one fuel injector is malfunctioning. Which fuel injector is
25 malfunctioning is determined through the following:

Firstly it is, as depicted above, determined whether the detection value is greater than the threshold value κ . Secondly it is determined which value $s_i(t)$ is corresponding to the detection value $d(t)$ being compared with the threshold value κ
30 by identifying the first element in the upgraded vector $s(t)$. The vector $s(t)$ is, as described above upgraded after each twentieth received engine speed value. Thus, it

is identified which engine speed values that correlates to the malfunctioning fuel injector. After the step s440 a subsequent step s445 is performed.

5 The step s445 comprises the step of storing a result of the identification step performed with reference to the step s440. The result of the identification step comprises information about which fuel injector is identified to be malfunctioning, i.e. having a too long on-time, implying that an excessive amount of fuel is injected. According to one embodiment the result of the identification step is displayed on a display such that the information can be provided to an operator. Thereafter the
10 method ends.

With reference to Figure 5, a diagram of one embodiment of the electronic control unit 110 is shown. The electronic control unit 110 is also referred to as apparatus. The apparatus comprises a computer program product in the form of a non-volatile
15 memory 520, a data processing device 510 and a read/write memory 550. Non-volatile memory 520 has a first memory portion 530 wherein a computer program, such as an operating system, is stored for controlling the function of apparatus. Further, apparatus comprises a bus controller, a serial communication port, I/O-means, an A/D-converter, a time date entry and transmission unit, an event counter
20 and an interrupt controller (not shown). Non-volatile memory 520 also has a second memory portion 540.

A computer program P comprising routines for identifying a malfunctioning injector/cylinder may be stored in an executable manner or in a compressed state in
25 computer program products in the form of a separate memory 560 and/or in the read/write memory 550. The memory 560 is a non-volatile memory, such as a flash memory, an EPROM, an EEPROM or a ROM.

When it is stated that the data processing device 510 performs a certain function it
30 should be understood that the data processing device 510 performs a certain part of

the program which is stored in the separate memory 560, or a certain part of the program which is stored in the read/write memory 550.

5 Data processing device 510 may communicate with a data communications port 599 by means of a data bus 515. The non-volatile memory 520 is adapted for communication with the data processing device 510 via a data bus 512. The separate memory 560 is adapted for communication with the data processing device 510 via a data bus 511. The read/write memory 550 is adapted for communication with the data processing device 510 via a data bus 514.

10 When data is received on the data port 599 from the engine speed sensor unit 80 it is temporarily stored in the second memory portion 540. When the received input data has been temporarily stored, the data processing device 510 is set up to perform execution of code in a manner described above. According to a preferred
15 embodiment of the invention, data received on the data port 599 comprises time information associated with the fly wheel 70. This information can be used by the apparatus so as to identify which cylinder of the engine 60 onboard the platform is malfunctioning.

20 Parts of the methods described herein can be performed by apparatus by means of the data processing device 510 running the program stored in the separate memory 560 or the read/write memory 550. When apparatus runs the program, parts of the methods described herein are executed.

25 According to an aspect of the invention the apparatus is arranged to run a computer program for identifying a malfunctioning fuel injector associated with an individual cylinder of a multicylinder combustion engine, comprising computer readable program code means for causing the apparatus, an electronic control unit or another computer connected to the electronic control unit to perform the steps of:

30 -generating a first data set $r(t)$ comprising engine-speed values (r_1 - r_{20} ; r_1 - r_{120}) corresponding to at least one cylinder of said engine;

- processing said first data set ($r(t)$) so as to generate a second data set ($s(t)$) depending upon said first data set ($r(t)$);
- processing said second data set ($s(t)$) so as to establish a detection value ($d(t)$)
- comparing said detection value ($d(t)$) with a predetermined threshold value (κ);
- 5 -identifying at least one malfunctioning fuel injector depending upon said comparison.

According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control
10 unit or another computer connected to the electronic control unit to perform the step of establishing the median value of a chosen number of said engine-speed values (r_1 - r_{20} ; r_1 - r_{120}) during the step of processing said first data set ($r(t)$).

According to an aspect of the invention the apparatus is arranged to run a computer
15 program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of weighting of said second data set by means of a weight vector during the step of establishing a detection value.

20 According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of normalizing said detection value during the step of establishing said detection value.

25 According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of resetting said first data set after each engine cycle.

According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of determining the malfunctioning of a fuel injector by identifying a high engine speed value relative to a desired value.

According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of periodically upgrading the second data set $s(t)$.

According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of identifying at least one malfunctioning fuel injector is established in dependence of the upgrade of $s(t)$.

According to an aspect of the invention the apparatus is arranged to run a computer program, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of identifying at least one malfunctioning fuel injector is established in dependence of a predetermined validation time.

The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated.

Claims

1. A method for identifying a malfunctioning fuel injector (150a, 150b, 150c, 150d, 150e, 150f) associated with an individual cylinder (Ca, Cb, Cc, Cd, Ce, Cf) of a multicylinder combustion engine (60), comprising the steps of:
- 5
- generating a first data set ($r(t)$) comprising engine-speed values (r_1 - r_{20} ; r_1 - r_{120}) corresponding to at least one cylinder of said engine;
 - processing said first data set ($r(t)$) so as to generate a second data set ($s(t)$)

10

 - depending upon said first data set ($r(t)$);
 - processing said second data set ($s(t)$) so as to establish a detection value ($d(t)$);
 - comparing said detection value ($d(t)$) with a predetermined threshold value (κ);
 - identifying at least one malfunctioning fuel injector depending upon said comparison;

15

 - in which said step of establishing a detection value involves weighting of said second data set by means of a weight vector (w).
2. Method according to claim 1 **characterized in that** the step of processing said first data set ($r(t)$) involves establishing the median value of a chosen number of
- 20
- said engine-speed values (r_1 - r_{20} ; r_1 - r_{120}).
3. Method according to claim 1 or 2 **characterized in that** the weight vector comprises elements, the sum of which is substantially zero (0).
- 25
4. Method according to any of claims 1-3 **characterized in that** the step of establishing said detection value ($d(t)$) involves normalizing said detection value.
5. Method according to any of claims 1-4 **characterized in that** said second data set ($s(t)$) constitutes a set of elements (s_1 - s_6), each element correlating to an
- 30
- individual cylinder.

6. Method according to any of claims 1-5 **characterized by** the step of:

- resetting said first data set after each engine cycle.

7. Method according to any of claims 1-6 **characterized by** the step of:

5 - periodically upgrading the second data set (s(t)).

8. Method according to claim 7 **characterized in that** the step of identifying at least one malfunctioning fuel injector is established in dependence of the upgrade of the second data set (s(t)).

10

9. Method according to any of claims 1-8 **characterized in that** the step of identifying at least one malfunctioning fuel injector is established in dependence of a predetermined validation time.

15 10. Computer program (P) for identifying a malfunctioning fuel injector (150a, 150b, 150c, 150d, 150e, 150f) associated with an individual cylinder (Ca, Cb, Cc, Cd, Ce, Cf) of a multicylinder combustion engine (60), comprising computer readable program code means for causing an electronic control unit (110) or another computer connected to the electronic control unit to perform the steps of:

20 - generating a first data set (r(t)) comprising engine-speed values (r1-r20; r1-r120) corresponding to at least one cylinder of said engine;

- processing said first data set (r(t)) so as to generate a second data set (s(t)) depending upon said first data set (r(t));

- processing said second data set (s(t)) so as to establish a detection value (d(t));

25 - comparing said detection value (d(t)) with a predetermined threshold value (κ);

- identifying at least one malfunctioning fuel injector based upon said comparison;

- weighting of said second data set by means of a weight vector during the step of establishing the detection value.

30 11. Computer program according to claim 10, comprising computer readable means for causing the electronic control unit or another computer connected to the

electronic control unit to perform the step of establishing the median value of a chosen number of said engine-speed values (r_1 - r_{20} ; r_1 - r_{120}) during the step of processing said first data set ($r(t)$).

5 12. Computer program according to claim 10 or 11, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of normalizing said detection value during the step of establishing said detection value.

10 13. Computer program according to any of claims 10-12, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of resetting said first data set after each engine cycle.

15 14. Computer program according to any of claims 10-13, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of determining the malfunctioning of a fuel injector by identifying a high engine speed value relative to a desired value.

20 15. Computer program according to any of claims 10-14, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of periodically upgrading the second data set ($s(t)$).

25 16. Computer program according to claim 15, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of identifying at least one malfunctioning fuel injector established in dependence of the upgrade of $s(t)$.

30

17. Computer program according to any of claims 10-16, comprising computer readable means for causing the electronic control unit or another computer connected to the electronic control unit to perform the step of identifying at least one malfunctioning fuel injector established in dependence of a predetermined validation time.

18. Computer program product (550, 560) comprising a computer program (P) according to any of claims 10-17 and a computer readable medium on which the computer program is stored.

19. Computer, such as an embedded electronic control unit or a vehicle external computer comprising a storage means and a computer program according to any of claims 10-18 stored in the storage means.

20. Platform (10) comprising a computer according to claim 19.

21. Platform according to claim 20 wherein said platform is chosen among a group comprising vehicle, water craft and underwater craft, such as truck, ship and submarine respectively, or power plant.

1/6

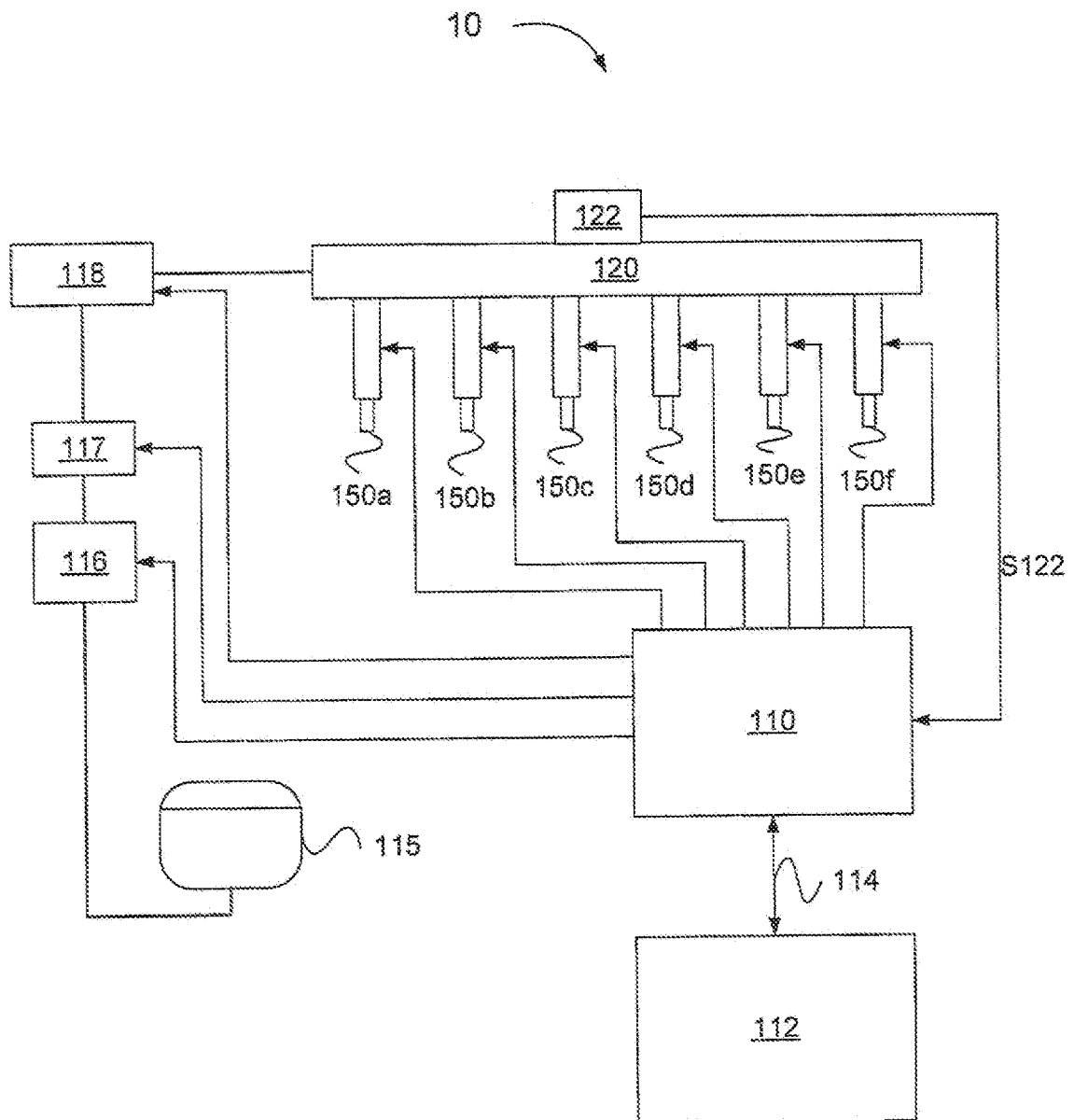


Fig. 1a

2/6

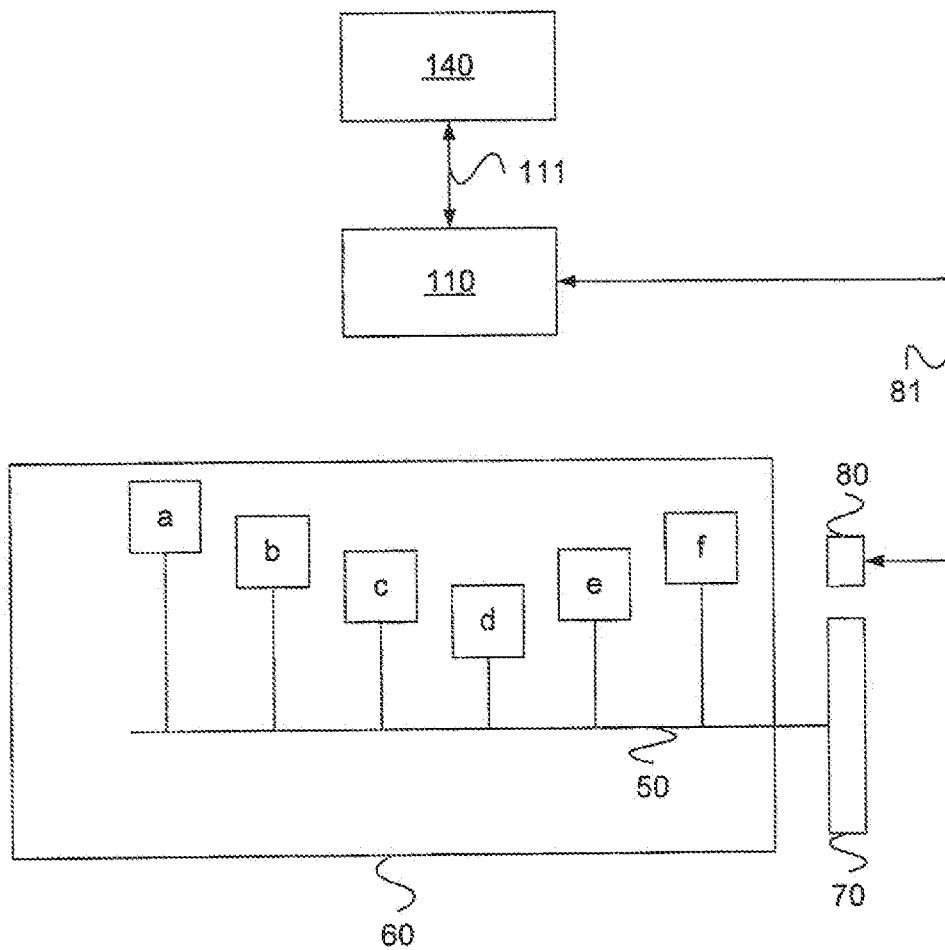


Fig. 1b

3/6

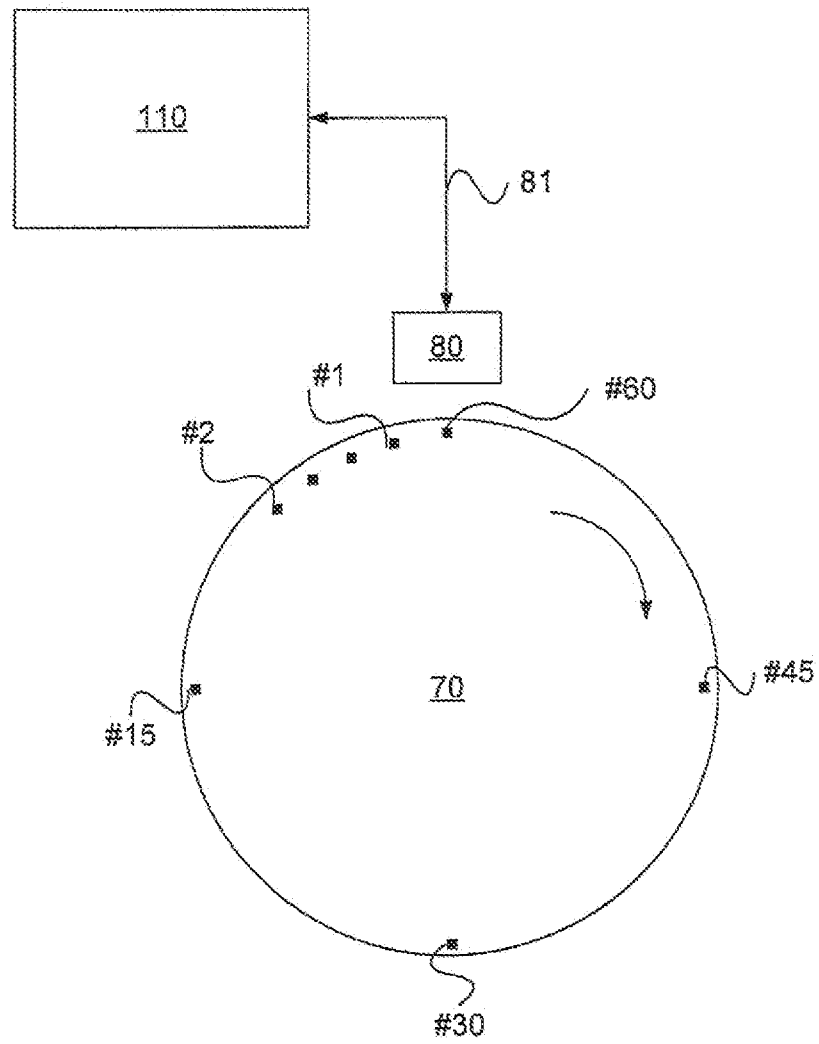


Fig. 2

4/6

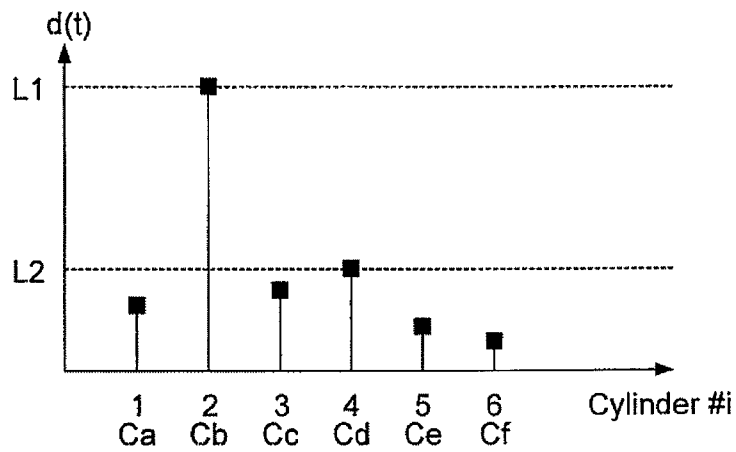


Fig. 3a

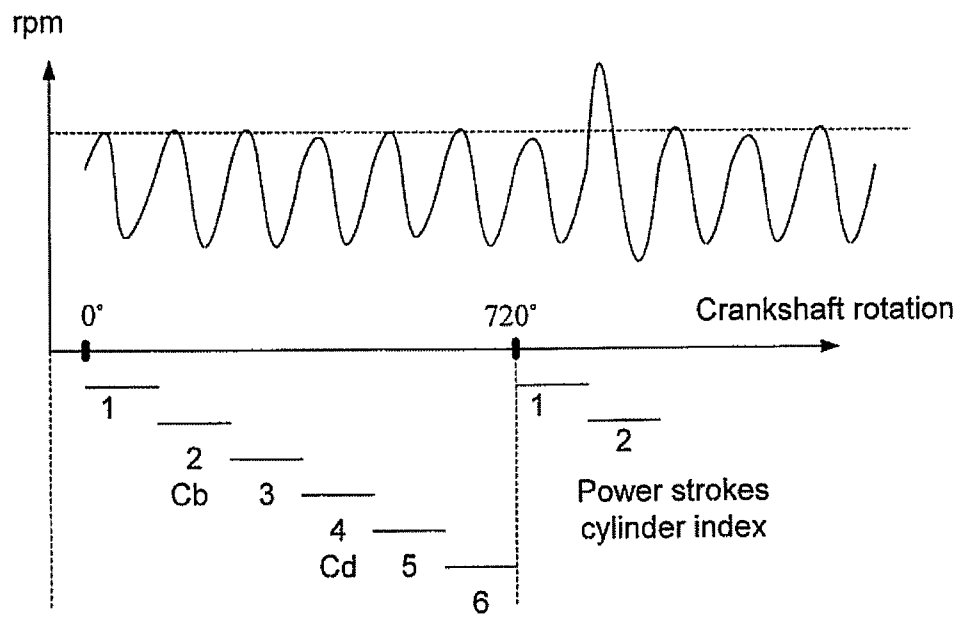


Fig. 3b

5/6

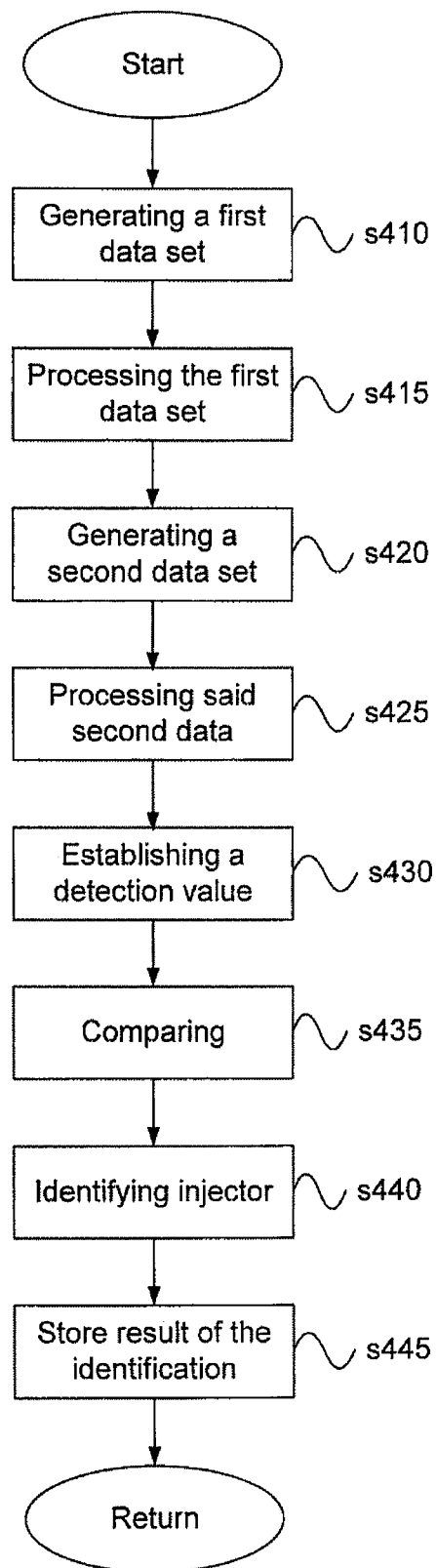


Fig. 4

6/6

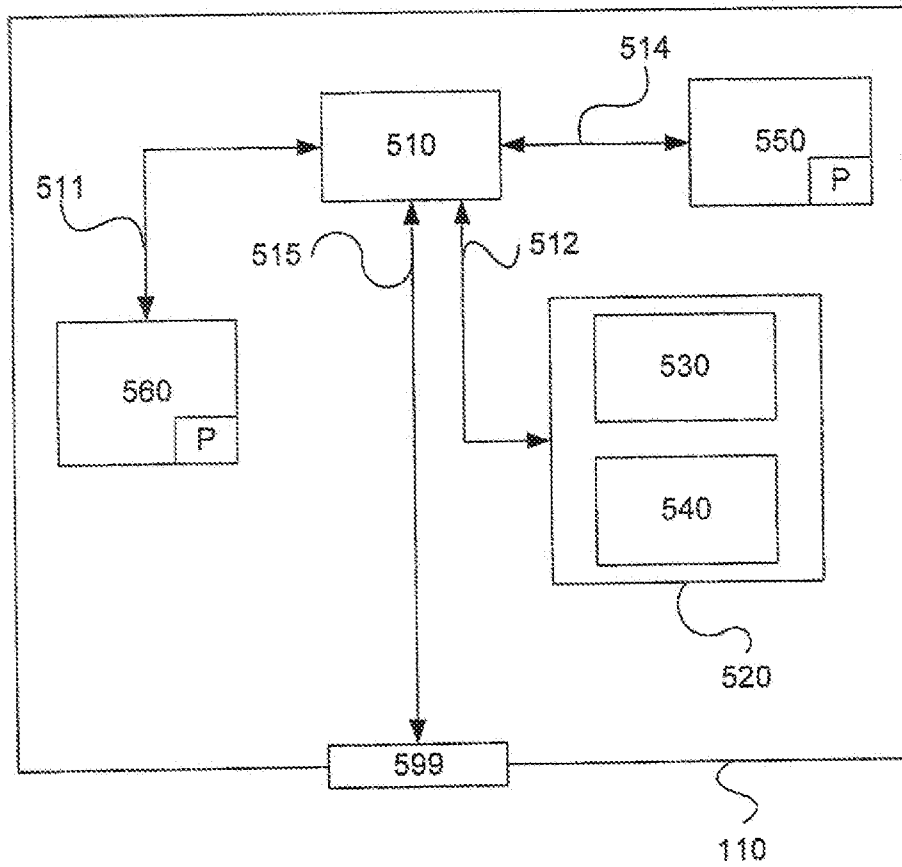


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2008/050519

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: F02M, F02D, G01M

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 5278760 A (W.R.RIBBENS ET AL), 11 January 1994 (11.01.1994), column 1, line 38 - line 42; column 3, line 24 - line 42; column 7, line 25 - line 36, col.12-li.62-li.68 --	1-21
X	US 5515720 A (D.J.REMBOSKI ET AL), 14 May 1996 (14.05.1996), column 3, line 50 - line 61; column 8, line 14 - line 27 --	1-21
X	US 20050033501 A1 (L.Y.LIU ET AL), 10 February 2005 (10.02.2005), paragraphs [0008], [0022],[0023],[0042]-[0045],[0059],[0064] --	1-21

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 August 2008

Date of mailing of the international search report

19-08-2008

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Sture Elnäs / itw
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2008/050519

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5699252 A (S.J.CITRON ET AL), 16 December 1997 (16.12.1997), column 7, line 62 - column 8, line 5 --	1-21
X	US 5044195 A (J.V.JAMES ET AL), 3 Sept 1991 (03.09.1991), column 7, line 9 - line 17, figure 3 --	1-21
X	US 5699253 A (G.V.PUSKORIUS ET AL), 16 December 1997 (16.12.1997), column 5, line 40 - line 48; column 8, line 36 - line 44 -- -----	1-21

International patent classification (IPC)**F02M 65/00** (2006.01)**F02D 41/14** (2006.01)**G01M 15/11** (2006.01)**Download your patent documents at www.prv.se**

The cited patent documents can be downloaded at www.prv.se by following the links:

- In English/Searches and advisory services/Cited documents (service in English) or
- e-tjänster/anförda dokument(service in Swedish).

Use the application number as username.

The password is **GQHDLVCSO**.

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/06/2008

International application No.

PCT/SE2008/050519

US	5278760	A	11/01/1994	DE	4227104 A,C	18/03/1993
				JP	6207551 A	26/07/1994
				US	5487008 A	23/01/1996
				US	5200899 A	06/04/1993
				US	5239473 A	24/08/1993

US	5515720	A	14/05/1996	DE	69529052 D,T	17/04/2003
				EP	0720735 A,B	10/07/1996
				JP	9503270 T	31/03/1997
				WO	9603630 A	08/02/1996

US	20050033501	A1	10/02/2005	CN	1717690 A	04/01/2006
				EP	1652124 A	03/05/2006
				JP	2006515911 T	08/06/2006
				US	6885932 B	26/04/2005
				WO	2005017803 A	24/02/2005

US	5699252	A	16/12/1997	WO	9320427 A	14/10/1993

US	5044195	A	03/09/1991	CA	2047956 A,C	25/02/1992
				GB	2247319 A,B	26/02/1992
				GB	9114978 D	00/00/0000
				US	5044194 A	03/09/1991
				US	5095742 A	17/03/1992
				US	5109695 A	05/05/1992

US	5699253	A	16/12/1997	DE	69617513 D,T	02/05/2002
				EP	0736760 A,B	09/10/1996
				JP	8284739 A	29/10/1996
