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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) Method for closed-loop control of timing of combustion in an internal combustion engine

(57) Described herein is a method for closed-loop control of timing of combustion in an internal-combustion engine (1), in particular a diesel engine, comprising: determination of a characteristic quantity of the combustion cycle ($\vartheta_{MFB50\%}$) in a cylinder (4) of the engine (1); and closed-loop control of timing of combustion of the engine (1) on the basis of said characteristic quantity of the combustion cycle ($\vartheta_{MFB50\%}$) and of a target value (ϑ_{TARG}) of the characteristic quantity ($\vartheta_{MFB50\%-TARG}$) said method being characterized in that determining said characteristic quantity ($\vartheta_{MFB50\%}$) comprises: determining the values of pressure ($P[i]$) inside the cylinder (4) during at least part of the combustion cycle in the cylinder (4) itself, said pressure values (P[i]) being determined at successive and equally spaced instants in time; measuring the times ($\Delta t[j]$) taken by the drive shaft of said engine (1) to cover successive angular distances ($\Delta\vartheta$)) of constant width; and determining said characteristic quantity ($\vartheta_{MFB50\%}$) on the basis of said pressure values ($P[i]$) and of said angular travel times ($\Delta t[j]$).

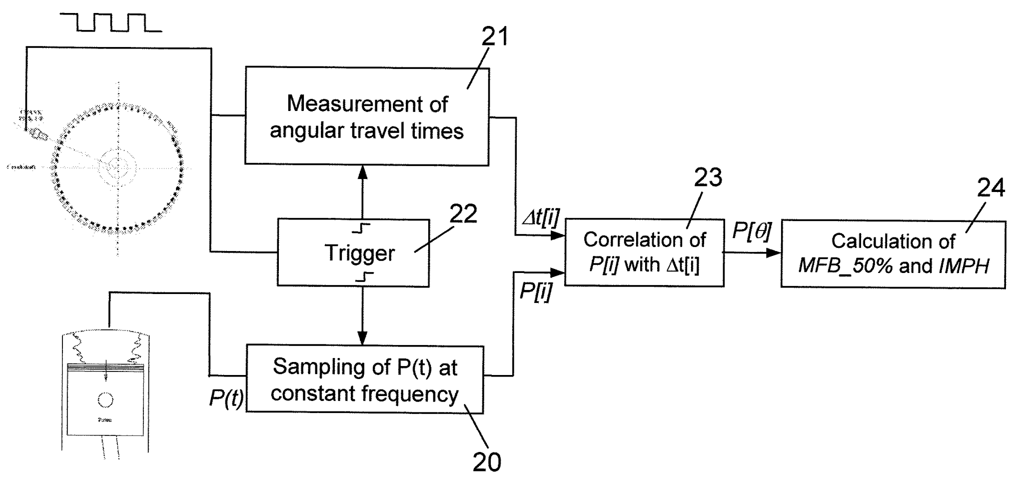

Fig.3

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Description

[0001] The present invention relates to a method for closed-loop control of timing of combustion in an internal-combustion engine, in particular a diesel engine.

[0002] As is known, in diesel engines, combustion is characterized by the presence of a delay time, commonly referred to as "ignition lag", defined as the time elapsing between the instant at which the fuel is injected into the combustion chamber and the instant of ignition of the fuel.

[0003] Ignition lag basically depends upon the conditions present in the combustion chamber and can vary each time according to the values assumed by physical and chemical parameters such as, for example, the cetane number of the fuel, the temperature and pressure in the combustion chamber, the air/fuel ratio, the mount of exhaust gases reintroduced into the air-intake manifold, etc.

[0004] In order to handle ignition lag both methods for open-loop control and methods for closed-loop control of the timing of combustion have been proposed.

[0005] In particular, the methods for open-loop control of timing of combustion are generally based upon correction of the engine angle of start of energization (SOE) of the fuel injectors, which is a function of the engine r.p.m. and of the torque required and is determined as a function of environmental quantities, such as, for example, the temperature and pressure of the air taken in, which contribute to creating the thermodynamic conditions in the combustion chamber.

[0006] The use of increasingly lower compression ratios and of increasingly greater amounts of exhaust gases re-introduced into the air-intake manifold for reducing the formation of nitrogen oxides (NOx) in order to satisfy future limits of type approval, tend, however, to render the conditions present in the combustion chamber unstable and considerably complicate open-loop control of the combustion process.

[0007] Consequently, methods have been proposed for closed-loop control of timing of combustion, in which correction of the engine angles of start of energization of the injectors is performed as a function of the quantities that characterize the combustion cycle, amongst which there may be cited the instant of start of combustion (SOC), the engine angle in which a predetermined fraction, generally 50%, of the mass of the fuel injected into the combustion chamber has been burnt, referred to as 50% mass fraction burnt (*MFB50%*), the engine angle of the pressure peak in the combustion chamber, the centroid of combustion, etc.

[0008] Amongst these quantities, the position of *MFB50%* is the one most widely used in the engine field for closed-loop control of the combustion process in so far as it is the quantity that best represents what occurs in the combustion chamber. In order to determine said engine angle, the evolution of the pressure inside the cylinder during the entire combustion cycle as a function of the engine angle is first of all determined generally by means of a pressure sensor set inside the cylinder and typically integrated in the glow plug associated to the cylinder itself, and then, on the basis of said evolution, the fraction of burnt fuel mass in the cylinder as a function of the engine angle is determined, and finally the angular position at which 50% of the mass of the fuel injected into the combustion chamber is burnt. Said position is then compared with a pre-set target position and, on the basis of the error existing between these two values, the engine angle of start of energization of the injector is corrected.

[0009] In the engine field, the engine angle is generally measured via a phonic wheel fitted on the drive shaft and constituted by a toothed wheel having a so-called "sixty teeth less two" toothing, i.e., in which two consecutive teeth are missing, that is, a toothed wheel provided, on its outer periphery, with identical teeth, generally numbering 58, spaced apart from one another with a pre-set angular pitch, of generally 6°, and in which the first and last tooth are separated from one another by the distance of three pitches, i.e., 18°. Set facing the phonic wheel is then an electromagnetic sensor generating a digital signal formed by a train of pulses corresponding to the passage of the teeth of the phonic wheel in front of the electromagnetic sensor itself.

[0010] In known methods used for calculating the engine angle of *MFB50%,* acquisition of the pressure inside a cylinder is performed in synchronism with the engine angle; that is, the pressure inside a cylinder is acquired at constant angular intervals $\Delta\vartheta$ of the engine angle, i.e., each time the drive shaft carries out a rotation equal to a pre-set angular distance, for example, the angular distance that separates two consecutive teeth of the phonic wheel (in the example considered 6°). In practical terms, if the phonic wheel of the example is used, which is capable of supplying an angular signal with resolution of 6°, and if it is desired to sample the pressure signal at angular increments of one engine degree, it is necessary to estimate appropriately the intermediate engine angles, where to carry out sampling of the signal of pressure inside the cylinder.

[0011] The aforesaid mode of acquisition presents, however, a series of intrinsic disadvantages and problems linked to the context of a embedded real-time system, such as that of an engine electronic control unit, which adversely affect calculation of MFB50% and, consequently, the engine angle of MFB50%, such as, for example:

- the difficulties linked to the need for synchronization of acquisition of the pressure with the engine angles at which said acquisition must necessarily be carried out;
- the imprecision linked to the need for acquiring the pressure inside the cylinder with an angular precision greater

than the one supplied by the phonic-wheel signal, that is at angular increments $\Delta\vartheta$ of the engine angle smaller than the mechanical one linked to the construction of the phonic wheel (for example, angular increments of 1°);

- the imprecision of the calculation of MFB50% deriving from the propagation of the error on the estimation of the engine angle in the sampling points;
- the need for ensuring an accurate conditioning (limitation of the bandwidth) of the pressure signal to be sampled at each engine r.p.m.; and
- the need for optimizing the computation resources in so far as the method of sampling with constant $\Delta\vartheta$ calls for processing of a number of samples per unit time (CPU load) that increases as the engine r.p.m. increases.

[0012] The aim of the present invention is hence to provide a method for calculation of engine parameters that can be derived from the measurement of the pressure inside the cylinder (for example, MFB50%) in order to perform closed-loop control of the combustion in an internal-combustion engine, in particular a diesel engine, and overcome at least in part the drawbacks referred to above, as defined in the annexed claims.

[0013] For a better understanding of the present invention a preferred embodiment is now described, purely by way of nonlimiting example and with reference to the attached plate of drawings, wherein:

- Figure 1 shows a block diagram of a common-rail fuel-injection system provided with an electronic control device that implements the method for closed-loop control of combustion according to the invention;
- Figures 2a, 2b, 2c and 2d show the graphs of engine quantities illustrating the principle underlying the present invention;
- Figure 3 shows a working block diagram of the method for control of combustion according to the invention; and
- Figures 4a, 4b, 4c and 4d show graphs of engine quantities involved in the method of the present invention.

[0014] With reference to Figure 1, designated as a whole by 1 is an internal-combustion engine, in particular a diesel engine, provided with a common-rail fuel-injection system 2, of which only the parts necessary for an understanding of the present invention are shown.

[0015] The injection system 2 comprises a plurality of electromagnetically controlled injectors 3 designed to take in fuel at a high pressure from a common rail 5 and to inject it into respective cylinders 4 of the engine 1. The common rail 5 is supplied with fuel at high pressure by a high-pressure pump 7, which is in turn supplied with fuel at low pressure by a low-pressure pump (not shown) housed inside the fuel tank 8.

[0016] The engine 2, of which only the parts necessary for an understanding of the present invention are shown, further comprises a drive shaft 9, indicated in Figure 1 by a dashed-and-dotted line, fitted on which is a phonic wheel 10 of the type described previously.

[0017] The injection system 2 and the engine 1 are controlled by an electronic control unit 11, designed to receive signals indicating the conditions of operation of the engine 1, such as the position of the accelerator pedal 12 detected by a purposely provided position sensor 13 and the angular position of the drive shaft 9, designated in what follows for reasons of brevity by the term "engine angle ϑ", detected by an electromagnetic sensor 14 of the type described above facing the phonic wheel 10, and signals coming from pressure sensors 15 housed inside the cylinders 4 of the engine 1 for measuring the pressure inside the cylinders 4.

[0018] In particular, the engine angle ϑ is determined by the electronic control unit 11 on the basis of the signal supplied by the electromagnetic sensor 14, as a function of the number of teeth of the phonic wheel 10 that have passed in front of the electromagnetic sensor 14 starting from a pre-set instant, and as a function of the angular pitch between two consecutive teeth of the phonic wheel 10.

[0019] The idea underlying the present invention is substantially to carry out acquisition of the values of pressure inside a cylinder independently of acquisition of the corresponding values of engine angle, which is performed by acquiring first of all these two sets of data separately and independently of one another, and then correlating only subsequently the two sets of data exploiting the temporal relation existing between them.

[0020] Figure 3 shows a block diagram of the method used.

[0021] In particular, the idea underlying the present invention is to sample at constant frequency f_c the pressure signal $P(t)$ supplied by the sensor, and simultaneously measure the times $\Delta t[j]$ taken by the drive shaft to cover angular intervals $\Delta\vartheta$ of constant and pre-defined width supplied by the phonic-wheel sensor 14. Given that the engine angle at start of sampling is known, it is possible to determine the angular displacements $\Delta\vartheta[i]$ performed by the drive shaft in the time intervals t_c elapsing between successive pressure samples, the duration of which, as is known, is constant and equal to the inverse of the sampling frequency f_c. On the basis of the angular displacements $\Delta\vartheta[i]$ thus determined and knowing the engine angle of start of sampling, the values of engine angle $\vartheta[i]$ corresponding to the instants of sampling of the pressure signal are then determined, and each pressure sample $P[i]$ is then correlated with the corresponding value of engine angle $\vartheta[i]$.

[0022] According to what is shown in Figure 3, the electronic control unit 11 samples each signal of pressure in the cylinder $P(t)$ at a constant sampling frequency f_c chosen appropriately as a function of the characteristics of the signal generated by the pressure sensor 15, for example, 20 kHz, thus generating a sequence of pressure samples $P[i]$, in the example considered every 50 μs (block 20), and, simultaneously, measuring the times $\Delta t[j]$ taken by the drive shaft 9 to cover angular intervals of constant width that are linked to the resolution of the phonic-wheel signal (block 21). The two sets of acquisitions are moreover synchronized, by the electronic control unit 11, with respect to the instant of start of acquisition, taking as starting position a pre-set value of engine angle (block 22). Next, for each pressure sample $P[i]$, the electronic control unit 11 determines the corresponding engine angle $\vartheta[i]$, the instant of sampling of $P[i]$ and the angular travel times $\Delta t[j]$ being known(block 23).

[0023] The method for determination of the values of engine angle corresponding to the instants of sampling of the pressure signal described above is shown graphically in Figures 2a, 2b, 2c and 2d. In particular, Figure 2a shows the evolution of the engine r.p.m. in time (by way of example, the engine r.p.m. passes linearly from 2000 r.p.m. to approximately 2018 r.p.m. in 15 ms), the graph of Figure 2b illustrates, instead, the temporal evolution of the signal of the pressure in the cylinder P(t) supplied by one of the pressure sensors arranged inside the cylinders and the various pressure samples (represented by dots) obtained by sampling the pressure signal at a constant frequency f_c (for example, 4 kHz); Figure 2c shows the graph of the evolution of the times $\Delta t[j]$ taken by the drive shaft to cover angular intervals $\Delta\vartheta$ of constant and pre-set width (in the example 6° - the typical spacing of a sixty-less-two phonic wheel), and finally Figure 2d shows the graph of the evolution of the angular displacements $\Delta\vartheta[i]$ performed by the drive shaft in the time intervals $t_c = 1/f_c$ lying between successive pressure samples, obtained by processing the information coming from the phonic wheel (Figure 2c) as a function of time. By way of example, in Figure 2a there is assumed, as pre-chosen operative condition, a linearly increasing rate of rotation of the drive shaft, corresponding to which is a reduction in the time taken by the drive shaft to cover angular intervals of constant width (Figure 2c) and, as may be seen in Figure 2d, an increase in the angular displacements performed by the drive shaft in the time intervals elapsing between successive pressure samples.

[0024] On the basis of the pressure samples $P[i]$ and of the corresponding engine angles $\vartheta[i]$, the electronic control unit 11 determines the characteristic quantities of the combustion cycle for the cylinder considered, in the example considered the angular position of MFB50%. In particular, in order to calculate the angular position of MFB50%, the electronic control unit 11 first of all calculates the heat-release integral on the cycle of compression and expansion of the cylinder considered, which can be expressed in the discrete form by the following equation:

$$MFB[i] = MFB[i-1] + \frac{Q_{IST}[i] + Q_{IST}[i-1]}{2} \cdot (\vartheta[i] - \vartheta[i-1])$$

where Q_{IST} is the instantaneous heat release in turn determined according to the following formula:

$$Q_{IST} = Q_V + Q_P$$

where:

$$Q_P = V[i] \cdot \frac{P[i+1] - P[i-1]}{(K-1) \cdot (\vartheta[i+1] - \vartheta[i-1])}$$

$$Q_v = K \cdot P[i] \cdot \frac{V[i+1] - V[i-1]}{(K-1) \cdot (\vartheta[i+1] - \vartheta[i-1])}$$

where:

- *K* is the polytropic constant;
- *P*[*i*] is the *i*-th pressure sample; and
- *V*[*i*] is the useful volume of the cylinder corresponding to the *i*-th pressure sample and can be calculated by applying the following formula:

$$V[i]=\left(\frac{\pi\cdot Bore^2}{4}\right)\cdot\left(\left(\left(\frac{Stroke}{2}+Conrod\right)-\left(\frac{Stroke}{2}\cdot\cos(\vartheta[i])+\sqrt{Conrod^2-\left(\frac{Stroke}{2}\right)^2-(\cos(\vartheta[i]))^2}\right)\right)+\frac{Stroke}{ComprRatio-1}\right)$$

[0025] On the basis of the values of *MFB*[*i*] thus obtained, the electronic control unit 11 then determines:

- 50% of the fraction of burnt mass according to the formula:

$$MFB\,50\,\% = \frac{Max[MFB[i]] + Min[MFB[i]]}{2}$$

- the angular position $\vartheta_{MFB50\%}$ in which the fraction of burnt mass in the cylinder is equal to 50%.

[0026] Next, the electronic control unit 11 compares the angular position $\vartheta_{MFB50\%}$ with a pre-set angular target position $\vartheta_{MFB50\%\text{-}TARG}$ and, on the basis of said comparison, controls timing of combustion correcting, if necessary, the engine angle of start of energization (SOE) of the fuel injectors. Figures 4a, 4b, 4c and 4d show, respectively, by way of example, the graphs of the energization control of an injector, the pressure in a cylinder, the heat release, and the fraction of burnt mass.

[0027] On the basis of the pressure samples *P*[*i*], the electronic control unit 11 then carries out also calculation of other indicators of combustion, amongst which the indicated mean effective pressure high (IMEPH), representing the torque supplied by the cylinder during combustion minus the losses for pumping, according to the following formula:

$$IMEPH = PH / V_{CYL}$$

where *PH* is the work carried out by the engine cycle during the compression phase (180° before explosion top dead centre) up to the end of the expansion phase (180° after explosion top dead centre), and can be calculated according to the following formula:

$$PH[i] = PH[i-1] + PMA[i]\cdot DVA[i]$$

where:

$$DVA[i] = V[i] - V[i-1]$$

$$PMA[i] = (P[i] + P[i-1])/2$$

and V_{CYL} is the unit engine displacement.

[0028] Next, the electronic control unit 11 calculates the indicated torque (IT) supplied by the engine according to the formula

$$IT = \frac{IMEPH \cdot V_{TOT}}{const}$$

where V_{TOT} is the total engine displacement and *const* is a constant equal to 0.126 in the case where *IMEPH* is expressed in bar and the total engine displacement V_{TOT} is expressed in dm^3.

[0029] The advantages of the present invention emerge clearly evident from the above description. In particular, the method forming the subject of the present invention enables:

- decoupling of the problems linked to sampling of the pressure signal from the ones regarding the angular positioning of the engine;
- appropriate calibration of the sampling frequency of the pressure signal as a function of the sensor used;
- accurate sampling of the pressure signal at each engine r.p.m.;
- minimization of error propagation in the calculation of the engine parameters of interest for control of combustion;
- optimization of the computation resources of the electronic control unit 11, in so far as the number of samples to be processed per unit time is constant, and consequently the computation resources used (CPU load) depend only marginally upon the engine r.p.m.; and
- simplification in the construction of an optimal anti-aliasing filter.

[0030] It is clear that modifications and variations may be made to the method described and illustrated herein, without thereby departing from the sphere of protection of the present invention, as defined in the annexed claims.

[0031] For example, the electronic control unit 11 could carry out a closed-loop control of timing of combustion based upon characteristic quantities of the combustion cycle other than *MFB50%,* for example, the instant of start of combustion, the centroid of combustion, etc.

Claims

1. A method for closed-loop control of timing of combustion in an internal-combustion engine (1), in particular a diesel engine, comprising:

• determination of a characteristic quantity of the combustion cycle ($\vartheta_{MFB50\%}$) in a cylinder (4) of said engine (1); and
• closed-loop control of timing of combustion in said engine (1) on the basis of said determined characteristic quantity of the combustion cycle ($\vartheta_{MFB50\%}$) and of a target value (ϑ_{TARG}) of said characteristic quantity ($\vartheta_{MFB50\%\text{-}TARG}$);
said method being **characterized in that** determination of said characteristic quantity $\vartheta_{MFB50\%}$) comprises:
• determining the values ($P[i]$) of pressure inside said cylinder (4) during at least part of the combustion cycle in the cylinder (4) itself, said pressure values ($P[i]$) being determined at successive and equally spaced instants in time;
• measuring the times ($\Delta t[j]$) taken by the drive shaft of said engine (1) to cover successive angular distances ($\Delta\vartheta$) of constant width; and
• determining said characteristic quantity ($\vartheta_{MFB50\%}$) on the basis of said pressure values ($P[i]$) and of said angular travel times ($\Delta t[j]$).

2. The method according to Claim 1, in which determining said characteristic quantity ($\vartheta_{MFB50\%}$) on the basis of said pressure values ($P[i]$) and of said angular travel times ($\Delta t[j]$) further comprises:

• determining the angular displacements ($\Delta\vartheta[i]$) performed by the drive shaft between the instants of time of determination of successive pressure values ($P[i]$), on the basis of said angular travel times ($\Delta t[j]$)*;*
• determining the engine angles $\vartheta[i]$ corresponding to said pressure values ($P[i]$) on the basis of said angular displacements ($\Delta\vartheta[i]$); and
• determining said characteristic quantity ($\vartheta_{MFB50\%}$) on the basis of said pressure values ($P[i]$) and of said engine angles ($\vartheta[i]$).

3. The method according to Claim 1 or Claim 2, in which said pressure values ($P[i]$) are determined during the phases of compression and expansion of the combustion cycle in said cylinder (4).

4. The method according to any one of the preceding claims, in which determining said pressure values ($P[i]$) comprises:

- generating a pressure signal indicating the pressure ($P(t)$) inside said cylinder; and
- sampling said pressure signal ($P(t)$) at a constant sampling frequency (f_c).

5. The method according to any one of the preceding claims, in which said characteristic quantity ($\vartheta_{MFB50\%}$) is the angular position of said drive shaft in which a given fraction of the mass of fuel injected into said cylinder (*MFB50%*) has been burnt.

Amended claims in accordance with Rule 137(2) EPC.

1. A method for closed-loop controlling combustion timing in an internal combustion engine (1), in particular a diesel engine, the method comprising:

- determining a combustion characteristic ($\vartheta_{MFB50\%}$) of a combustion cycle in a cylinder (4) of said internal combustion engine (1); and
- closed-loop controlling the combustion timing of said internal combustion engine (1) based on said determined combustion characteristic ($\vartheta_{MFB50\%}$) and on a target value ($\vartheta_{MFB50\%-TARG}$) of said combustion characteristic ($\vartheta_{MFB50\%}$)

characterized in that determining a combustion characteristic ($\vartheta_{MFB50\%}$) comprises:

- determining in-cylinder pressure values ($P[i]$) at successive and equally spaced time instants during at least part of said combustion cycle in said cylinder (4);
- measuring travel times ($\Delta t[j]$) taken by a drive shaft of said internal combustion engine (1) to cover successive, constant-width angular distances ($\Delta\vartheta$); and
- determining said combustion characteristic ($\vartheta_{MFB50\%}$) based on said pressure values ($P[i]$) and said travel times ($\Delta t[j]$).

2. The method according to claim 1, wherein determining said combustion characteristic ($\vartheta_{MFB50\%}$) based on said pressure values ($P[i]$) and said travel times ($\Delta t[j]$) comprises:

- determining angular displacements ($\Delta\vartheta[i]$) of said drive shaft between successive time instants when said in-cylinder pressure values ($P[i]$) are determined, based on said travel times ($\Delta t[j]$);
- determining crank angles $\vartheta[i]$ corresponding to said pressure values ($P[i]$) based on said angular displacements ($\Delta\vartheta[i]$); and
- determining said combustion characteristic ($\vartheta_{MFB50\%}$) based on said pressure values ($P[i]$) and said crank angles ($\vartheta[i]$).

3. The method according to claim 1 or 2, wherein said pressure values ($P[i]$) are determined during compression and expansion strokes in said combustion cycle in said cylinder (4).

4. The method according to any one of the preceding claims, wherein determining pressure values ($P[i]$) comprises:

- generating a pressure signal indicative of a pressure ($P(t)$) in said cylinder (4); and
- sampling said pressure signal ($P(t)$) at a constant sampling frequency (f_c).

5. The method according to any one of the preceding claims, wherein said combustion characteristic ($\vartheta_{MFB50\%}$) is an angular position of said drive shaft where a given mass fraction (*MFB50%*) of fuel injected into said cylinder (4) has burnt.

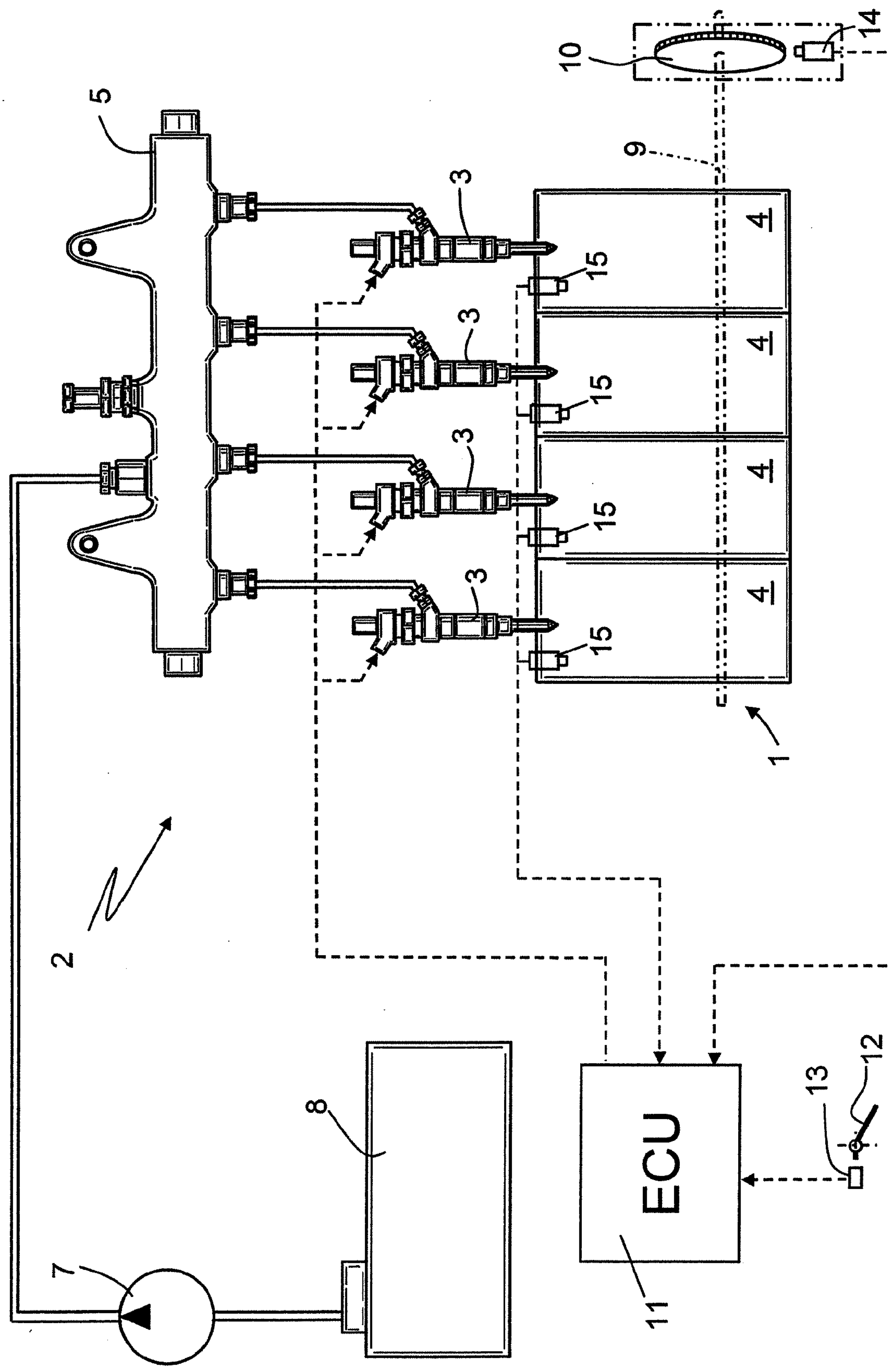

Fig.1

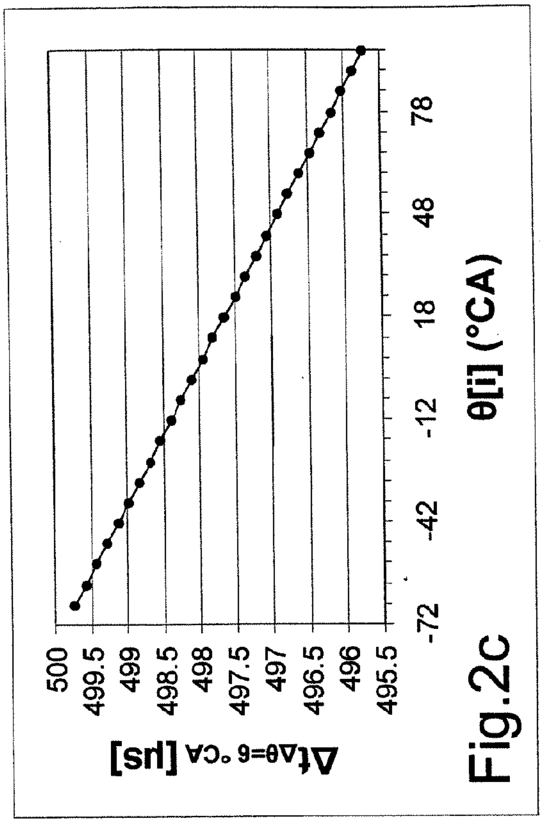

Fig.2c

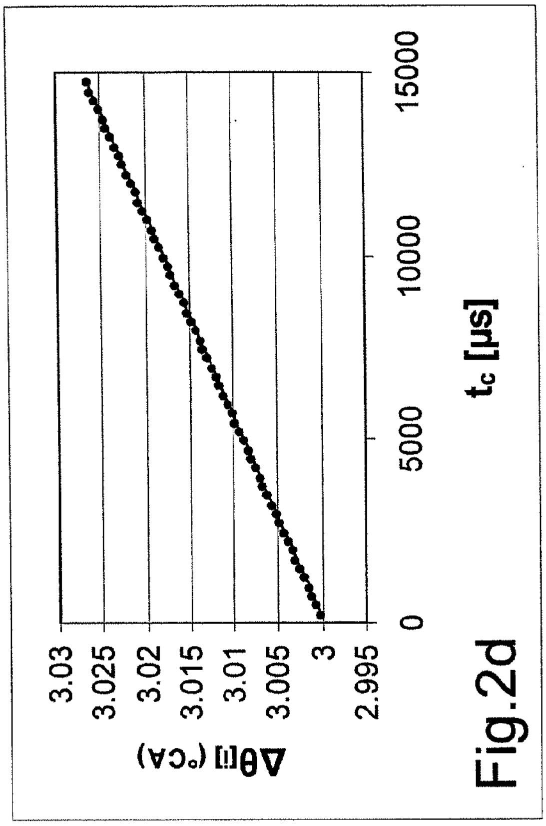

Fig.2d

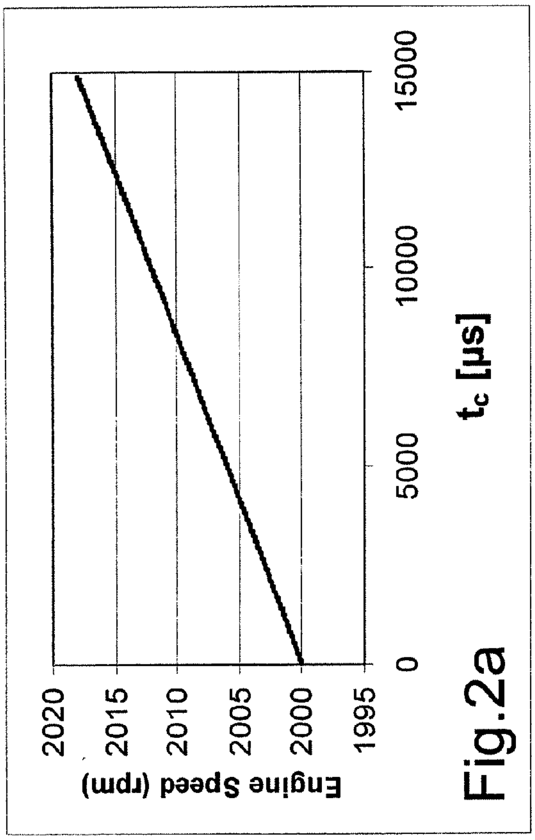

Fig.2a

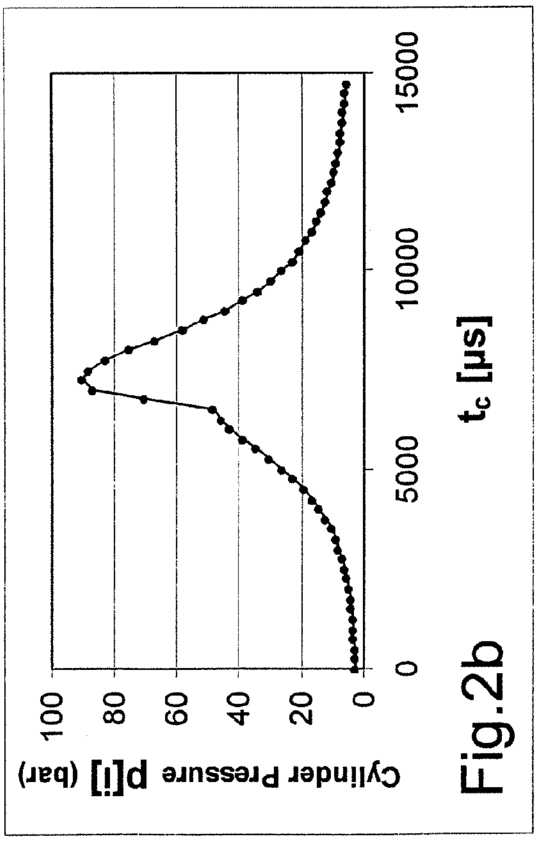

Fig.2b

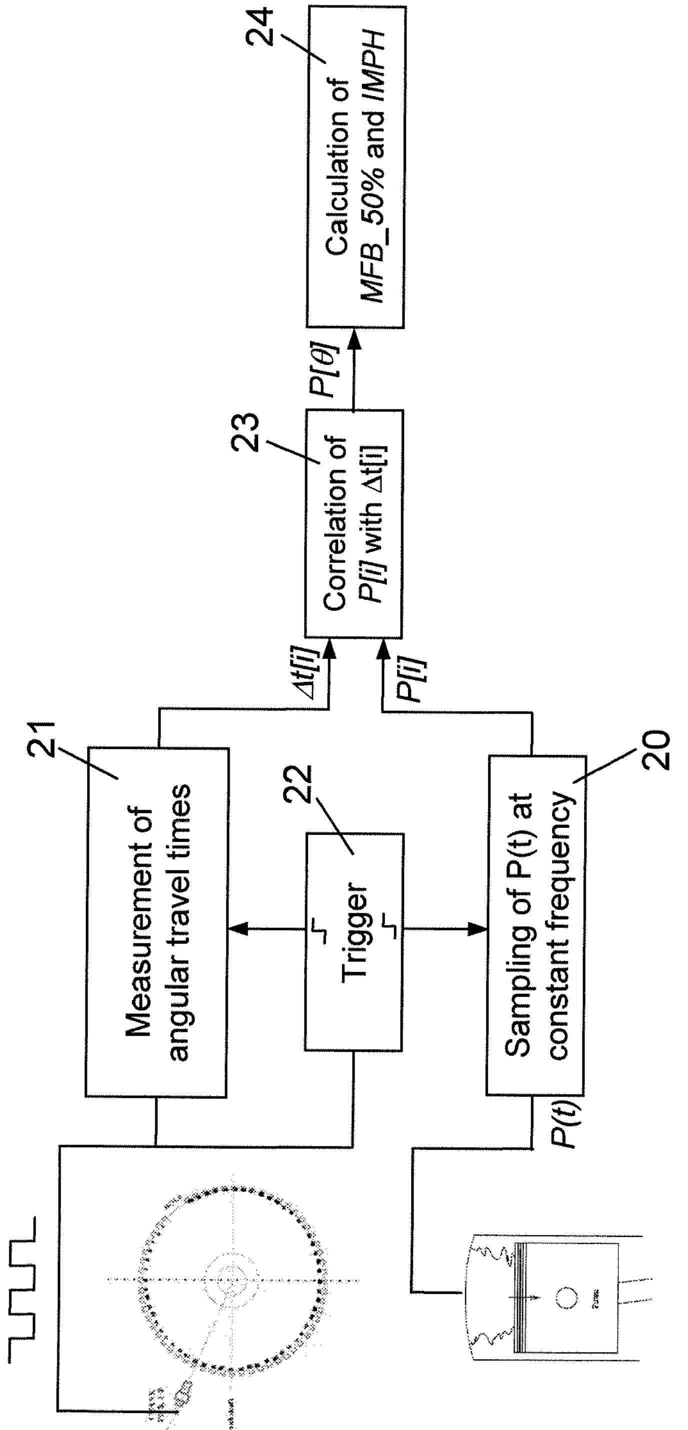
24
Calculation of MFB_50% and IMPH
P[θ]
23
Correlation of P[i] with Δt[i]
Δt[i]
P[i]
21
Measurement of angular travel times
22
Trigger
20
Sampling of P(t) at constant frequency
P(t)

Fig.3

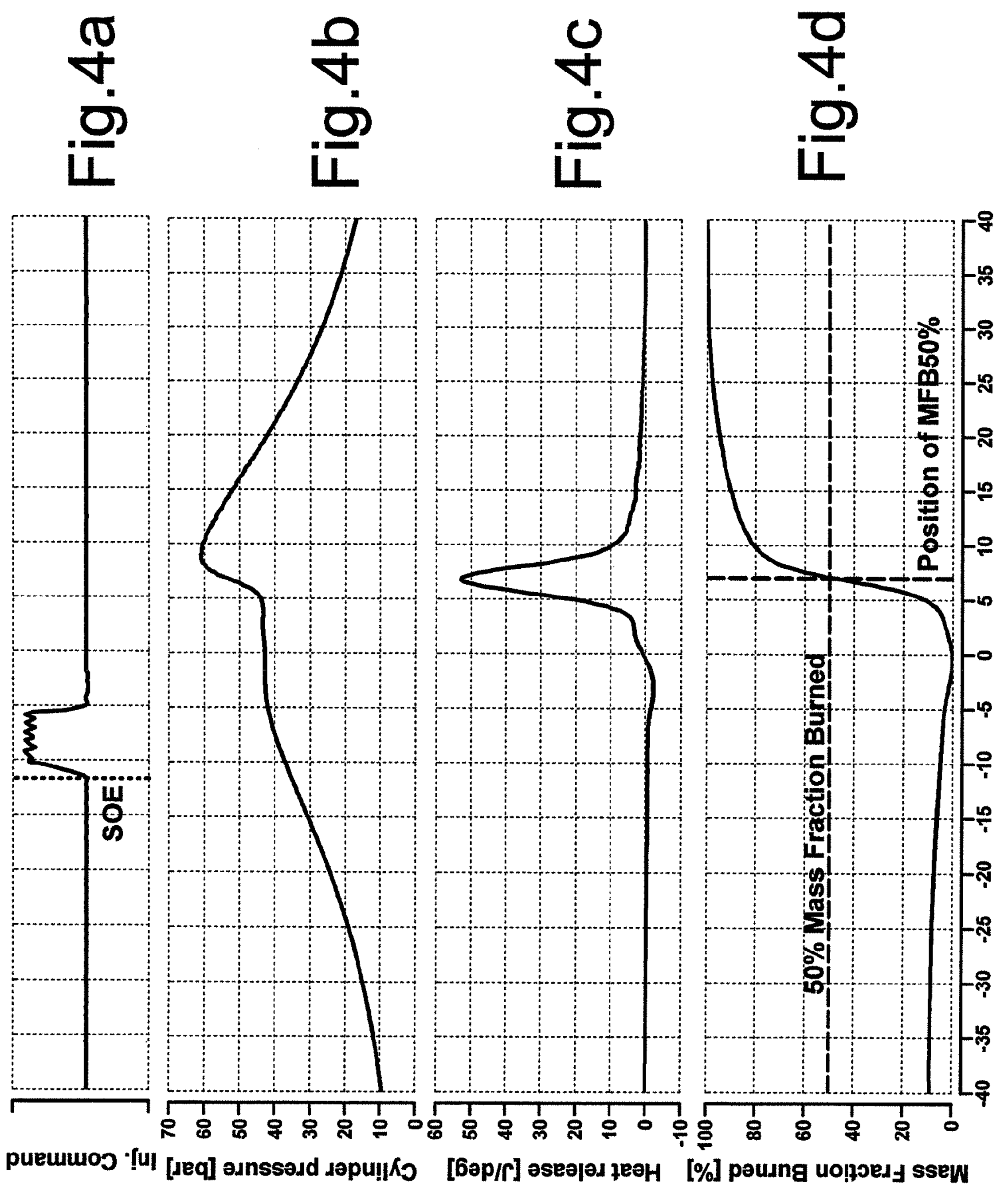
Fig.4a
Fig.4b
Fig.4c
Fig.4d
Inj. Command
SOE
Cylinder pressure [bar]
Heat release [J/deg]
Mass Fraction Burned [%]
50% Mass Fraction Burned
Position of MFB50%
Crank angle [deg ATDC]

European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 06 42 5629

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	US 2004/084024 A1 (MALACZYNSKI GERARD WLADYSLAW [US] ET AL) 6 May 2004 (2004-05-06) * paragraphs [0011], [0019] * -----	1-5	INV. F02D41/30 F02D35/02
X	WO 02/095191 A (RICARDO CONSULTING ENG [GB]; TRUSCOTT ANTHONY J [GB]; NOBLE ANDREW D [) 28 November 2002 (2002-11-28) * page 6, line 15 - line 18 * * page 7, line 4 - line 8 * -----	1-5	
X	US 2004/084025 A1 (ZHU GUOMING G [US] ET AL) 6 May 2004 (2004-05-06) * paragraphs [0008] - [0010] * * paragraphs [0014], [0015] * * paragraph [0125] * -----	1-5	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02D

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	7 May 2007	Jackson, Stephen

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C07)

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INCOMPLETE SEARCH SHEET C

Application Number
EP 06 42 5629

Claim(s) searched incompletely:
1-5

Claim(s) not searched:
-

Reason for the limitation of the search:

Claim 1 defines a method for closed loop timing control of an internal combustion engine. The features defining the invention are so broad that they include many different alternatives which are not supported by the description, and claim 1, therefore, does not meet the requirements of Article 84 EPC.

Claim 1 defines determining a characteristic quantity of the combustion cycle in a cylinder of an engine. This could mean any of several possibilities, including an angle at which the 50% mass fraction burn time occurs, in-cylinder pressure, temperature, ionic current, noise levels, NOx content, ignition angle etc. From page 9 lines 22-23 of the description it would appear that the characteristic quantity which is to be determined is the angle at which the 50% mass faction burn time occurs. The other alternatives are not mention in the description, and are, therefore, not supported therein.

The search report has been drawn up assuming that the characteristic quantity of the combustion cycle to be determined is indeed the angle at which the 50% mass fraction burn time occurs.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 06 42 5629

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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07-05-2007

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