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(54) **Engine system implementing speed parameter-based injector balancing**

(57) A method is disclosed for operating an engine that may have at least one cylinder with a piston reciprocally movably arranged. The method may include measuring a speed parameter of the engine. Information about a variation of the speed parameter associated with firing of the at least one cylinder may be obtained. Based on this information, an amount of fuel that may be supplied into the cylinder may be regulated so that an actual speed parameter variation value may be obtained which may be substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values. In another aspect of the disclosure an engine may be provided that may have a sensor for sensing an engine speed parameter and that may have a controller that can perform the above method.

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Description

Technical Field

[0001] The disclosure relates to an engine system and more particularly to an engine system that implements speed parameter-based injector balancing.

Background

[0002] Internal combustion engines include at least one cylinder in which a piston is reciprocally movable. The reciprocal movement of the piston is converted into a rotational movement of a crankshaft. Generally, the rotational movement of the crankshaft is used for driving a load. Fuel and air are supplied to the cylinder chamber and ignited with an ignition arrangement or by self ignition through compression. When a higher speed is necessary more fuel is supplied to the cylinder. For this purpose, a controller can be present to vary engine operation based on a signal indicative of the rotational speed of the crankshaft.

[0003] Combustion engines with a common rail injection system are generally known. In this type of combustion engine multiple combustion chambers are provided. An injector is allocated to each combustion chamber, with each injector connected to a common high-pressure rail, generally referred to as common rail, for supplying fuel. In common rail systems, but also in other types of internal combustion engines with fuel injection, due to production tolerances of the injectors and other factors, variations with regard to the quantity of fuel injected by individual injectors occur. This difference in quantity of fuel injection leads to variations in the power which is provided by each piston. That is undesirable in view of an unbalanced load of the various cylinder/piston assemblies and, consequently, an uneven wear of these cylinder/piston assemblies. Further, it may lead to vibrations in the motor block which is undesired.

[0004] One known method to account for this variation is to measure the injection characteristics of each injector after production and to note it on the injector in coded form, for example in the form of a barcode. When the injector is fitted to an engine, this information is then entered into the control unit of the engine by a corresponding reading device. The control unit is then able to control the injectors using their unique, individually measured injection characteristics in order to provide uniform injection among the engine's combustion chambers. This type of method is called electronic trim or e-trim.

[0005] The method known as e-trim, however, is rather complex and may require a special reading device when injectors are installed in an engine in order to import the coded information of the individual characteristics of the injector into the engine control unit. For the correct import of this information, a certain degree of training and care are required. Also, with the e-trim method the injection characteristics of the injectors are measured only in the new state. Therefore, the method is not able to take into account the effect of wear and tear which changes the injection characteristics of the injector throughout its service life. This may lead to problems if, for example, a single or several injectors are changed in an engine while others are not. In this case, the same engine is provided both with new injectors, the injection characteristics of which are known in the new state, and with old injectors, the injection characteristics of which were originally known but which may have changed. However, because the engine control assumes that the old injectors still have the same injection characteristics as in the new state, considerable differences can arise with regard to the injection of fuel into the individual combustion chambers.

[0006] In large engines, for example in engines for marine applications, it is known to monitor the exhaust gas temperatures of the individual combustion chambers and to issue a warning if the exhaust gas temperature of a combustion chamber substantially deviates from the exhaust gas temperatures of the other combustion chambers. This type of temperature deviation can be due to different reasons and may indicate a malfunction or damage to the combustion engine. One source of exhaust gas temperature deviation is the quantity of fuel which has been supplied to each combustion chamber, and this can depend upon normal tolerances of the fuel injection system. For example, injectors often have flow rate tolerances of +/- 5% and more. Some current injectors have a flow rate tolerance of + 2.5% and -1.5%.

[0007] The present disclosure is aimed at overcoming or alleviating at least some of the problems associated with the prior art.

Summary of the Invention

[0008] In one aspect of the disclosure a method for operating an engine may be provided. The engine may have at least one cylinder with a piston reciprocally movably arranged. The method may include measuring a speed parameter of the engine. Information about a variation of the speed parameter associated with firing of the at least one cylinder may be obtained. Based on this information, an amount of fuel which may be supplied into the cylinder may be regulated so that an actual speed parameter variation value may be obtained which may be substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

[0009] In another aspect of the disclosure an engine may be provided which may include at least one cylinder and a corresponding piston reciprocally movable in the at least one cylinder. The engine may further include a sensor situated to sense a speed parameter of the engine. A controller may be included which may be connected to said sensor. The controller may be configured to analyze a signal from the sensor indicative of the speed parameter in order to obtain information about a speed parameter variation associated with the firing of the at least one cylinder. The controller may be configured to, based on this information, regulate an amount of fuel which may be supplied into the at least one cylinder so that an actual speed parameter variation value of the at least one cylinder may be obtained which may be substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

Brief Description of the Drawings

[0010] Fig. 1 is a schematical cross section of an embodiment of an engine;

[0011] Fig. 2 is a diagram showing the value of the actual speed parameter versus the crank shaft angle in normal operation;

[0012] Fig. 3 shows a similar diagram as shown in Fig. 2 in which the second cylinder does not operate as desired;

[0013] Fig. 4 shows a similar diagram as Figs. 2 and 3 in which the second cylinder does not operate at all;

[0014] Fig. 5 is a flow chart showing possible process steps of an exemplary embodiment of the control system.

Detailed Description

[0015] Fig. 1 shows a longitudinal cross section of an exemplary embodiment of a combustion engine 1. The combustion engine 1 may have at least one combustion chamber 2, that may be enclosed by a combustion cylinder 3. In each chamber a piston 4 may be reciprocally moveable. Each piston may be connected via a connecting rod 5 to a crankshaft 6. The reciprocal movement of the pistons 4 in the cylinders 3 may drive the crankshaft 6. The embodiment shown in Fig. 1 has six cylinders. However, the present disclosure is aimed at engines having any number of combustion chambers or even a single combustion chamber.

[0016] Each combustion chamber may include a fuel inlet 25. The fuel inlet 25 may be provided with a fuel injector 7 in the corresponding cylinder head 8. Each injector 7 may have a nozzle tip 9 pointing into the corresponding combustion chamber 2 for injecting fuel into the combustion chamber 2 and forming a fuel outlet. The injectors 7 may be connected through a fuel line 10 to a common high pressure rail 11, generally indicated as common rail. The injectors 7 may be controllable via control valves 12. The control valves 12 may be electromagnetically energized via electromagnetic acutuators 13. The electromagnetic actuators may be controlled by a controller 14. Instead of, or in addition to electromagnetic actuators 13, also hydraulic or pneumatic actuators may be used. The controller 14 may be an electrical, hydraulic or pneumatic controller 14. The controller 14 may be connected to the respective actuators 13 via control lines 15. In one embodiment the controller 14 may be configured to vary the opening time of a each control valve 12 to regulate the amount of fuel that is supplied into each of the plurality of cylinders. In another embodiment, the control valves 12 may have a variable throughput opening and the controller 14 may be configured to adjust the throughput opening of each of the plurality of control valves 12 to regulate the amount of fuel that is supplied into each of the plurality of cylinders 2. The common rail 11 may be pressurized via a high pressure pump 29 which may be connected to the common rail 11 via a fuel line 16 in which a check valve 17 may be present. The high pressure fuel pump 29 may be driven by a shaft 18 which may be driven via a gear assembly 19 by the crankshaft 6. It is also possible that the high pressure fuel pump 29 is driven by a separate motor or by other rotating parts of the engine. The high pressure fuel pump 29 may be fed by a feed pump 20 via a feed line 21. The feed pump 20 may extract the fuel from a fuel tank 22. Alternatively, the high pressure fuel pump 29 may also directly extract the fuel from a fuel tank. Instead of a high pressure common rail 11, the fuel injectors 7 may also be connected to separate high pressure fuel sources. For example a high pressure pump may be provided for each fuel injector. A plunger pump having a corresponding plunger for each fuel injector may be provided. In another embodiment a rotary pump having a corresponding pump element for each fuel injector may be provided.

[0017] A sensor 23 may be provided which may be situated to sense a speed parameter of the engine. The sensor may be connected via a signal line 24 to the controller 14. In the embodiment shown, the sensor is situated to sense the rotation of the crank shaft. However, the sensor may also be situated to sense a speed parameter of other parts of the engine of which the movement is directly related to the speed of the crank shaft 6. The sensor may, for example, be situated to sense the rotational speed of the gear train 19 or to sense the rotational speed parameter of the high pressure pump shaft 18. Also other rotating parts such as, for example, a camshaft, if present, may be used to sense the speed parameter thereof with the sensor. It is also feasible that the reciprocal movement of a piston 4 is sensed by the sensor. In one embodiment the sensor 23 may be a speed sensor, for example, for measuring the rotational speed of a rotating part, such as, for example, the crankshaft, the camshaft or the gear train 19. In another embodiment the sensor may also be a linear speed sensor for measuring the linear speed of a linearly moving part, such as, for example a piston 4 or a connecting rod 5. In yet another embodiment the sensor 23 may also be an acceleration sensor which produces a signal which is indicative of acceleration of a moving part. The signals produced by the sensor 23 may be transmitted to the controller 14 via control line 24. The control line 24 may be a physical line but may also be a wireless connection. Also the control lines 15 via which the fuel injectors 7 may be connected to the controller 14 may be of a physical or a wireless type.

[0018] The accuracy with which the sensor 23 senses the speed parameter signal may be such that it is able to produce a signal which varies as a consequence of the stroke which is made by a piston 4. In view thereof, the signal may not be a mean value of the speed parameter, for example, produced during the complete rotation of the crank shaft. Instead, the speed parameter may be sensed by the sensor 23 such that for each angle of the crankshaft 6 a value of the speed parameter may be obtained. Thus, a speed parameter variation may be measured within a stroke made by a piston 4. As a consequence, the influence of the combustion on the speed parameter may be sensed by the sensor 23. In view thereof, when a sampled signal may be provided by the sensor, the sampling frequency of the sensor 23 may be an order or more higher than the rotational speed of the engine.

[0019] Fig. 2 shows a diagram of a four cylinder engine in which the rotational speed is set out on the vertical axis and the crankshaft angle is set out on the horizontal axis. The plotted line shows the speed variation of the crankshaft 6 caused by or associated with the firing of respectively cylinder 1, cylinder 3, cylinder 4 and cylinder 2 of the four cylinder engine. The plotted line clearly shows that the firing causes an increase of the rotational speed which is indicated by the upward peaks 26 shortly after 0°, 180°, 360° and 540° of the crankshaft angle. The compression of the gases in a combustion chamber leads to a slight decrease in the rotational speed, which decreases are indicated by the downward peaks 27 shortly before 180°, 360°, 540° and 720° of the crank shaft angle. The mean rotational speed, indicated by dotted line 28, is 600 rotations per minute in the present example. Fig. 2 is the pattern which may be obtained when all injectors 7 function properly.

[0020] In this example, the rotational speed of the crankshaft 6 may indicate the speed parameter value. As stated before, the speed parameter value may, in other embodiments also be a rotational speed or acceleration of a camshaft or of a gear train. Further, the speed parameter value may, in other embodiments, be a linear speed or linear acceleration of a connecting rod or a piston.

[0021] From this plot or from the data that forms the basis of this plot, a speed parameter variation value may be determined for each piston/cylinder-assembly. The speed parameter variation value may, for example, be the absolute height of the peak caused by or associated with the firing. The speed parameter variation value may also be the height of the peak minus the mean rotational speed of the crankshaft 6. The speed parameter variation value may also be the actual value of the acceleration of the rotational speed of the crankshaft 6 associated with the firing of a piston/cylinder-assembly. The speed parameter variation value may be any value that indicates the variation, normally increase, of the speed parameter value caused by or associated with the firing in each one of the specific piston/cylinder assemblies. In other words, when a combustion takes place in a piston/cylinder-assembly, this may lead to an impulse that may cause an increase of the rotational speed of the crankshaft. The impulse may also cause increase of the linear speed of the piston. The impulse may also cause a temporary acceleration the crankshaft and the piston. The speed parameter variation value may be an indication of the variation in the speed parameter value caused by or associated with the firing in a piston/cylinder-assembly. Such a speed parameter variation value may be determined for each piston/cylinder-assembly and may indicate whether the firing in a specific piston/cylinder-assembly leads to the desired effect.

[0022] Fig. 3 shows a similar figure as Fig. 2. However, in this example, the injector 7 of the second cylinder is injecting less fuel than the other cylinders. As a consequence thereof, the acceleration peak 26' produced by the second piston/cylinder-assembly is less high than the acceleration peaks 26 produced by the other piston/cylinder-assemblies. In other words, the speed parameter variation value which may be determined from the speed parameter values that may be measured by the sensor, may be outside a desired range of speed parameter variation values. Controller 14 may comprise a routine in which the control of actuator 13 of the injector 7 of the second cylinder is adjusted so that the amount of fuel which is supplied into the combustion chamber 2 of second cylinder 3 may lead to a speed parameter variation value which may be substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

[0023] Fig. 4 shows a similar diagram as shown in Figs. 2 and 3. However, in this example, the second cylinder does not seem to function at all. At least, the second cylinder does not produce an acceleration peak of the speed parameter value measured by sensor 23. This may for example indicate that the injector 7 of the second cylinder is broke down and should be replaced.

[0024] Fig. 5 shows a flow chart in which a possible control scheme which can be used by controller 14 is schematically depicted.

Industrial Applicability

[0025] The engine system may be applicable in any combustion engine having controllable fuel injection per cylinder. The disclosure provides a reliable system for balancing an engine with one or more cylinders by determining whether an actual speed parameter variation value is within a range of desired speed parameter values. The flow chart of Fig. 5 shows an embodiment for controlling the various injectors of a combustion engine. The individual process steps may be controlled by the controller 14. In block 100 the engine may be started and the individual injectors 7 may be controlled by means of a fuel map, as is common in engine technology.

[0026] Next, in block 102 an actual speed parameter variation value SP^{act}_n associated with the firing of cylinder N is determined. This determination may be repeated for each cylinder as indicated in block 104. When the actual speed parameter variation values for a plurality or all cylinders n are determined, the controller 14 may determine a desired speed parameter variation value SP^{des} as indicated in block 106. The desired speed parameter variation value SP^{des} may, for example, be determined by the average value of the various actual speed parameter variation values SP^{act}_n. However, also other methods for determining a desired speed parameter variation value SP^{des} may be used. For example, the controller 14 may have access to a list or a map of desired speed parameter variation values in its memory, wherein each desired speed parameter variation value SP^{des} may correspond with a certain position of a fuel controller of the engine. Also other factors may determine the desired speed parameter variation value SP^{des}, for example, the torque of the load which may be driven by the engine, the outside temperature, the temperature of the engine, and/or the type of fuel used. When a single cylinder engine is to be controlled, the average value of the speed parameter variation values is not a feasible entity to determine a desired speed parameter value SP^{des} because only one piston/cylinder-assembly is available for determining an average.

[0027] Next, as shown in block 108 the actual speed parameter variation value SP^{act}_n of a certain cylinder n may be compared with the desired speed parameter variation value SP^{des}. When the actual speed parameter variation value SP^{act}_n for cylinder n is larger than the desired speed parameter variation value SP^{des} plus a certain threshold 1 value, the amount of fuel which is injected by the injector 7 in cylinder N may be decreased as indicated in block 110. When it is determined in block 108 that the actual speed parameter variation value SP^{act}_n for cylinder n is not larger than the desired speed parameter variation value SP^{des} plus the threshold1 value, then it may be determined in block 112 whether the actual speed parameter variation value SP^{act}_n for cylinder n is smaller than the desired speed parameter minus a certain threshold2 value. Threshold1 value and threshold2 value may be used to define a certain range around the desired speed parameter variation value SP^{des} . If SP^{act}_n is smaller than (SP^{des} + threshold1) and larger than (SP^{des} - threshold2), then the actual speed parameter variation value SP^{act}_n for cylinder n may be in a desired range and the above procedure may be followed for the next cylinder n+1. As indicated with block 114, consequently, a new desired speed parameter variation value SP^{des} may be determined and the range comparison may be made for the next cylinder n+1. In another embodiment it may also be possible that the range determination for the cylinder n+1 is done without first determining a new desired speed parameter variation value SP^{des}.

[0028] When in block 112 the actual speed parameter variation value for cylinder n is smaller than the desired speed parameter variation value minus a threshold2, then the actuator 13 for injector 7 of that cylinder may be controlled such that the fuel injection for cylinder n is increased as indicated in block 116. In order to determine whether the actual speed parameter variation value for cylinder n is in the desired range, the range comparison may be repeated for that cylinder when an increase or a decrease of fuel injection for that cylinder has taken place. However, when such an adjustment of fuel injection has not been effected, the range comparison may be performed for the next cylinder n+1 as already indicated above. It is of course possible that, even after several attempts to get the actual speed parameter variation value SP^{act}_n of a certain cylinder n within the desired range, an adjustment of the nozzle actuation so that the speed parameter variation value SP^{act}_n is in the desired range is still not achieved. In order to prevent endless attempts to correct the actual speed parameter variation value SP^{act}_n for a certain cylinder n without success, block 120 may be provided in which the number of attempts to get the actual speed parameter variation value SP^{act}_n in the desired range may be counted and compared with a set value. When the counted number is larger than the set value, an error message may be provided. The engine may even be stopped in order to prevent damage to the engine due to the fact that one of the cylinder/piston-assemblies is not working properly. When the number of attempts for cylinder n is less or equal than the set value, another attempt to get the actual speed parameter variation value SP^{act}_n within the range may be taken.

[0029] With a control system of which Fig. 5 shows an example, the differences between the various injectors 7 due to wear or due to manufacturing tolerances may be adjusted. This may prevent an uneven wear of the cylinder/piston assemblies. Further, it may prevent undesired vibrations in the engine. In fact, the control system may provide that the speed parameter variation values for at least two, or all of the cylinders are substantially equal in case of a multi cylinder engine or within a range of desired speed parameter variation values. In case of a single cylinder engine, the system may provide that the actual speed parameter variation value SP^{act}_n is always in a desired range of speed parameter variation values SP^{des}. When the actual speed parameter variation value SP^{act}_n is outside the range, an error message may be provided, so that the user of an engine may be prompted to check the injector 7 and replace it when necessary. It is even possible, that the engine is stopped when the actual speed parameter variation value SP^{act}_n is outside an even larger range of desired speed parameter variation values SP^{des}.

[0030] It is important to note that the speed parameter variation value may be a rotational speed, a rotational speed difference, an acceleration or an acceleration difference and that the speed parameter variation value may be measured so accurately, that for each cylinder the effect of that cylinder on the speed parameter variation value may be determined per stroke. It should be noted that a multitude of variations on the control flow chart as depicted in Fig. 5 is possible. For example, instead of counting the number of repetitions for obtaining a desired speed parameter variation value before an error message is provided, it may also be possible that the actuation signal which may be given to a certain injector may be compared with a range of actuation signals, for example according to a fuelling map as stored in the memory of the controller 14.

[0031] The change to the actuation signal wave form of the various injectors 7 may be stored in a memory of the controller 14. The change may indicate that a certain injector 7 has to be replaced by a new injector 7. Furthermore, the recorded change values may be used as a basis for actuating the individual injectors 7 when an engine 1 is restarted. In this way, during normal operation of the engine 1, it is possible for the engine 1, when restarted, to be operated from the start with an optimized actuation map. Following maintenance or repair work to the engine 1, the changed values may be, however, reset to the normal actuation map.

[0032] The disclosed method and system for controlling the fuel injection into the combustion chamber in a combustion engine may provide improved engine performance and reduced wear and reduced vibration in the engine.

[0033] It will be apparent to those having ordinary skill in the art that various modifications and variations can be made to the disclosed injector balancing. Other embodiments will be apparent to those having ordinary skill in the art from consideration of the specification. It is intended that the specification and examples be considered as exemplary only. Other aspects, features and advantages will be apparent upon an examination of the attached drawings and appended claims.

Claims

1. A method for operating an engine having at least one cylinder with a piston reciprocally movably arranged therein, the method comprising:

    measuring a speed parameter of the engine;
    obtaining information about a variation of said speed parameter associated with the firing of the at least one cylinder; and
    based on this information, regulating an amount of fuel which is supplied into the cylinder so that an actual speed parameter variation value is obtained which is substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

2. The method according to claim 1, wherein:

    the engine has a plurality of cylinders and a corresponding plurality of pistons; and the method further includes:

        obtaining information for at least two of the cylinders about a variation of the speed parameter associated with the firing of the at least two cylinders; and
        based on the information obtained for each of the at least two cylinders, regulating an amount of fuel which is supplied the at least two cylinders so that for each of the at least two of cylinders an actual speed parameter variation value is obtained which is substantially equal to the desired speed parameter variation value or within a range of desired speed parameter variation values.

3. The method according to claim 2, wherein the supply of fuel in each of the plurality of cylinders is regulated such that the speed parameter variation values associated with the firing of each of the plurality of cylinders are substantially equal to or within a desired range of each other.

4. The method according to any one of claims 1-3, wherein the speed parameter is rotational speed of at least one of a crankshaft and a camshaft of the engine.

5. The method according to any one of claims 1-3, wherein the speed parameter is rotational acceleration of at least one of a crankshaft and a camshaft of the engine.

6. The method according to any one of claims 1-5, wherein the amount of fuel supplied is decreased when an actual speed parameter variation value is above the desired speed parameter variation value plus a first threshold value, and wherein the amount of fuel supplied is increased when an actual speed parameter variation value is under the desired speed parameter variation value minus a second threshold value.

7. An engine comprising:

    at least one cylinder and a corresponding piston reciprocally movable in the at least one cylinder;
    a sensor situated to sense a speed parameter of the engine; and
    a controller connected to the sensor and configured to:

        analyze a signal from the sensor indicative of the speed parameter in order to obtain information about a speed parameter variation associated with the firing of the at least one cylinder; and
        based on this information, regulate an amount of fuel which is supplied into the at least one cylinder so that an actual speed

parameter variation value of the at least one cylinder is obtained which is substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

8. The engine according to claim 7, wherein:

the engine has a plurality of cylinders and a corresponding plurality of pistons; and wherein the controller is configured to:

obtain for at least two of the cylinders, information about the speed parameter variation value associated with the firing of a respective one of the plurality of cylinders; and to regulate, based on this information, an amount of fuel which is supplied into each of the at least two cylinders so that for each of the at least two cylinders an actual speed parameter variation value is obtained which is substantially equal to a desired speed parameter variation value or within a range of desired speed parameter variation values.

9. The engine according to any one of claims 7-8, wherein the controller is configured to regulate the supply of fuel in each of the plurality of cylinders such that the actual speed parameter variation value associated with the firing of the plurality of cylinders is substantially equal to, or within a desired rang of each other.

10. The engine according to any one of claims 7-9, wherein the engine includes a sensor situated to measure a signal which is indicative of the speed parameter.

11. The engine according to claim 10, wherein the sensor is a rotational speed sensor.

12. The engine according to claim 10, wherein the sensor is an acceleration sensor.

13. The engine according to any of claims 10-12, wherein the sensor senses the speed parameter of at least one of crankshaft and a camshaft of the engine.

14. The engine according to any one of claims 7-13, wherein:

a fuel inlet of each cylinder is provided with a control valve having an inlet which is connected with a fuel supply under pressure, and an outlet which is in fluid communication with a corresponding one of the plurality of cylinders; and the controller is configured to regulate an amount of fuel which is supplied into each one of the plurality of cylinders by opening the control valve.

15. The engine according to claim 14, wherein the controller is configured to vary the opening time of the control valve to regulate the amount of fuel which is supplied into the plurality of cylinders.

16. The engine according to claim 14, wherein the control valve has a variable throughput opening, and the controller is configured to adjust the throughput opening of the control valve to regulating the amount of fuel which is supplied into the plurality of cylinders.

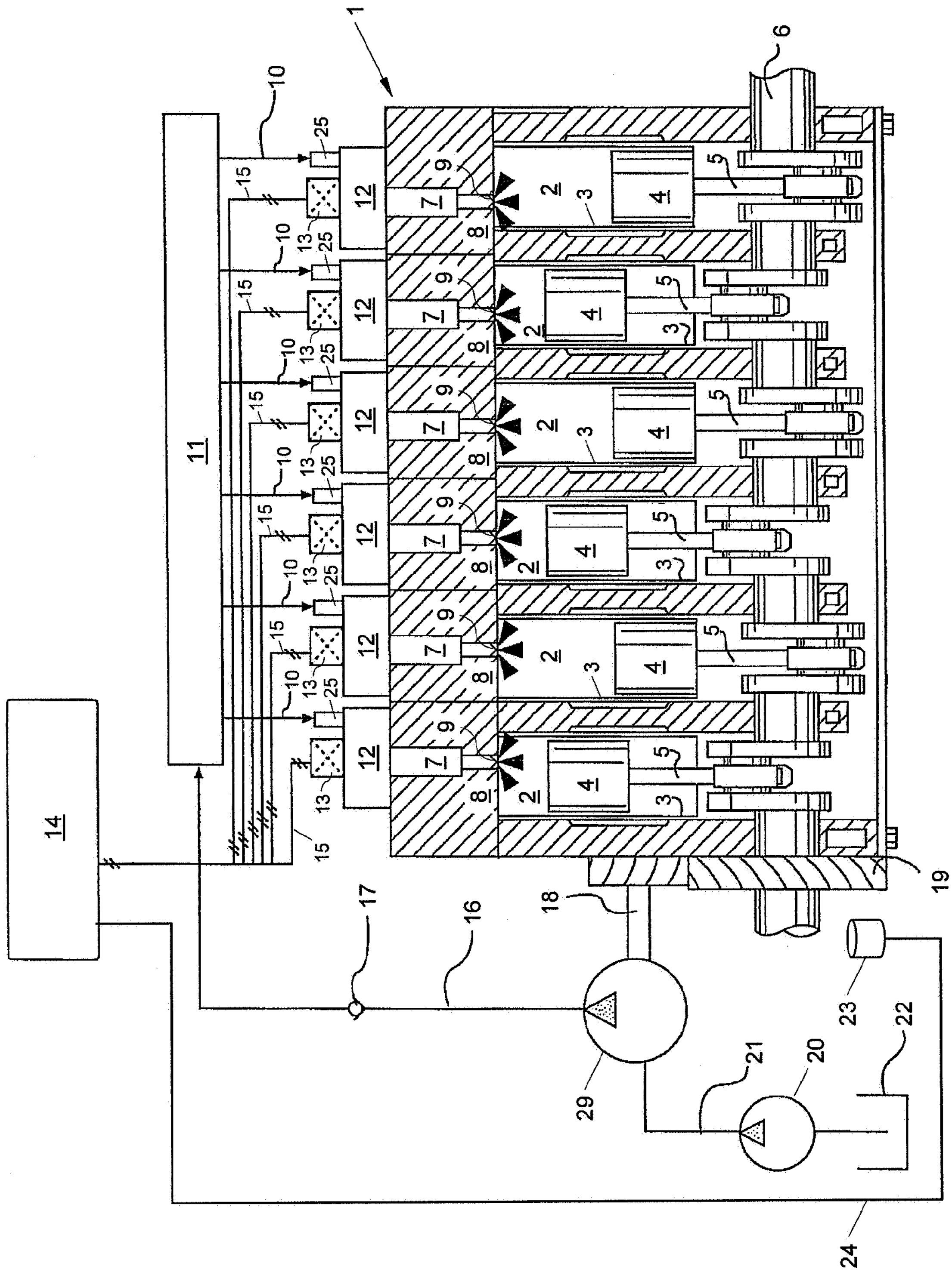

Fig. 1

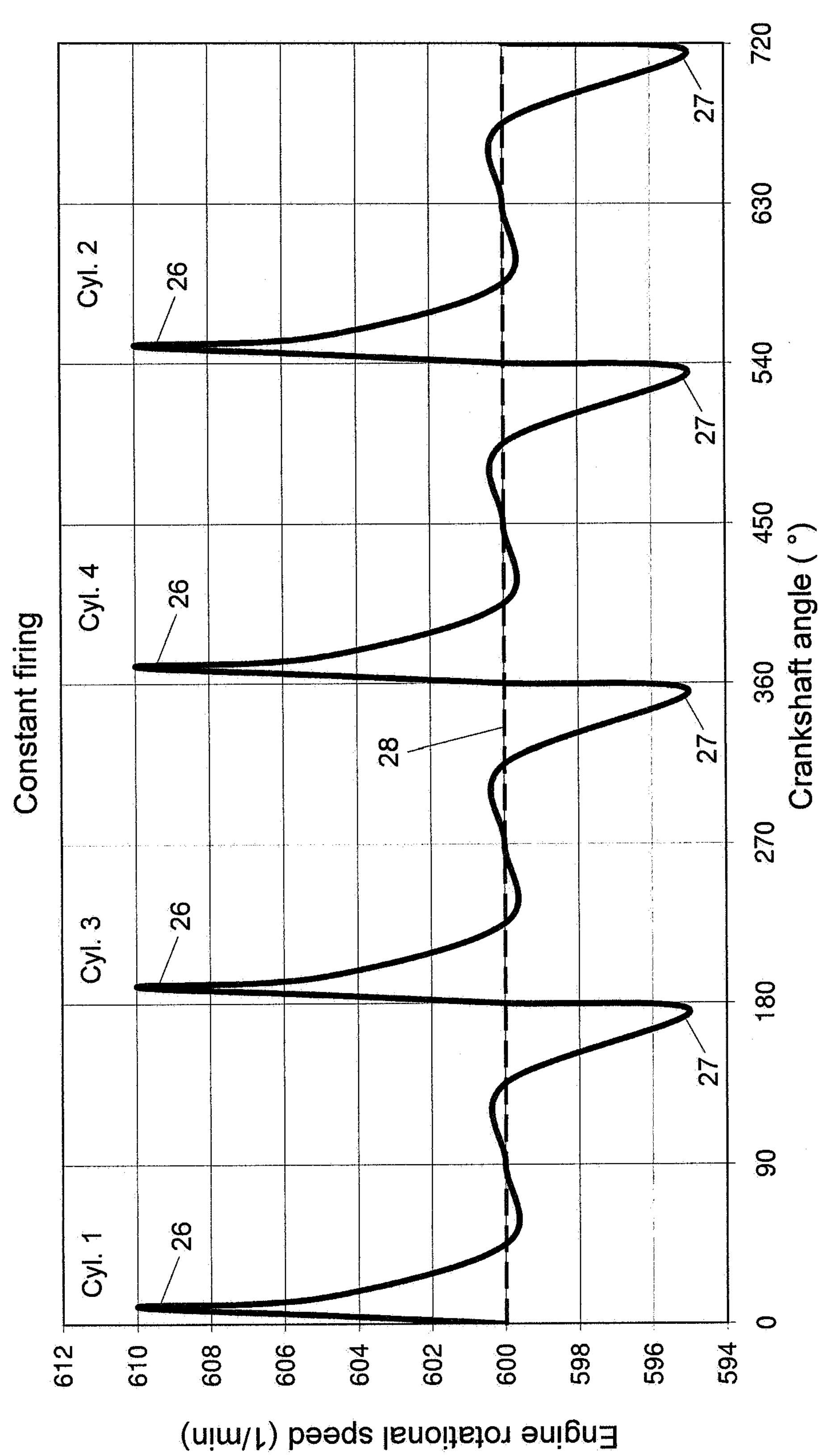
Constant firing
Cyl. 1
Cyl. 3
Cyl. 4
Cyl. 2
26
27
28
Engine rotational speed (1/min)
612
610
608
606
604
602
600
598
596
594
Crankshaft angle (°)
0
90
180
270
360
450
540
630
720

Fig. 2

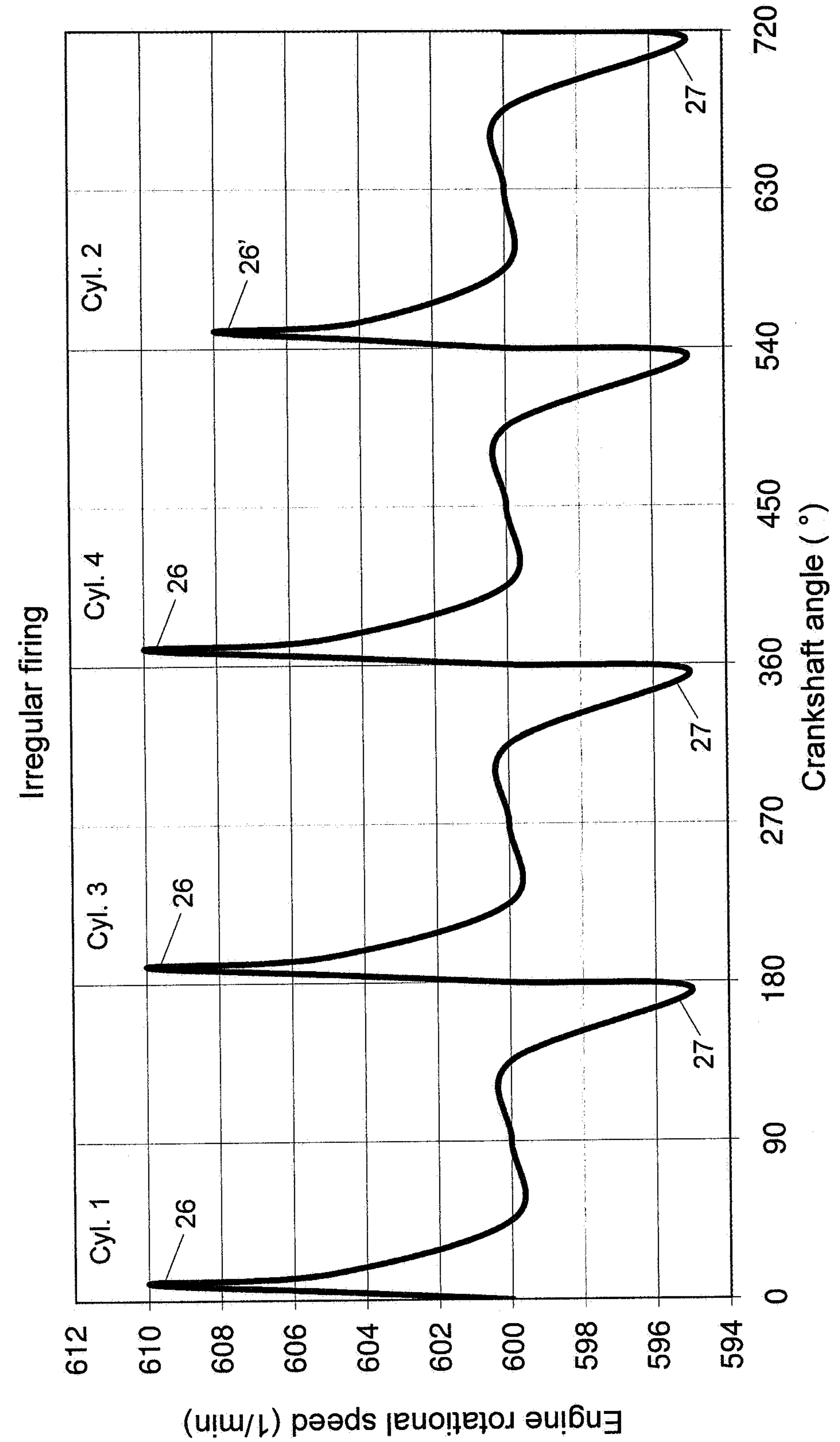
Irregular firing
Engine rotational speed (1/min)
612
610
608
606
604
602
600
598
596
594
Crankshaft angle (°)
0
90
180
270
360
450
540
630
720
Cyl. 1
Cyl. 3
Cyl. 4
Cyl. 2
26
26
26
26'
27
27
27

Fig. 3

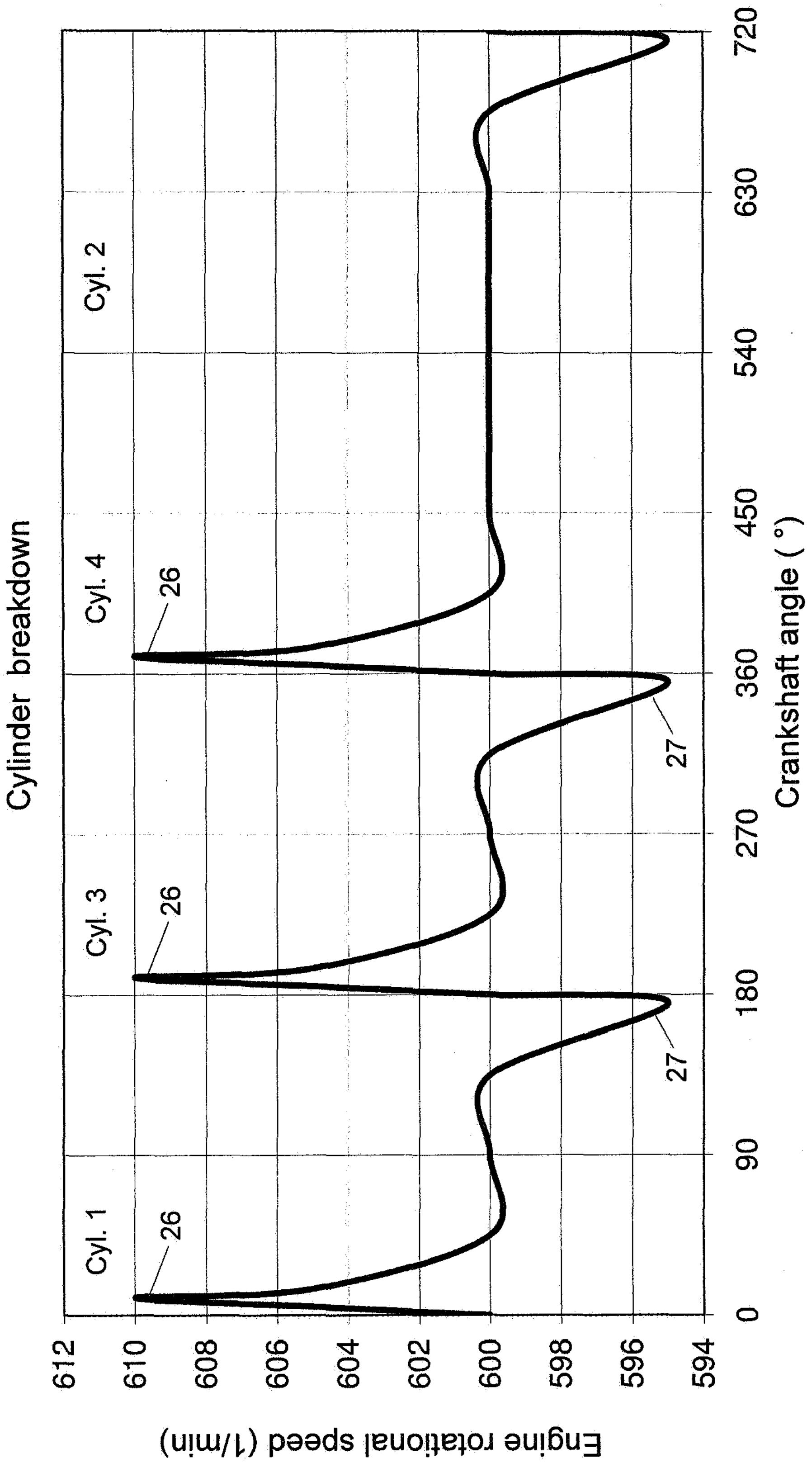
Cylinder breakdown
Engine rotational speed (1/min)
612
610
608
606
604
602
600
598
596
594
Crankshaft angle (°)
0
90
180
270
360
450
540
630
720
Cyl. 1
Cyl. 3
Cyl. 4
Cyl. 2
26
26
26
27
27

Fig. 4

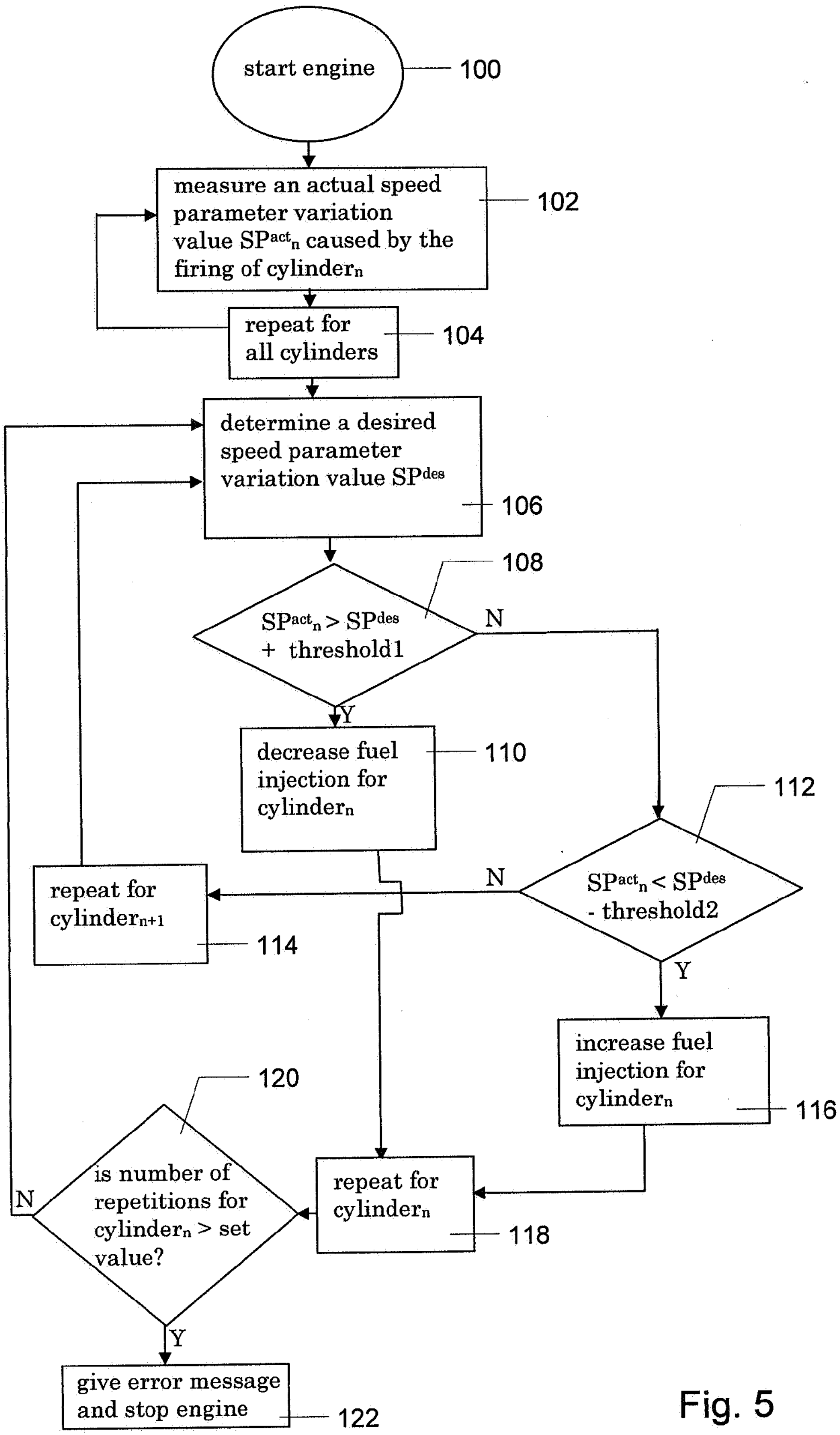
start engine
100
measure an actual speed parameter variation value SPactn caused by the firing of cylindern
102
repeat for all cylinders
104
determine a desired speed parameter variation value SPdes
106
108
SPactn > SPdes + threshold1
N
Y
decrease fuel injection for cylindern
110
112
repeat for cylindern+1
114
N
SPactn < SPdes - threshold2
Y
increase fuel injection for cylindern
116
120
is number of repetitions for cylindern > set value?
N
Y
repeat for cylindern
118
give error message and stop engine
122

Fig. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 12 1925

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	DE 197 41 965 C1 (SIEMENS AG [DE]) 21 January 1999 (1999-01-21) * abstract; claim 1; figures 1,2 * * column 2, line 21 - column 2, line 53 *	1-15 16	INV. F02D41/00 F02D41/14
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13 May 2008	Van der Staay, Frank

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