(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 457 644 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.11.2005 Bulletin 2005/47

(51) Int Cl.[7]: **F01L 1/26**, F02D 41/22, F02D 41/14

(21) Application number: **03075727.2**

(22) Date of filing: **12.03.2003**

(54) **Method and apparatus for monitoring the position of a variable valve control**

Verfahren und Vorrichtung zur Überwachung der Stellung einer variablen Ventilsteuerung

Méthode et dispositif pour surveiller la position d'une commande variable de soupapes

(84) Designated Contracting States:
DE GB SE

(43) Date of publication of application:
15.09.2004 Bulletin 2004/38

(73) Proprietor: **Ford Global Technologies, LLC**
Dearborn, MI 48126 (US)

(72) Inventors:
- **Stotsky, Alexander Anatoljevich**
  42252 Göteborg (SE)
- **Eriksson, Sören**
  44290 Kungälv (SE)

(74) Representative: **Ekström, Nils**
Albihns Göteborg AB
P.O. Box 142
401 22 Göteborg (SE)

(56) References cited:
US-A- 4 532 798
US-A- 5 195 470
US-A- 5 359 518
US-A- 6 006 152
US-B1- 6 213 068

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The invention relates to a method for monitoring the position of a variable valve control in a combustion engine according to the preamble of claim 1. In particular the invention relates to a method for monitoring which of a first cam having a first cam profile and a second cam having a second cam profile greater that said first cam profile currently is acting on lift mechanisms for gas exchange valves being arranged for controlling gas exchange into or out from said plurality of cylinders. The invention further relates to an apparatus for monitoring the position of a variable valve control in a combustion engine according to the preamble of claim 10. In particular the invention relates to an apparatus for monitoring which of a first cam having a first cam profile and a second cam having a second cam profile greater that said first cam profile currently is acting on lift mechanisms for gas exchange valves being arranged for controlling gas exchange into or out from said plurality of cylinders.

BACKGROUND ART

[0002] Internal combustion engines for use in, for example, vehicles, must be capable of operation at various engine speeds and loads. The timing of the opening and closing of the intake and exhaust valves must be set to optimise the power output and efficiency of the engine over a reasonable range of speeds and loads.

[0003] For example, in a high output, multi-valve, spark ignition four stroke engine which is designed to operate at high engine speeds, it is generally desirable to provide means, such as cams, to control the opening of the inlet valves which preferably have a long valve opening period, in order to maximise the combustible charge drawn into the combustion chambers during the suction strokes of the engine. This has the advantage of improving the volumetric efficiency of the engine, thereby increasing the maximum power and torque outputs of the engine.

[0004] However, if such an engine is operated at speeds below that at which maximum power is developed, since the inlet valves are open for a relatively long period, some of the combustible charge drawn into each combustion chamber on its suction stroke can be forced back through the valve before it closes. This effect clearly reduces the volumetric efficiency, and hence the output, of the engine. It also causes uneven engine idling and low speed operation, and also makes exhaust emissions more difficult to control.

[0005] It is therefore desirable to additionally provide a valve control mechanism for use only at low engine speeds which has a relatively short operating or opening period.

[0006] Control systems for combustion engines having variable valve control are known from inter alia US 5287830.

[0007] In internal combustion engine with variable valve control, it is necessary to monitor the function of this variable valve control at regular intervals. Generally, known monitoring methods determine the position of a component used to adjust the valve control in order to thus determine the current position of the valve control. However a monitoring method of this kind provides only a general idea of how the valve control is being controlled at a given moment.

[0008] Since variable valve control, such as cam profile switching (CPS) technology, where different cam profiles are used in order to provide different gas exchange characteristics for the cylinders of the engine at different operating conditions, has significant effect on drivability, exhaust emissions and fuel consumption, there is a requirement to have an effective diagnostic method for identification of the system failure. The valve lift event can not be directly measured and special diagnostic algorithms, based on indirect information about the valve lift, are required to identify a failure in the system.

[0009] A couple of methods which allow to detect the CPS state are known. In US Patent 6213 068 detection is based on the difference in the air charge inducted in the cylinders for different lifts. The inducted air charge measured by Manifold Air Flow (MAF) sensor is compared with the air charge model based on the measured position of the throttle flap, intake manifold pressure and engine speed. The CPS state is associated with the error between measured and modeled air charge. A drawback of the method described in the Patent 6213 068 is that the method does not allow cylinder individual failure detection. However, it is suitable for the failure detection of the whole 3 cylinders bank.

[0010] In US 6 006 152 a method for combustion state monitoring using fluctuations of the engine speed is disclosed. The method disclosed therein is based on the fact that the combustion state changes considerably during shifting of valve mode of the engine. The combustion state is monitored via irregularities of the engine speed. Irregularities are associated with the CPS state. The method allows cylinder individual failure detection. The method uses torque estimation technique well known in the literature devoted to the combustion efficiency monitoring functions, see for example US 4 532 592, and references therein.

[0011] However, the techniques described in the prior art documents presented above allow the detection of the CPS state during steady-state only. The invention described in the US Patent 6 006 152 proposes to detect the average value of the nonuniformity of the engine speed fluctuations and compare it with the reference average value of the nonuniformity. During the engine speed transient nonuniformity changes depending on the transient characteristics.

The reference average value, which also depends on the transient characteristics is impossible to find for all the transients. That makes the method described in US Patent 6 006 152 not suitable for the detection of the CPS state during transients. Since switching is likely to occur during engine speed transients, the method disclosed in US 6 006 152 does not provide adequate detection of the CPS state at all engine operating conditions.

[0012] It is worth remarking that there is a number of prior art documents disclosed in the field devoted to the detection of the combustion state of automotive engines via the measurements of the engine speed variations US 4532798, US 5539644, EP 0437057, EP 0609451. In US 4532798 and US 5539644, several methods for measuring variations of the engine speed are provided. However, the main attention is paid to the dependence of the engine speed fluctuations from the road conditions. Namely, the change of the engine speed which occurs in accordance with roughness and smoothness of the road surface was studied. In EP 0437057, a method which takes into account the reciprocating inertia of the pistons is proposed for measuring the engine speed variations. The reciprocating inertia has significant effect on the engine speed fluctuations at high rotational speeds only, therefore the inertia effect can be neglected in the case of the CPS state detection since the cam profile is switched at relatively low engine speeds. It is worth remarking that the techniques for the combustion state monitoring is widely used for the misfire detection (see for example EP 0609451 and references therein).

[0013] In the present Invention, following US Patent 6 006 152, the combustion state of the engine is associated with the CPS state. Despite the fact that the misfire detection problem is not discussed in the present invention the technique proposed here can definitely be applied to solve the misfire detection problem during engine speed transients.

DISCLOSURE OF INVENTION

[0014] An object of the invention is to provide a method for monitoring the position of a variable valve control and in particular detection of the CPS state during transients.

[0015] This object is achieved by a method according to the characterising portion of claim 1. The present invention deals with the transient detection of the position of a variable valve control and in particular the CPS position using nonuniformity of the rotational speed under the transient conditions. In this invention a linear model for the crankshaft speed fluctuations during transients is constructed. Coefficients of the model are found by minimizing the distances from the measured amplitudes to the model outputs. The technique allows the CPS failure detection during engine speed transients via compensation of the transient component of the crankshaft speed fluctuations.

[0016] In preferred embodiments relative distances, i.e., distances from the measured amplitudes to the outputs of the model divided by the output of the model evaluated for every cylinder are averaged for a number of cycles and compared with a reference value.

[0017] Further preferred embodiments are described in the dependent claims.

[0018] Another object of the invention is to provide an apparatus for monitoring the position of a variable valve control in a combustion engine, which is arranged for monitoring the position of a variable valve control and in particular detection of the CPS state during transients. This object is achieved by an apparatus as disclosed in claim 8.

BRIEF DESCRIPTION OF DRAWINGS

[0019] An embodiment of the invention will be described in detail below, with references to appended drawings, where:

Fig. 1 show a diagram of engine speed and crank shaft speed fluctuations at a transient condition,

Fig. 2 show a diagram of crank shaft speed fluctuations, an determined linear model of a transient and relative distances between the amplitudes of the fluctuations and the linear model for a set of combustion numbers at a transient condition,

Fig. 3 show a diagram of an average relative amplitude as a function of a cycle number,

Fig. 4 show a relative average amplitude for individual cylinders,

Fig. 5 show a performance index proposed in US 6 006 152 as a function of cycle number,

Fig. 6 show engine speed variation at an interval where the relative distance had a large value,

Fig. 7 is a schematic diagram of an internal combustion engine with a variable valve control and a control device therefor constructed in accordance with preferred embodiments of the present invention,

Fig. 8 is a side sectional view of a tappet and valve assembly which may be used in connection with the invention in order to provide a first and a second cam profile, and

Fig. 9 show a flow chart of a method for monitoring the position of a variable valve control in a combustion engine having a plurality of cylinders.

MODE(S) FOR CARRYING OUT THE INVENTION

[0020] Initially a theoretical background of the invention will be described with references to figures 1- 6.

[0021] It is known that the time rate change of the crankshaft angular velocity is proportional to the net torque acting on the system divided by inertia moment J.

[0022] Angular acceleration is proportional to the fraction $\frac{Te - Tl}{J}$, where Te is the engine produced torque by all cylinders at the time t, Tl is the engine load torque. Integrating between the times where engine speed gets minimal and maximal values respectively for a single cylinder, whose combustion stroke occurs in the interval, one gets

$$A_i = \omega_f - \omega_s = \int_{ts}^{tf} \frac{Te - Tl}{J} dt \quad \text{(E1)}$$

where A_i is the crankshaft speed fluctuation over the time interval [ts tf], where ts is the start time of the interval and tf is the end time. This fluctuation A_i is the measure of the net engine torque over the interval involved.

[0023] Equation (E1) allows to determine the average value of the torque produced by the cylinder whose combustion stroke occurs in the interval.

[0024] Ideally, in the steady state operation the speed fluctuation is the same for all the cylinders since the speed wave form is regular. However, in real engine even at the steady state the wave amplitudes are not the exactly the same. To obtain a relation for the average torque produced by the engine over all the cylinders, the wave amplitude can be averaged over the engine cycle. To obtain a relation for the average torque produced by cylinder number i during a number of cycles n_c, the wave amplitude can be averaged over the number of cycles involved, i.e.,

$$\overline{A} = \frac{\sum_{i=1}^{N} Ai}{N} \quad \text{(E2)}$$

$$\overline{Ai} = \frac{\sum_{j=1}^{nc} Aij}{nc} \quad \text{(E3)}$$

where $\overline{A}$ is the average amplitude of the engine speed fluctuations over the engine cycle for all N cylinders, $\overline{Ai}$ is the average amplitude of the engine speed fluctuations for the cylinder i over the number of cycles nc, j = 1,...,nc is the cycle number.

[0025] In the method disclosed in US 6 006 152 comparison of the average values calculated by formulas (E2) and (E3) with the reference values depending on the speed and load is suggested with the purpose to detect the CPS state. For the steady-state operation the engine speed remains constant over the engine cycle and the crankshaft speed fluctuations are approximately the same. On the contrary during engine transients the speed fluctuations are different from the steady-state fluctuations due to the changing average speed.

[0026] Therefore the values of the transient crankshaft speed fluctuations are and can not be included in the calculation of the average amplitudes by using formulas (E2) and (E3).

[0027] However, by using a method according to the invention the information about CPS position can still be extracted from the crankshaft speed fluctuations. To this end the average speed during transients should be removed from the performance indexes which are constituted by the average values calculated by formula (E2) and (E3).

[0028] In the present invention a performance indexes are proposed instead of the formulas (E2) and (E3), which allow the transient detection of the CPS failure. This is achieved by removing an average transient component from the indexes received by functions (E2), and (E3).

[0029] At the first step the model of the crankshaft speed fluctuations is constructed. This is done by assigning a function representing a transient component of engine speed fluctuation over said at least one engine cycle, said function being represented by a set of model coefficients.

[0030] Furthermore for a given engine cycle N values of the crankshaft speed fluctuation Ai, i = 1,...N are measured.

[0031] In a preferred embodiment of the invention the assigned function will be linear. Assuming the linearity of the crankshaft speed fluctuations model one gets

$$y_i = c_0 + c_1\, x_i \qquad \text{(E4)}$$

where y_i is the crankshaft speed fluctuations model output, c_0 and c_1 are the model coefficients and x_i = 1, ... N is the number of the amplitude of the fluctuation within the cycle.

[0032] The following sum is minimized:

$$I_j = \sum_{i=1}^{N} (Ai - (c0 + c1\, xi))^2 \qquad I_j \longrightarrow \min \qquad \text{(E5)}$$

with respect to the model coefficients c_0 and c_1,

j= 1,..., nc is the cycle number.

[0033] The minimization problem stated above is well-known least-squares curve fitting problem and can be solved by equating to zero partial derivatives of I_j with respect to c_0 and c_1, i.e., $\frac{\partial I_j}{\partial c_0} = 0$ and $\frac{\partial I_j}{\partial c_1} = 0$.

[0034] Last two equations are solved with respect to c_0 and c_1 for every engine cycle.

[0035] The solution to the minimization problem results in a first performance index, according to the following:

$$k_i = A_i - (c_0 + c1 x_i) \qquad \text{(E5A)}$$

[0036] The coefficient c_0 represents the offset value of the amplitude of the fluctuations and coefficient c_1 is the tangent of the angle which reflects directly the character of the transient. The model (E4) can be seen as model of the average of the crankshaft speed fluctuations. In the steady-state the average value of the fluctuations is constant and c_1 is approximately zero. On the contrary under the transients average value of the crankshaft speed fluctuations changes within the cycle and can be well approximated by the model (E4).

[0037] It is worth remarking that higher order polynomials could be used for modeling the crankshaft speed fluctuations (E4). The model could be constructed using information from several engine cycles. In the embodiment disclosed herein the simplest case is considered.

[0038] The next step is to calculate relative distances between the amplitudes of the fluctuations and the outputs of the model (E4). The relative distances can be used as a second performance index. These distances do not depend on the transient and can be computed as follows

$$d_i = \frac{A_i - (c_0 + c_1 x_i)}{(c_0 + c_1 x_i)} * 100 \qquad \text{(E6)}$$

where i = 1,...,N; N is the number of cylinders.

[0039] A third and a fourth performance indexes can be obtained by reformulating the performance indexes (E2) and (E3) suggested by US 6 006 152. The following third and fourth performance index is obtained:

$$\bar{d} = \frac{\sum_{i=1}^{N} di}{N} \qquad \text{(E7)}$$

$$\overline{di} = \frac{\sum_{j=1}^{nc} dij}{nc} \quad (E8)$$

where $\bar{d}$ is the average relative amplitude of the deviation of the engine speed fluctuations from the average model over the engine cycle for all N cylinders, $\bar{d}_i$ is the average relative amplitude of the deviation of the engine speed fluctuations from the average model for the cylinder i over the number of cycles nc, j = 1,...,nc is the cycle number.

[0040] The fundamental difference between the indexes (E2), (E3) and (E7),(E8) is that (E7) and (E8) compute the average relative values of the deviation of the amplitude from the linear model of fluctuations in the cycle, i.e., remove the effect induced by the engine speed transients.

[0041] A preferred embodiment of a CPS failure detection algorithm can be summarized as follows:

<u>Step1</u>

[0042] Compute the difference Ai between the instantaneous engine speed where it gets minimal and maximal values respectively for a single cylinder, whose combustion stroke occurs in the interval. In Fig. 1 engine speed (rpm) for a single cycle on Volvo 5 cylinder engine is plotted with a line marked with + signs and Ai is the difference between the dashed lines.

<u>Step2</u>

[0043] Compute the coefficients c_0 and c_1 of the model

$$y_i = c_0 + c_1 x_i \quad (E9)$$

for every engine cycle, by minimizing the cost function (E5). Amplitudes Ai (rpm) as a function of the combustion number are plotted in Fig.2 with a line marked with + signs. The output y_i of the model (E9) is plotted with a dashed line.

<u>Step3</u>

[0044] Compute relative distances between the amplitudes of the fluctuations and the outputs of the model (E9).

$$d_i = \frac{A_i-(c_0+c_1 x_i)}{(c_0+c_1 x_i)} *100 \quad (E10)$$

where x_j= 1,...,N is the combustion number in the cycle.
Relative distance d_i (per cent) as a function of cycle number is plotted in Fig. 2 with a line marked with o signs.

<u>Step4</u>

[0045] Compute the average amplitude of the relative deviation of the engine speed fluctuations from the average model over the engine cycle for all N cylinders and the average relative amplitude of the deviation of the engine speed fluctuations from the average model for the cylinder i over the number of cycles nc :

$$\bar{d} = \frac{\sum_{i=1}^{N} di}{N} \quad (E11)$$

$$\overline{di} = \frac{\sum_{j=1}^{nc} dij}{nc} \quad (E12)$$

[0046] Average relative amplitude $\bar{d}$ (per cent) as a function of a cycle number is plotted in Fig.3. Average relative amplitude for the cylinder i, $\bar{d}_i$, i = 1,..., 5 is plotted in Fig. 4, where d1 is a line marked with reference 1, d2 a line marked with reference 2, d3 a line marked with reference 3, d4 a line marked with reference 4 and d5 a line marked with reference 1.

[0047] The performance index (E3) $\bar{A}_i$, i = 1,..., 5, proposed in the US 6 006 152, as a function of a cycle number is plotted in Fig. 5. The Figure shows that the index (E3) is not suitable for use during the transient (the first 20 cycles). During the transient the performance index (E3) has too big values despite of quite equal combustions.

<u>Step5</u>

[0048] Compare the values computed on the previous step with the reference values stored in the memory.

$$\bar{d} = \frac{\sum_{i=1}^{N} di}{N} \geq d_{01} \; (E13)$$

$$\overline{di} = \frac{\sum_{j=1}^{nc} dij}{nc} \geq d_{02} \; (E14)$$

where d_{01} and d_{02} are reference values which are functions of engine speed and load.

[0049] Fig.3 shows that the biggest value the performance index (E11) gets in the cycle 28. Engine speed for the cycle 28 is plotted in Fig.6, which shows significant combustion irregularities in the cycle.

[0050] FIG. 7 shows in schematic form an internal combustion engine 1 equipped with a variable valve control 2. According to a preferred embodiment the variable valve control 2 is arranged to control gas exchange into or out from a plurality of cylinders 3 of the combustion engine 1 by selection of cam shaft profile of a cam shaft 4. The cam shaft 4 has a first cam having a first cam profile and a second cam having a second cam profile greater that said first cam profile, as will be described in further detail below. The variable valve control 2 includes an actuating device 5, which is controlled by an electronic control unit 6. The actuating device 5 manoeuvres the cam shaft in order to set which cam profile is currently is acting on lift mechanisms 7 for gas exchange valves 8. The variable valve control, which in the embodiment shown is arranged on the intake valve, can also be arranged on the exhaust valve.
The invention is also applicable for variable valve control 2 which is arranged to control the position of a camshaft 4, which is variable with respect to the angular position of a crankshaft 8 by means of an adjusting device.

[0051] The adjusting device 5 for change of camshaft mode is controlled by a valve control unit 10 arranged in the electronic control unit 6. The control is performed in a manner know to a person skilled in the art in order to provide switching of camshaft mode in dependence of engine operating condition.

[0052] The electronic control unit 6 furthermore includes an evaluation device 11, and a monitoring device 12. Evaluation device 11 and monitoring device 12 together with crankshaft sensor 9, which in this case acts as a sensing device to detect nonuniformity of the rotational speed of crankshaft 8, together constitute an apparatus for monitoring the position of variable valve control 2.

[0053] Evaluating device 11 receives from crankshaft sensor 9 a signal corresponding to the angular position of crankshaft 8. In the present embodiment, this signal consists of a pulse train, with each pulse corresponding to a specific section of an angle swept by crankshaft 8. At a designated position of the crankshaft, a mark 13 is made that generates a special pulse and therefore makes it possible to determine the absolute position of the crankshaft.

[0054] The evaluating device 11 includes means for measuring engine speed 13 over at least one engine cycle for all cylinders. The measurement is performed in a manner known to a person skilled in the art by performing a time derivative of the angular position provided from the crankshaft sensor.

[0055] The evaluating device 11 furthermore includes means for determining engine speed fluctuations 14 for respective cylinder as the difference between maximum and minimum engine speed at a time interval including the combustion stroke of respective cylinder. The maximum and minimum values are obtained in a known manner from the variation of sampled values of the engine speed. The sampled values vary in a manner as shown in figure 1.

[0056] The maximum and minimum values are stored in a memory 15 arranged in the evaluating device.

[0057] The evaluating device 11 also includes means for assigning 16 a function representing a transient component of engine speed fluctuation over said at least one engine cycle, said function being represented by a set of model coefficients. The means for assigning a function 16 can be arranged by a storage area where the model coefficients are stored. The form of the function is decided when implementing the control device by deciding which form the function should have. In a preferred embodiment the function is chosen to be a linear model.

[0058] The evaluating device furthermore includes means 17 for determining the model coefficients. The means for determining the model coefficient, is preferably constitute by means for minimising a cost function for the determined engine speed fluctuations for respective cylinder in respect of said function representing a transient component and thereby determining said model coefficients. The means for minimising the cost function 17 are constituted by means for least square adaptation of a function to the set of values representing the maximum and minimum values stored in the memory 15 and possibly all sampled values of the engine speed. Means for least square adaptation are well known to a person skilled in the art. The cost function has an appearance as shown in equation (E5)

[0059] The monitoring device 12 includes means for calculating 18 the distance between the determined engine speed fluctuations and a value of said function representing a transient component corresponding to respective determined engine speed fluctuation whereby a first performance index is obtained. The distance is calculated in accordance with formula (E5A).

[0060] In a preferred embodiment, the means for monitoring 12 further includes means 19 for determining a relative distance between the determined engine speed fluctuations and the value of said function representing a transient component in respect of said value of said function representing a transient component corresponding to respective determined engine speed fluctuation for use as a second performance index. The relative distance is determined in accordance with formula (E6).

[0061] In a still preferred embodiment the means for monitoring 12 further includes means for calculating 20 an average amplitude of said relative distance over one engine cycle, wherein said average amplitude is used as a third performance index. The average amplitude is determined in accordance with formula (E7).

[0062] In yet another preferred embodiment the means for monitoring 12 further includes means 21 for calculating an average amplitude of said relative distance over for respective cylinder over a number of engine cycles, wherein said average amplitude is used as a fourth performance index. The average amplitude for respective cylinder is determined in accordance with formula (E8).

[0063] The means for monitoring 12 further includes means 22 for comparing at least one of said performance indexes with reference values stored in a memory 23. The comparison is made in accordance with formulas (E11) and (E12). In the event the performance indexes exceeds the reference values an indication of that the correct valve mode is not operating is given.

[0064] The means 22 for comparing performance indexes with reference values constitutes means for determining which of a first cam having a first cam profile and a second cam having a second cam profile greater that said first cam profile currently is acting on lift mechanisms for gas exchange valves in the event the an apparatus according to the invention is used to monitor a CPS engine.

[0065] All the different means included in the means for evaluating 11 and the means for monitoring 12 are constituted by programs running in a microcontroller having processing means and storage areas. The microcontroller is programmed to execute calculation of formulas (E5) - (E12) by use of information provided from the engine speed sensor 9. In figure 8 a valve assembly is shown, which may be used in connection with the invention in order to provided two different cam modes.

Referring to FIG. 8 there is shown a valve 110 having a head 111 which is movable in an axial direction to seal the passageway 105. The valve 110 is slidably mounted in a bore 112 in cylinder block 113 and passes through a cavity 114. In the cavity 114 around valve 110 there is located a spring 115 one end of which rests against a lower surface of said cavity 114 and the other end of which is located in a collar 116 mounted on the valve 110 so as to generally bias the valve 110 in an upwards direction.

[0066] Mounted on an upper end of valve 110 is a tappet assembly 118. The tappet assembly 118 comprises a coaxial inner tappet 120 and outer tappet 121. The inner tappet bears on a hydraulic lash adjustment element 122 of known type which in turn bears on the upper end of valve 110. The tappet assembly 118 is slidably mounted within bore 119 which extends from the cavity 114 to the upper surface of the cylinder block 113. A cylinder head cover may be positioned over and secured to the upper surface of the cylinder block 113.

[0067] Located above the cylinder block 113 is a rotatable camshaft 130, which is drivable in the usual arrangement 131, which comprises a pair of outer cam lobes 126 in between which is situated a central cam lobe 123. The central cam lobe 123 has a profile designed to optimise engine performance over a selected portion of engine speed and load range. Although the central cam lobe 123 is illustrated as having a generally eccentric form it is envisaged that this cam lobe can be a circular form allowing valve deactivation while under control of this cam lobe. The outer cam lobes 126 are of a substantial identical profile to each other and are designed to optimise engine performance over another portion of engine speed and load range.

[0068] The camshaft 130 is located such that in low speed conditions an upper surface 120a of the inner tappet 120 is driven by the central cam lobe via finger follower 124. The upper surface 121 a of outer tappet 121 is kept in contact with the outer cam lobes 126 by means of a spring 125 which is coaxially positioned around spring 115 and which locates at one end in recesses 132 in the lower end surface of outer tappet 121. At its lower end spring 125 bears on the lower surface of cavity 114

[0069] Cam profile selection is achieved by either connecting the inner tappet 120 and outer tappet 121 so that they move together which allows the outer tappet 121 and outer cam lobes 126 to control the valve 110 or by disconnecting the inner tappet 120 and outer tappet 121, which allows the inner tappet 120 and inner cam lobe 123 to control valve 110.

[0070] In figure 9 a flow chart of a method for monitoring the position of a variable valve control in a combustion engine having a plurality of cylinders is shown.

[0071] In a first method step 210 engine speed is measured over at least one engine cycle for all cylinders included in said plurality of cylinders.

[0072] In a second method step 211 engine speed fluctuations for respective cylinder as the difference between maximum and minimum engine speed at a time interval including the combustion stroke of respective cylinder is determined.

[0073] In a third method 212 step of: a function representing a transient component of engine speed fluctuation over said at least one engine cycle is assigned. The function being represented by a set of model coefficients.

[0074] In a fourth method step 213 the model coefficeints, that is the coefficients for the assigned function are determined. This is preferably done by minimising the cost function for the determined engine speed fluctuations for respective cylinder in respect of said function representing a transient component.

[0075] In a fifth method step 214 the distance between the determined engine speed fluctuations and a value of said function representing a transient component corresponding to respective determined engine speed fluctuation is calculated whereby a first performance index is obtained.

[0076] Optionally further performance indexes are calculated in further method steps as disclosed below.

[0077] In a sixth method 215 step a relative distance between the determined engine speed fluctuations and the value of said function representing a transient component in respect of said value of said function representing a transient component corresponding to respective determined engine speed fluctuation is determined for use as a second performance index.

[0078] In a seventh method 216 step an average amplitude of said relative distance is calculated over one engine cycle, wherein said average amplitude is used as a third performance index.

[0079] In a eight method 217 step an average amplitude of said relative distance over for respective cylinder is calculated over a number of engine cycles, wherein said average amplitude is used as a fourth performance index.

[0080] In a ninth method 218 step at least one of said performance indexes is compared with reference values stored in a memory.

[0081] The invention should not be restricted to the embodiments disclosed above, but may be varied within the scope of the appended claims.

Claims

1. A method for monitoring the position of a variable valve control (2) in a combustion engine (1) having a plurality of cylinders (3), comprising the followings steps:

measuring (210) engine speed over at least one engine cycle for all cylinders (3) included in said plurality of cylinders,

determining (211) engine speed fluctuations (A_i) for respective cylinders as the difference between maximum and minimum engine speed at a time interval including the combustion stroke of respective cylinders, **characterised in that** the method further includes the steps of:

assigning (212) a function (E4) representing a transient component of engine speed fluctuation (A_i) over said at least one engine cycle, said function being represented by a set of model coefficients,

determining (213,E5) said model coefficients, and

calculating (214,E5A) the distance (k_i) between the determined engine speed fluctuations (A_i) and a value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuations (A_i).

2. A method according to claim 1, **characterised in that** the model coefficients are determined by minimising a cost function (E5) for the determined engine speed fluctuations (A_i) for respective cylinder in respect of said function (E4) representing a transient component.

3. A method according to claim 1 or 2 **characterised in that** said distance (k_i) between the determined engine speed fluctuations (A_i) and a value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuation (A_i) is used as a first performance index.

4. A method according to claims 2 or 3, **characterised in that** a relative distance (d_i) between the determined engine speed fluctuations (A_i) and the value of said function (E4) representing a transient component in respect of said value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuation is determined (E6) for use as a second performance index.

5. A method according to claim 4, **characterised in that** an average amplitude $\bar{d}$ of said relative distance (d_i) is calculated (E7) over one engine cycle, wherein said average amplitude is used as a third performance index.

6. A method according to claim 4 or 5, **characterised in that** an average amplitude $\overline{di}$ of said relative distance (d_i) over for respective cylinder is calculated (E8) over a number of engine cycles, wherein said average amplitude is used as a fourth performance index.

7. A method according to any of the preceding claims,
characterised in that at least one of said performance indexes is compared with reference values stored in a memory.

8. A method according to any of the preceding claims,
characterised in that at least one of said performance indexes is used for determination of which of a first cam (123) having a first cam profile and a second cam (126) having a second cam profile greater that said first cam profile currently is acting on lift mechanisms (7) for gas exchange valves (8) being arranged for controlling gas exchange into or out from said plurality of cylinders.

9. A method according to any of the preceding claims,
characterised in that said function (E4) representing a transient component of engine speed fluctuation over said at least one engine cycle is expressed as $f = c_0 + c_1x_i$, where c_0 and c_1 are model coefficients and x_i is the number of the amplitude of the fluctuation within a engine cycle.

10. An apparatus for monitoring the position of a variable valve control (2) in a combustion engine (1) having a plurality of cylinders (3), comprising:

means (13) for measuring engine speed over at least one engine cycle for all cylinders included in said plurality of cylinders,
means (14) for determining engine speed fluctuations (A_i) for respective cylinders (3) as the difference between maximum and minimum engine speed at a time interval including the combustion stroke of respective cylinders,
characterised in that said apparatus further includes:
means (16) for assigning a function (E4) representing a transient component of engine speed fluctuations (A_i) over said at least one engine cycle, said function (E4) being represented by a set of model coefficients,
means (17) for determining said model coefficients, and
means (18) for calculating the distance (k_i) between the determined engine speed fluctuations (A_i) and a value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuations (A_i).

11. An apparatus according to claim 10, **characterised in that** said means (17) for determining the model coefficients includes means for minimising a cost function (E5) for the determined engine speed fluctuations (A_i) for respective cylinder in respect of said function (E4) representing a transient component.

12. An apparatus according to claims 10 or 11, **characterised in that** said distance (k_i) between the determined engine speed fluctuations (A_i) and a value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuation (A_i) is used as a first performance index.

13. An apparatus according to claim 12, **characterised in that** said apparatus further includes means (19) for determining (E6) a relative distance (d_i) between the determined engine speed fluctuations (A_i) and the value of said function (E4) representing a transient component in respect of said value of said function (E4) representing a transient component corresponding to respective determined engine speed fluctuation (A_i) for use as a second performance index.

14. An apparatus according to claim 13, **characterised in that** said apparatus further includes means (20) for calculating (E7) an average amplitude ($\bar{d}$) of said relative distance (d_i) over one engine cycle, wherein said average amplitude is used as a third performance index.

15. An apparatus according to claim 13 or 14, **characterised in that** said apparatus further includes means (21) for calculating (E8) an average amplitude ($\overline{di}$) of said relative distance (d_i) for respective cylinder over a number of engine cycles, wherein said average amplitude is used as a fourth performance index.

16. An apparatus according to any of claims 12 - 15, **characterised in that** said apparatus further includes means (22) for comparing at least one of said performance indexes with reference values stored in a memory.

17. An apparatus according to any of claims 12 - 16, **characterised in that** said apparatus further includes means for determining (22) which of a first cam (123) having a first cam profile and a second cam (126) having a second cam profile greater that said first cam profile currently is acting on lift mechanisms (7) for gas exchange valves (8) being arranged for controlling gas exchange into or out from said plurality of cylinders (3) from comparing at least one of said performance indexes is used for determination of with a reference value stored in a memory.

18. An apparatus according to any of claims 12 - 17, **characterised in that** said function (E4) representing a transient component of engine speed fluctuations (A_i) over said at least one engine cycle is expressed as $f = c_0 + c_1x_i$, where c_0 and c_1 are model coefficients and x_i is the number of the amplitude of the fluctuation within a engine cycle.

Patentansprüche

1. Verfahren zum Überwachen der Position einer variablen Ventilsteuerung (2) in einem Verbrennungsmotor (1), welcher eine Mehrzahl von Zylindern (3) aufweist, mit den nachfolgenden Schritten:

Messen (210) einer Motordrehzahl über mindestens einen Motorzyklus für alle Zylinder (3), welche in der Mehrzahl von Zylindern beinhaltet sind,
Bestimmen (211) von Motordrehzahlfluktuationen (A_i) für entsprechende Zylinder als den Unterschied zwischen einer maximalen und einer minimalen Motordrehzahl in einem Zeitintervall, welches den Arbeitshub der entsprechenden Zylinder beinhaltet, **gekennzeichnet dadurch, dass** das Verfahren die weiteren Schritte beinhaltet:

Zuordnen (212) einer Funktion (E4), welche eine transiente Komponente einer Motordrehzahlfluktuation (A_i) über den letzten Motorzyklus repräsentiert, wobei die Funktion durch einen Satz von Modellkoeffizienten repräsentiert wird,
Bestimmen (213, E5) der Modellkoeffizienten und
Berechnen (214, ESA) des Abstands (k_i) zwischen den vorbestimmten Motorgeschwindigkeitsfluktuationen (A_i) und einem Wert der Funktion (E4), welche eine transiente Komponente repräsentiert, welche mit einer entsprechend bestimmten Motordrehzahlfluktuation (A_i) korrespondiert.

2. Verfahren nach Anspruch 1, **gekennzeichnet dadurch, dass** die Modellkoeffizienten durch Minimieren einer Kostenfunktion (E5) für die bestimmten Motordrehzahlfluktuationen (A_i) für einen entsprechenden Zylinder in Bezug auf die Funktion (E4) bestimmt werden, welche eine transiente Komponente repräsentiert.

3. Verfahren nach einem der Ansprüche 1 oder 2, **dadurch gekennzeichnet, dass** als erster Performance Index der Abstand (k_i) zwischen den bestimmten Motordrehzahlfluktuationen (A_i) und einem Wert der Funktion (E4) verwendet wird, welche eine transiente Komponente repräsentiert, welche mit den entsprechenden bestimmten Motordrehzahlfluktuationen (A_i) korrespondiert.

4. Verfahren nach einem der Ansprüche 2 oder 3, **dadurch gekennzeichnet, dass** zur Verwendung als zweiten

Performance Index ein relativer Abstand (d_i) zwischen den bestimmten Motordrehzahlfluktuationen (Ai) und dem Wert der Funktion (E4), welche eine transiente Komponente repräsentiert, in Bezug auf den Wert der Funktion (E4) welche eine transiente Komponente repräsentiert, welche mit der entsprechenden bestimmten Motordrehzahlfluktuation korrespondiert; bestimmt wird.

5. Verfahren nach Anspruch 4, **dadurch gekennzeichnet, dass** eine mittlere Amplitude $\bar{d}$ des relativen Abstandes (d_i) über einen Motorzyklus berechnet wird (E7), wobei die mittlere Amplitude als dritter Performance Index verwendet wird.

6. Verfahren nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** eine mittlere Amplitude $\overline{di}$ des relativen Abstandes (d_i) über eine Anzahl von Motorzyklen für einen entsprechenden Zylinder berechnet wird (E8), wobei die mittlere Amplitude als vierter Performance Index verwendet wird.

7. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet dadurch, dass** mindestens einer der Performance Indizes mit Referenzwerten verglichen wird, welche in einem Speicher gespeichert sind.

8. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet dadurch, dass** mindestens einer der Performance Indizes zum Bestimmen verwendet wird, welche von einer ersten Nocke (123), welche ein erstes Nockenprofil aufweist, und einer zweiten Nocke (126), welche ein zweites Nockenprofil aufweist, welches größer als das erste Nockenprofil ist, im Moment an einem Hebemechanismus (7) für Gasaustauschventile (8) agiert, welche zum Steuern eines Gaswechsels in oder aus der Mehrzahl von Zylindern angeordnet sind.

9. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Funktion (E4), welche eine transiente Komponente der Motordrehzahlfluktuation über den mindestens einen Motorzyklus repräsentiert, als $f = c_0 + c_1x_i$ ausgedrückt wird, wobei c_0 und c_1 Modellkoeffizienten und x_i die Nummer der Amplitude der Fluktuation innerhalb eines Motorzyklusses ist.

10. Vorrichtung zum Überwachen der Position einer variablen Ventilsteuerung (2) in einem Verbrennungsmotor (1), welcher eine Mehrzahl von Zylindern (3) aufweist, mit:

einer Einrichtung (13) zum Messen einer Motordrehzahl über mindestens einen Motorzyklus für alle Zylinder, welche in der Mehrzahl von Zylindern beinhaltet sind, eine Einrichtung (14) zum Bestimmen von Motordrehzahlfluktuationen (A_i) für entsprechende Zylinder (3) als den Unterschied zwischen einer maximalen und einer minimalen Motordrehzahl in einem Zeitintervall, welches den Arbeitshub der entsprechenden Zylinder beinhaltet, **gekennzeichnet dadurch, dass** die Vorrichtung ferner beinhaltet:

einer Einrichtung (16) zum Zuordnen einer Funktion (E4), welche eine transiente Komponente von Motordrehzahlfluktuationen (A_i) über den mindestens einen Motorzyklus repräsentiert, wobei die Funktion (E4) durch einen Satz von Modellkoeffizienten repräsentiert wird,
einer Einrichtung (17) zum Bestimmen der Modellkoeffizienten und
einer Einrichtung (18) zum Berechnen des Abstandes (k_i) zwischen den bestimmten Motordrehzahlfluktuationen (A_i) und einem Wert der Funktion (E4), welche eine transiente Komponente repräsentiert, welche mit den entsprechenden bestimmten Motordrehzahlfluktuationen (A_i) korrespondiert.

11. Vorrichtung nach Anspruch 10, **gekennzeichnet dadurch, dass** die Einrichtung (17) zum Bestimmen der Modellkoeffizienten eine Einrichtung zum Minimieren einer Kostenfunktion (E5) für die bestimmten Motordrehzahlfluktuationen (A_i) für einen entsprechenden Zylinder in Bezug auf die Funktion (E4) beinhaltet, welche eine transiente Komponente repräsentiert.

12. Vorrichtung nach einem der Ansprüche 10 oder 11, **dadurch gekennzeichnet, dass** als erster Performance Index der Unterschied (k_i) zwischen den bestimmten Motordrehzahlfluktuationen (A_i) und einem Wert der Funktion (E4) verwendet wird, welche eine transiente Komponente repräsentiert, welche mit einer entsprechenden bestimmten Motordrehzahlfluktuation (A_i) korrespondiert.

13. Vorrichtung nach Anspruch 12, **dadurch gekennzeichnet, dass** die Vorrichtung ferner eine Einrichtung (19) zum Bestimmen (E6) eines relativen Abstandes (d_i) zwischen den bestimmten Motordrehzahlfluktuationen (A_i) und dem Wert der Funktion (E4), welche eine transiente Komponente repräsentiert in Bezug auf den Wert der Funktion (E4), welche eine transiente Komponente repräsentiert, welche mit einer entsprechenden bestimmten Motordrehzahlfluktuation (A_i) korrespondiert, zur Verwendung als zweiter Performance Index, beinhaltet.

14. Vorrichtung nach Anspruch 13, **dadurch gekennzeichnet, dass** die Vorrichtung ferner eine Einrichtung (20) zum Berechnen (E7) einer mittleren Amplitude ($\bar{d}$) des relativen Abstandes (d_i) über einen Motorzyklus beinhaltet, wobei die mittlere Amplitude als dritter Performance Index verwendet wird.

15. Vorrichtung nach Anspruch 13 oder 14, **dadurch gekennzeichnet, dass** die Vorrichtung ferner eine Einrichtung (21) zum Berechnen (E8) einer mittleren Amplitude ($\overline{di}$) des relativen Abstandes (d_i) über eine Anzahl von Motorzyklen für einen entsprechenden Zylinder aufweist, wobei die mittlere Amplitude als vierter Performance Index verwendet wird.

16. Vorrichtung nach einem der Ansprüche 12 bis 15, **dadurch gekennzeichnet, dass** die Vorrichtung ferner eine Einrichtung (22) zum Vergleichen von mindestens einem der Performance Indizes mit Referenzwerten beinhaltet, welche in einem Speicher gespeichert sind.

17. Vorrichtung nach einem der Ansprüche 12 bis 16, **dadurch gekennzeichnet, dass** die Vorrichtung ferner aufweist:

eine Einrichtung zum Bestimmen (22), welche von einer ersten Nocke (123), welche eine erstes Nockenprofil aufweist, und einer zweiten Nocke (126), welche ein zweites Nockenprofil aufweist, welches größer als das erste Nockenprofil ist, im Moment an Hubmechanismen (7) für Gasaustauschventile (8) agiert, welche zum Steuern eines Gasaustausches in oder aus der Mehrzahl von Zylindern (3) angeordnet sind, wobei ein Vergleich von mindestens einem der Performance Indizes zum Bestimmen mit
einem Referenzwert verwendet wird, welcher in einem Speicher gespeichert ist.

18. Vorrichtung nach einem der Ansprüche 12 bis 17, **dadurch gekennzeichnet, dass** die Funktion (E4), welche eine transiente Komponente der Motordrehzahlfluktuationen (A_i) über den mindestens einen Motorzyklus repräsentiert, als $f = c_0 + c_1x_i$ ausgedrückt ist, wobei c_0 und c_1 Modellkoeffizienten sind und x_i die Nummer der Amplitude der Fluktuation innerhalb eines Motorzyklusses ist.

Revendications

1. Procédé pour surveiller la position d'une commande de soupape variable (2) dans un moteur à combustion (1) ayant une pluralité de cylindres (3), comportant les étapes consistant à :

mesurer (210) la vitesse moteur sur au moins un cycle moteur pour tous les cylindres (3) inclus dans ladite pluralité de cylindres,
déterminer (211) des fluctuations de vitesse moteur (A_i) pour des cylindres respectifs sous la forme de la différence entre des vitesses moteur maximum et minimum au niveau d'un intervalle de temps incluant la course de combustion de cylindres respectifs, **caractérisé en ce que** le procédé comporte en outre les étapes consistant à :

assigner (212) une fonction (E4) représentant une composante transitoire de fluctuation de vitesse moteur (A_i) sur ledit au moins un cycle moteur, ladite fonction étant représentée par un ensemble de coefficients modèles,
déterminer (213, E5) lesdits coefficients modèles, et
calculer (214, E5A) la distance (k_i) entre les fluctuations de vitesse moteur déterminées (A_i) et une valeur de ladite fonction (E4) représentant une composante transitoire correspondant à des fluctuations de vitesse moteur déterminées respectives (A_i).

2. Procédé selon la revendication 1, **caractérisé en ce que** les coefficients modèles sont déterminés en minimisant une fonction de coût (E5) pour les fluctuations de vitesse moteur déterminées (A_i) pour un cylindre respectif compte tenu de ladite fonction (E4) représentant une composante transitoire.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** ladite distance (k_i) entre les fluctuations de vitesse moteur déterminées (A_i) et une valeur de ladite fonction (E4) représentant une composante transitoire correspondant à une fluctuation de vitesse moteur déterminée respective (A_i) est utilisée en tant que premier indice de performance.

4. Procédé selon la revendication 2 ou 3, **caractérisé en ce qu'**une distance relative (d_i) entre les fluctuations de vitesse moteur déterminées (A_i) et la valeur de ladite fonction (E4) représentant une composante transitoire compte tenu de ladite valeur de ladite fonction (E4) représentant une composante transitoire correspondant à une fluctuation de vitesse moteur déterminée respective est déterminée (E6) pour utilisation en tant que deuxième indice de performance.

5. Procédé selon la revendication 4, **caractérisé en ce qu'**une amplitude moyenne $\bar{d}$ de ladite distance relative (d_i) est calculée (E7) sur un cycle moteur, dans lequel ladite amplitude moyenne est utilisée en tant que troisième indice de performance.

6. Procédé selon la revendication 4 ou 5, **caractérisé en ce qu'**une amplitude moyenne $\overline{di}$ de ladite distance relative (d_i) pour un cylindre respectif est calculée (E8) sur plusieurs cycles moteur, ladite amplitude moyenne étant utilisée en tant que quatrième indice de performance.

7. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**au moins un desdits indices de performance est comparé à des valeurs de référence mémorisées dans une mémoire.

8. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**au moins un desdits indices de performance est utilisé pour déterminer laquelle d'une première came (123) ayant un premier profil de came, et d'une seconde came (126) ayant un second profil de came plus grand que ledit premier profil de came agit sur des mécanismes de levage (7) de soupapes d'échange de gaz (8) agencées pour commander un échange de gaz entre l'intérieur et l'extérieur de ladite pluralité de cylindres.

9. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** ladite fonction (E4) représentant une composante transitoire de fluctuation de vitesse moteur sur ledit au moins un cycle moteur est exprimée par $f = c_0 + c_1x_i$ où c_0 et c_1 sont de coefficients modèles et x_i est le chiffre de l'amplitude de fluctuation dans un cycle moteur.

10. Dispositif pour surveiller la position d'une commande de soupape variable (2) dans un moteur à combustion (1) ayant une pluralité de cylindres (3), comportant :

des moyens (13) pour mesurer une vitesse moteur sur au moins un cycle moteur pour tous les cylindres inclus dans ladite pluralité de cylindres,
des moyens (14) pour déterminer des fluctuations de vitesse moteur (A_i) pour des cylindres respectifs (3) sous la forme de la différence entre des vitesses moteur maximum et minimum à un intervalle de temps incluant la course de combustion de cylindres respectifs, **caractérisé en ce que** ledit dispositif comporte en outre :

des moyens (16) pour assigner une fonction (E4) représentant une composante transitoire de fluctuations de vitesse moteur (A_i) sur ledit au moins un cycle moteur, ladite fonction (E4) étant représentée par un ensemble de coefficients modèles,
des moyens (17) pour déterminer lesdits coefficients modèles, et
des moyens (18) pour calculer la distance (k_i) entre les fluctuations de vitesse moteur déterminées (A_i) et une valeur de ladite fonction (E4) représentant une composante transitoire correspondant aux fluctuations de vitesse moteur déterminées respectives (A_i).

11. Dispositif selon la revendication 10, **caractérisé en ce que** lesdits moyens (17) pour déterminer les coefficients modèles comportent des moyens pour minimiser une fonction de coût (E5) pour les fluctuations de vitesse moteur déterminées (A_i) pour un cylindre respectif compte tenu de ladite fonction (E4) représentant une composante transitoire.

12. Dispositif selon la revendication 10 ou 11, **caractérisé en ce que** ladite distance (k_i) entre les fluctuations de vitesse moteur déterminées (A_i) et une valeur de ladite fonction (E4) représentant une composante transitoire correspondant à une fluctuation de vitesse moteur déterminée respective (A_i) est utilisée en tant que premier indice de performance.

13. Dispositif selon la revendication 12, **caractérisé en ce que** ledit dispositif comporte en outre des moyens (19) pour déterminer (E6) une distance relative (d_i) entre les fluctuations de vitesse moteur déterminées (A_i) et la valeur de ladite fonction (E4) représentant une composante transitoire compte tenu de ladite valeur de ladite fonction

(E4) représentant une composante transitoire correspondant à une fluctuation de vitesse moteur déterminée respective (A_i) pour utilisation en tant que deuxième indice de performance.

14. Dispositif selon la revendication 13, **caractérisé en ce que** ledit dispositif comporte en outre des moyens (20) pour calculer (E7) une amplitude moyenne ($\bar{d}$) de ladite distance relative (d_i) sur un cycle moteur, dans lequel ladite amplitude moyenne est utilisée en tant que troisième indice de performance.

15. Dispositif selon la revendication 13 ou 14, **caractérisé en ce que** ledit dispositif comporte en outre des moyens (21) pour calculer (E8) une amplitude moyenne ($\overline{di}$) de ladite distance relative (d_i) pour un cylindre respectif sur plusieurs cycles moteur, dans lequel ladite amplitude moyenne est utilisée en tant que quatrième indice de performance.

16. Dispositif selon l'une quelconque des revendications 12 à 15, **caractérisé en ce que** ledit dispositif comporte en outre des moyens (22) pour comparer au moins un desdits indices de performance avec des valeurs de référence mémorisées dans une mémoire.

17. Dispositif selon l'une quelconque des revendications 12 à 16, **caractérisé en ce que** ledit dispositif comporte en outre des moyens pour déterminer (22) laquelle d'une première came (123) ayant un premier profil de came, et d'une seconde came (126) ayant un second profil de came plus grand que ledit premier profil de came, agit sur des mécanismes de levage (7) de soupapes d'échange de gaz (8) agencées pour commander un échange de gaz entre l'intérieur et l'extérieur de ladite pluralité de cylindres (3) à partir d'une comparaison d'au moins un desdits indices de performance utilisés pour la détermination, à une valeur de référence mémorisée dans une mémoire.

18. Dispositif selon l'une quelconque des revendications 12 à 17, **caractérisé en ce que** ladite fonction (E4) représentant une composante transitoire de fluctuations de vitesse moteur (A_i) sur ledit au moins un cycle moteur est exprimée sous la forme $f = c_0 + c_1 x_i$, où c_0 et c_1 sont des coefficients modèles, et x_i est le chiffre de l'amplitude de fluctuation dans un cycle moteur.

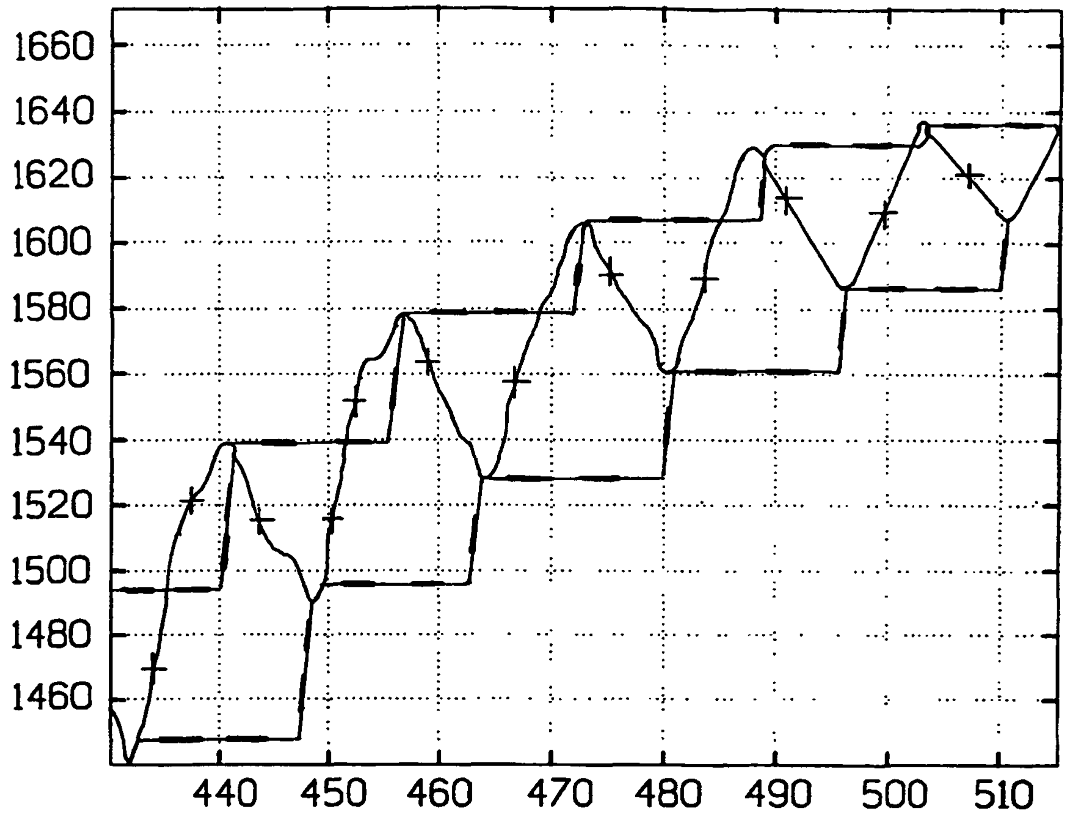
1660
1640
1620
1600
1580
1560
1540
1520
1500
1480
1460
440
450
460
470
480
490
500
510

FIG.1

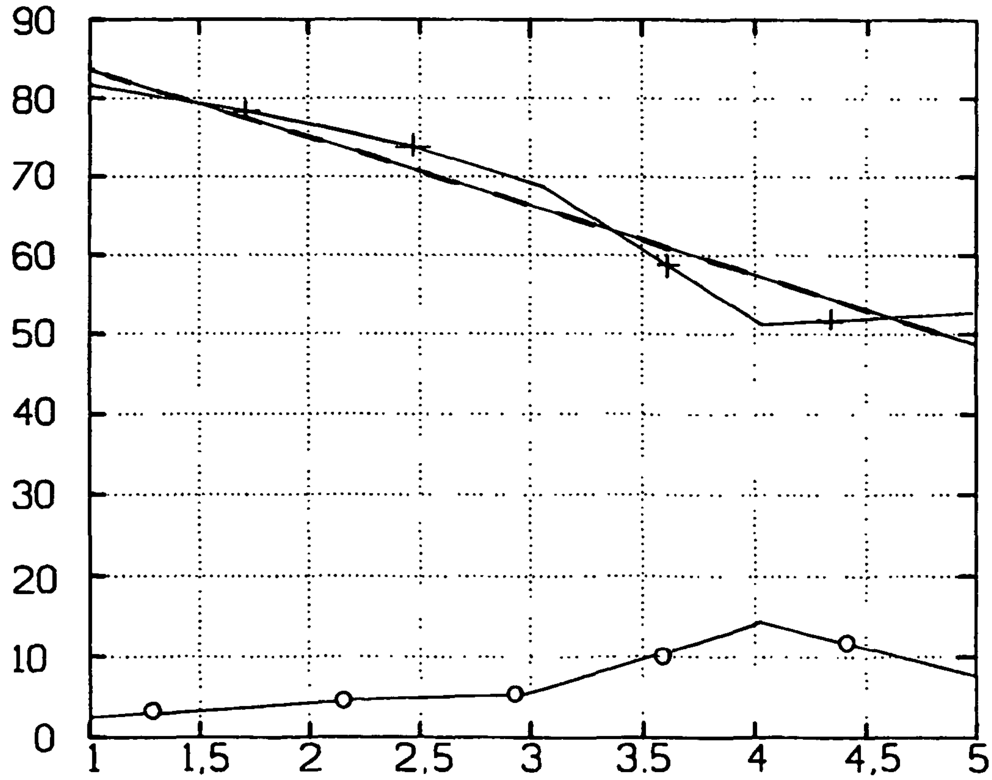
90
80
70
60
50
40
30
20
10
0
1
1,5
2
2,5
3
3,5
4
4,5
5

FIG.2

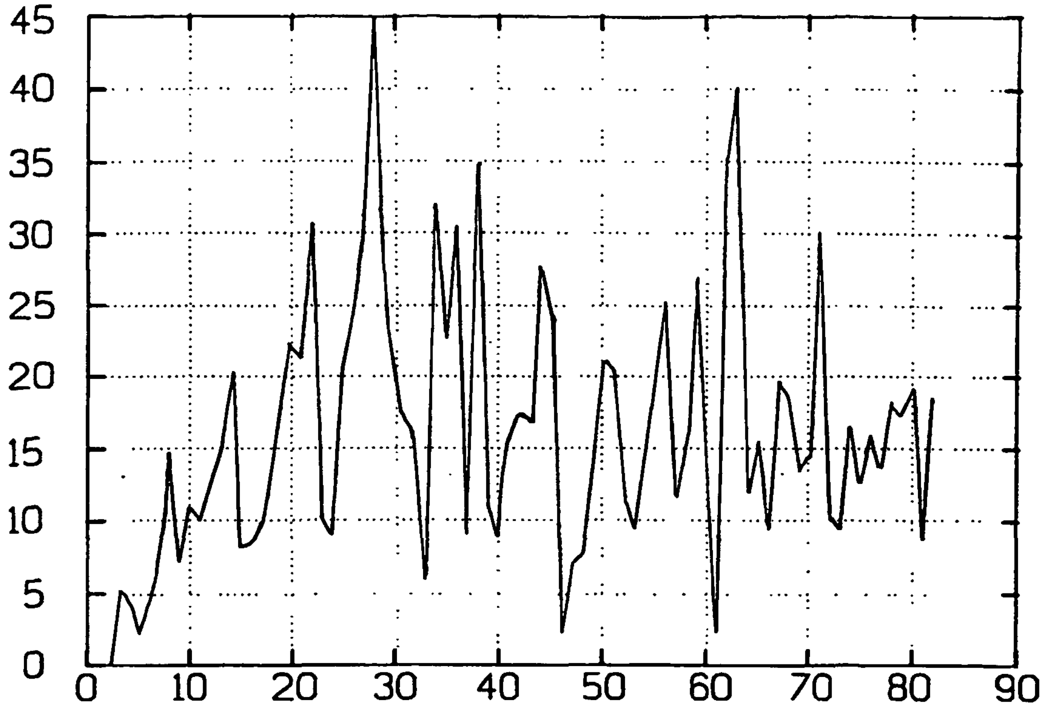
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90

FIG.3

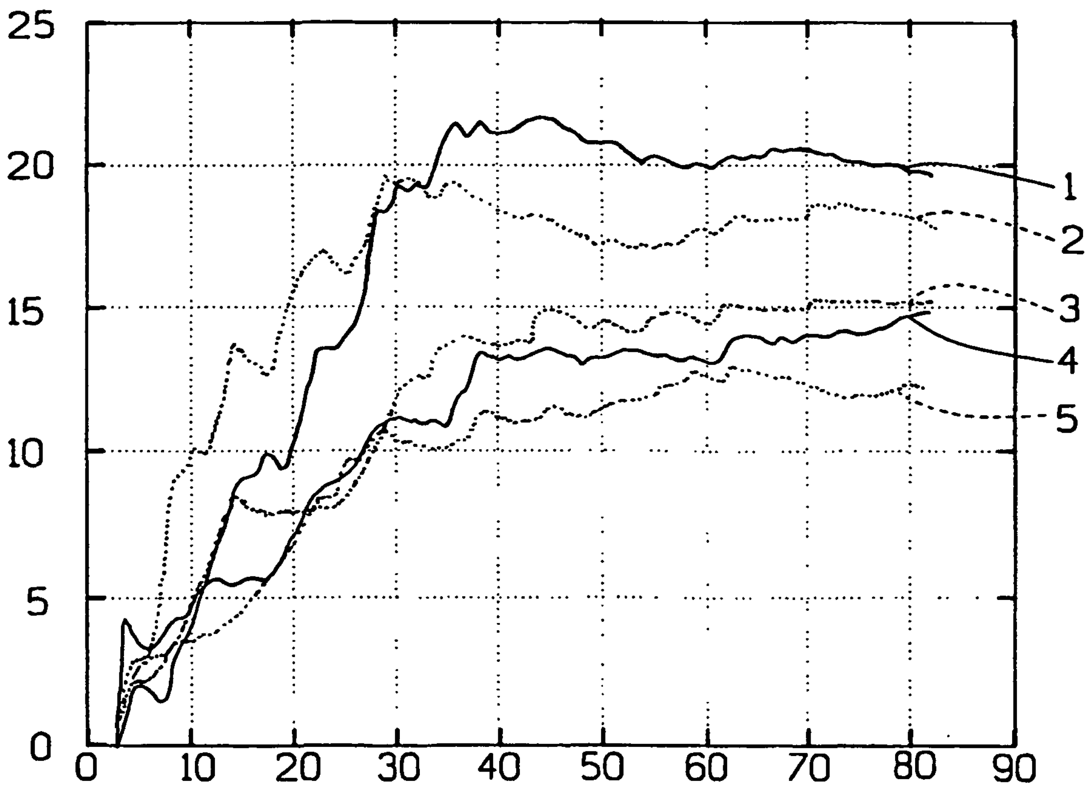
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
1
2
3
4
5

FIG.4

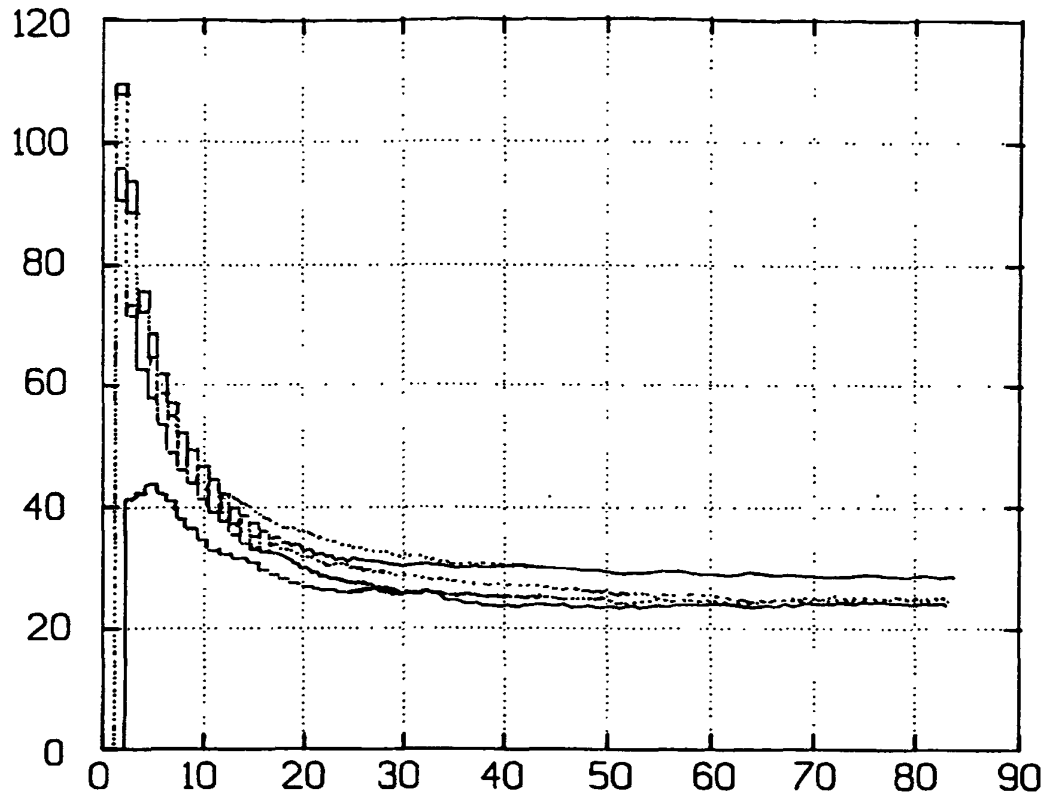
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90

FIG.5

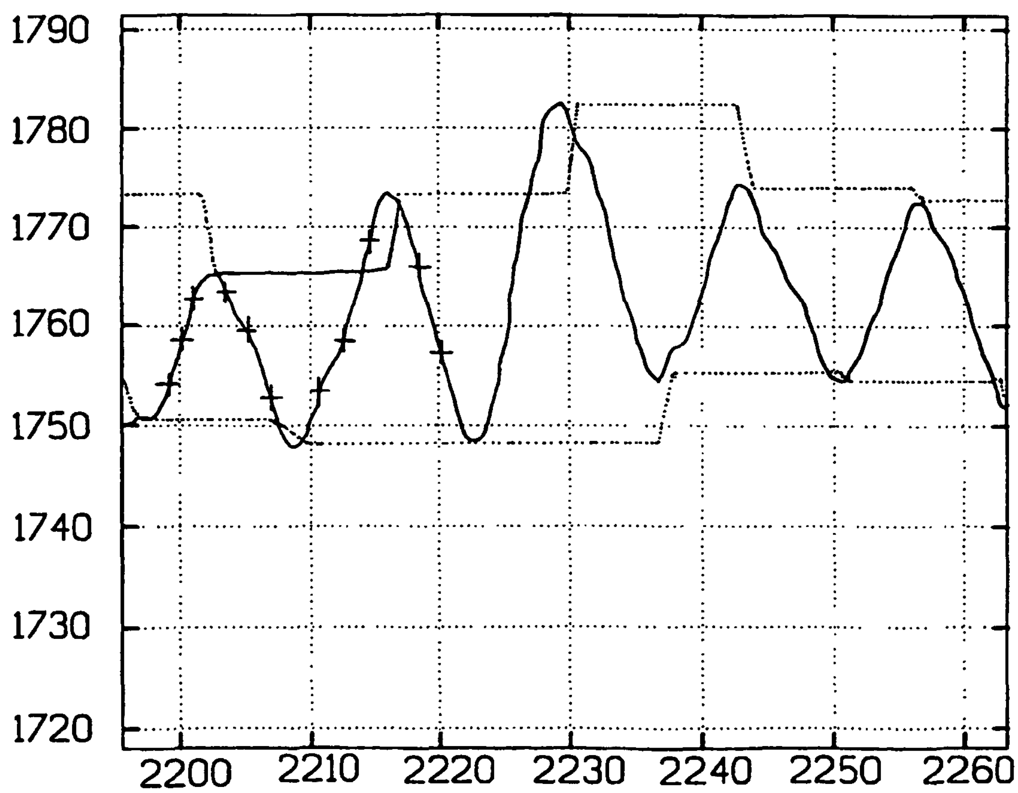
1790
1780
1770
1760
1750
1740
1730
1720
2200
2210
2220
2230
2240
2250
2260

FIG.6

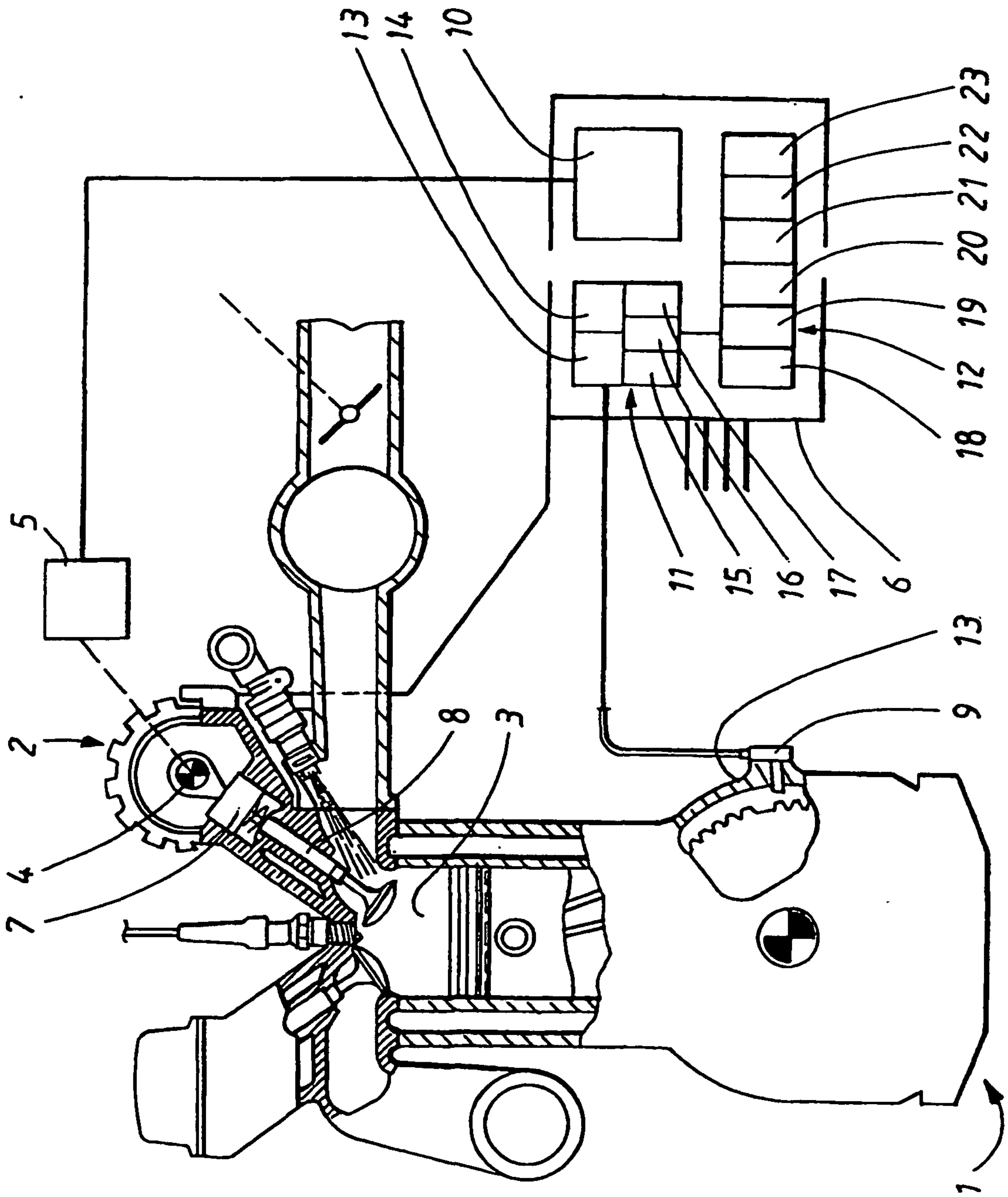

FIG. 7

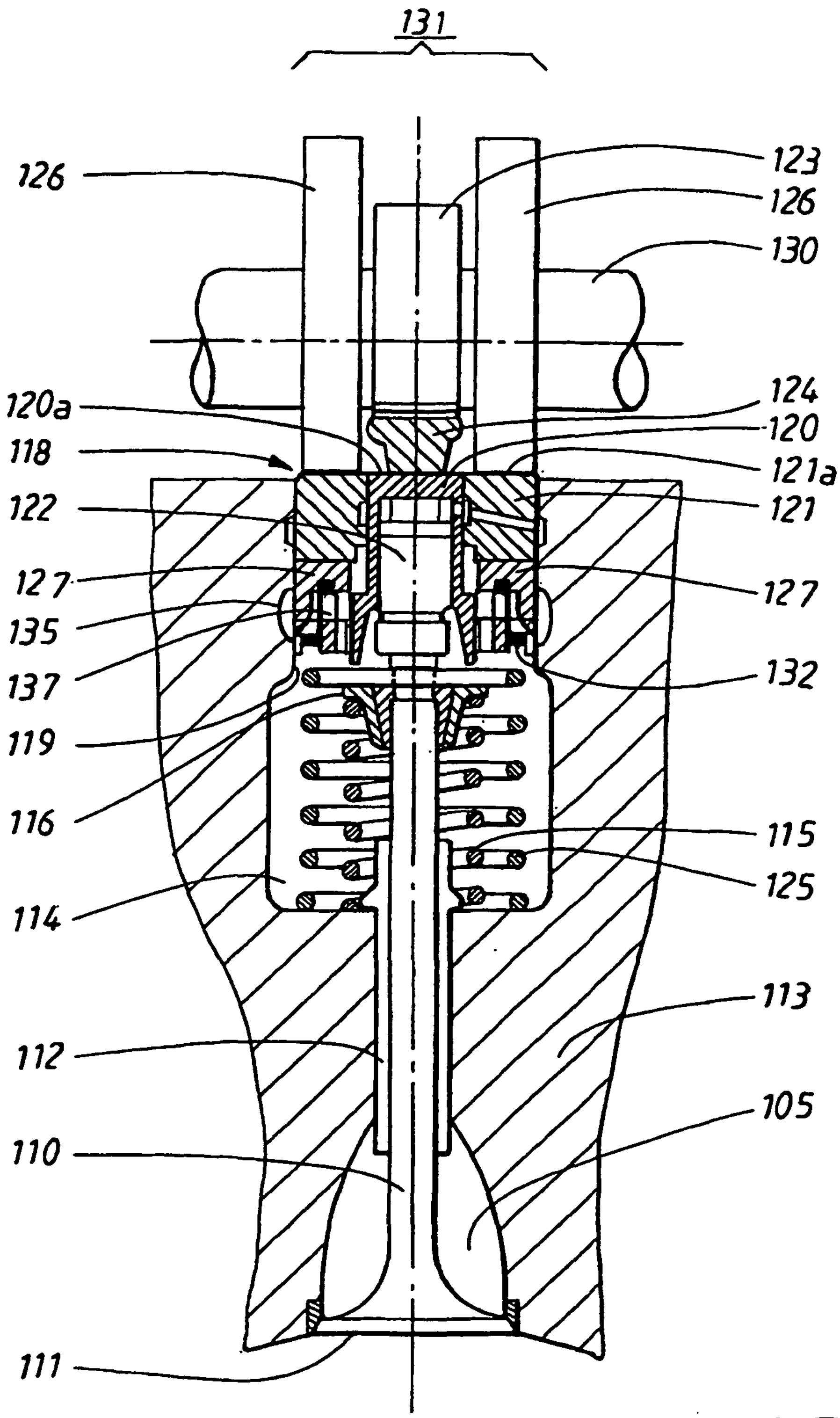
131
126
123
126
130
124
120a
120
118
121a
122
121
127
127
135
137
132
119
116
115
125
114
113
112
105
110
111

FIG. 8

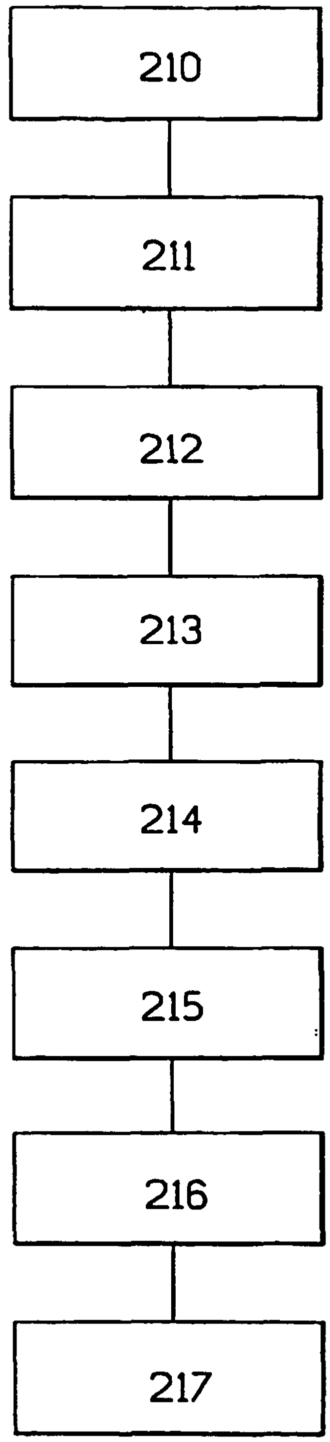

FIG. 9