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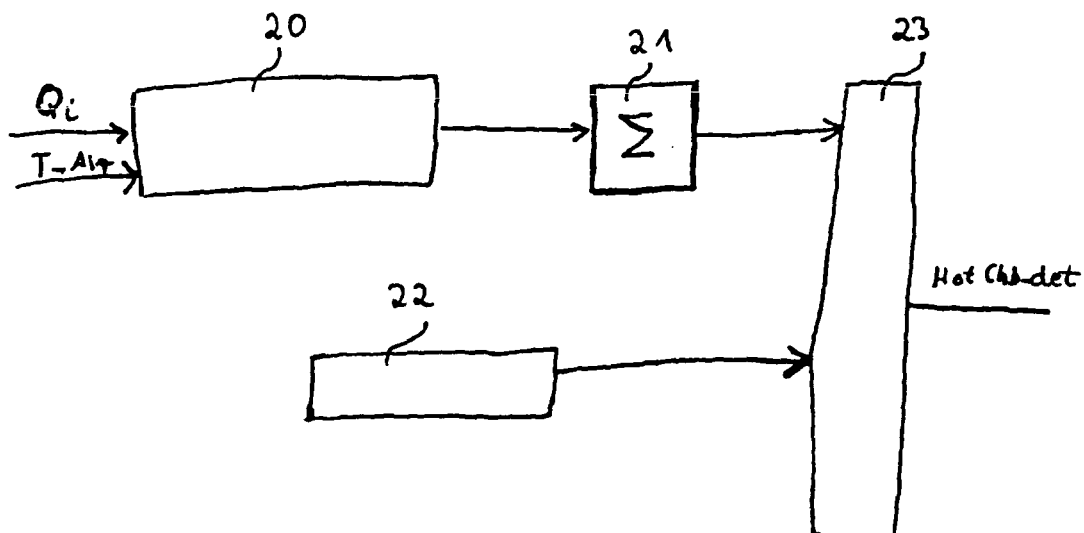
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(54) **Method of assessment of the combustion chamber thermal state in internal combustion engines**

(57) Method for determining the temperature in a combustion chamber of an internal combustion engine and device for determining the temperature in a combustion chamber of an internal combustion engine

It is provided method and an apparatus for determining the temperature in a combustion chamber of an internal combustion engine. The temperature is estimated based on the quantity of fuel being injected in the internal combustion engine and on the ambient temperature.

**Fig. 2**

Description

[0001] The invention relates to a method for determining the temperature in a combustion chamber of an internal combustion engine and to a device for determining the temperature in a combustion chamber of an internal combustion engine.

[0002] In some applications, the control of an internal combustion may be improved if the temperature inside the combustion chamber is known. It would be difficult to measure the temperature in the combustion chamber directly. In the EP 1 457 653, a control microprocessor is connected to a coolant temperature sensor that allows an estimation of the temperature in the combustion chamber. However, due to high temperature shifts in the coolant, there is a risk that the coolant sensor fails during the lifetime of the internal combustion engine which would make the internal combustion engine less effective.

[0003] It is accordingly an object of the invention to provide an improved method for determining the temperature in a combustion chamber of an internal combustion engine and a device for determining the temperature in a combustion chamber of an internal combustion engine.

[0004] A method is provided for determining the temperature in a combustion chamber of an internal combustion engine. The temperature is estimated based on the quantity of fuel injected in the internal combustion engine and on the ambient air temperature. This temperature is the temperature of the air outside the engine and outside the exhaust. The method provides a detection of the temperature in the combustion chamber without the need of an additional temperature sensor in the exhaust or the coolant. The implementation of additional temperature sensors increases the cost of the engine. Furthermore, a coolant or exhaust sensor has to work in a large temperature range with the risk that the sensor cracks due to thermal stress.

[0005] In contrast, estimating the temperature in the combustion chamber based on injected fuel quantity and the ambient air temperature means that the estimation is based on data that is available in almost every modern car from an air temperature sensor and an engine control system already provided.

[0006] The quantity of injected fuel may be the quantity that was injected in the previous time step, that is injected currently or that will be injected in the following time step.

[0007] There are internal combustion engines in which not the complete quantity of injected fuel is burnt inside the combustion chamber. This is for example the case for diesel engines with a diesel particle filter (DPF) by which, in some engine operating modes, additional fuel is injected in order to regenerate the filter. The first injection is called torque forming because it will self-ignite, burn and make the piston and the crankshaft move. The second quantity, which is injected at a different phase of the engine cycle, is called non-torque forming.

[0008] The strategy is based on the following assumption: If a fuel injection is a torque forming fuel injection, then the whole injected fuel injection is completely oxidised inside the combustion chamber.

[0009] One the other hand, if an injection is not torque forming, the injected fuel quantity is not completely oxidised in the combustion chamber. Since the combustion chamber thermal conditions are mainly influenced by the fuel injected quantity burning inside the combustion chamber, the torque forming fuel injection quantity has to be taken into account when dealing with combustion chamber thermal conditions.

[0010] Accordingly, if the injection comprises a torque forming part and a non-torque forming part of the injections, only the torque forming part is used as basis for the estimation of the temperature. If, for example all injections are torque forming, the estimation is accordingly based on all injections.

[0011] In an embodiment, a stored value S is increased by a value X if the torque forming quantity Q_i is > 0 in the last time step and a value Y is subtracted from the stored value S if the torque forming quantity Q_i equals zero in the last time step.

[0012] In an embodiment, the step of adding comprises the calculation of S according to

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \quad (\text{Formula 1}).$$

[0013] S_j and S_{j-1} are the values of S at the time points T_j and T_{j-1} and $Q(t)$ is the injected fuel quantity. This integration can be performed with standard microprocessor functions. The formula 1 takes into account that the injected quantity may differ during the time step $[T_{j-1}; T_j]$ and gives a precise calculation method for these cases.

[0014] In a preferred embodiment, an upper limit UL for the value S is set such that formula 1

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \quad \text{is used only if} \quad S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} < UL, \quad \text{else } S_j \text{ equals the upper limit } UL. \text{ This}$$

ensures that the value S does not exceed a upper limit when the engine runs for a long time and takes into account that the temperature of a combustion chamber saturates at an upper limit.

[0015] If value Y depends on the ambient temperature the method follows the observation that the combustion chamber cools off faster than at high air temperatures.

[0016] If the stored value S is compared with a threshold value, the compare information may be directly used in the control of the fuel injection to determine if the internal combustion engine is considered to be hot. When the fuel injection has to be precisely controlled it is important to know if the combustion chamber is hot or cold.

[0017] The invention further provides an apparatus for determining the temperature in a combustion chamber of an internal combustion engine. The apparatus comprises a fuel determination block for determining the quantity of injected fuel, a temperature sensor for the ambient temperature and a calculator for estimating the temperature based on the outputs of the fuel determination block and on the output of the temperature sensor.

[0018] Such apparatus is easy to implement as it may use devices that are already part of a modern vehicle. Almost every modern car, for example comprises a temperature sensor for the ambient temperature. The calculator may be implemented as an additional function in the control microprocessor of the internal combustion engine. The apparatus does not rely on an additional temperature sensor in the exhaust or the coolant which increases the costs and the risk of failure.

[0019] In an embodiment, the calculator comprises a counter which is built for counting up by a value of X if a torque forming quantity $Q_i > 0$ was injected during in the last time step. On the other hand, it counts down by Y from the stored value S if the torque forming quantity Q_i equals zero in the combustion chamber in the last time step.

[0020] The counter value when counting up from S_{j-1} to S_j is preferably set according to the formula

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \quad \text{whereby } S_j \text{ and } S_{j-1} \text{ are the counter values at the time points } T_j \text{ and } T_{j-1} \text{ and } Q(t) \text{ is the}$$

injected fuel quantity.

[0021] The invention will be further described based on the drawings showing an embodiment of the invention.

Figure 1 shows in a schematic overview an internal combustion engine for which the method of determining the temperature in the combustion chamber is provided.

Figure 2 shows in a schematic overview of the apparatus for determining the temperature in the combusting chamber.

[0022] Figure 1 is a schematic overview of a Diesel internal combustion engine 1 for a vehicle, for example an automobile. Air is aspirated through an intake passage 3 through the intake valve 15. Fuel is injected from the fuel injector 2 to form a compressed gaseous mixture with the air. The gaseous mixture ignites to burn which makes the piston 6 move downward and the crankshaft 7 rotate. The combustion gas is discharged through the exhaust passage 8 by the opening the exhaust valve 9.

[0023] Figure 2 shows a schematic of the detection model for the temperature in the combustion chamber 5 comprising a step determination block 20, a counter 21, a threshold determination 22 and a comparator 23. The signal Q_i being proportional to the torque forming quantity of injected fuel and the signal T_{Air} which represents the air temperature are input to the step determination block 20.

[0024] According to an embodiment, the ambient temperature is measured in the intake 3. However any sensor of the vehicle measuring the ambient air temperature may be used.

[0025] The output of the step determination block 20 is input to the counter 21 which outputs a count value to the compare block 22. The temperature threshold determination 22 outputs a threshold value which is compared in the compare block 22 with the output of the counter 22.

[0026] The quantity of injected fuel Q_i is derived from the engine control. The driver of the automobile requests more torque by pushing the accelerator pedal. This request, together with other requests coming from other devices, is received by a digital control logic, which calculates how much fuel is needed to produce the requested torque. This signal is input to the control of the fuel injector and, at the same time, to the step determination block 20. Accordingly, the signal Q_i represents the quantity of fuel that will be injected in the next timestep. In other embodiments, the signal Q_i represents

what is currently injected in the combustion chamber 5 or what was injected in the previous time step.

[0027] The output of the step determination block 20, which is also called step size for the counter, is determined according to the following logic. Q_i is the torque forming fuel injected quantity. If $Q_i = 0$, the counter is decreased by means of a calibratable step. The step size derives from a calibratable vector as a function of the air temperature. In

one embodiment, if the air temperature is low, the step size is larger than in case of a high air temperature. **[0028]** In contrast, if $Q_i \neq 0$, or in other words $Q_i > 0$, the output step size is positive. The step size is equal to the torque forming injected fuel quantity, which is measured in mm^3 per stroke. The counter is increased by means of a step. Thus, the torque forming injected quantity is integrated.

[0029] In practice, during fuel cut-offs, especially at low air temperature, the combustion chamber is assumed to cool off, whereas, when torque forming fuel is injected, the combustion chamber heating is presumed to be proportional to the quantity of fuel actually injected, until overcoming a threshold appropriately calibrated.

[0030] At key-on of the vehicle, when the engine starts, the counter 21 is initialised at zero. It has a calibratable lower and upper saturation or in other words lower and upper limits. The counter starts counting when the engine starts running, i. e. when the combustion engine starts. At each calculation task, the counter is incremented by means of a step size.

[0031] The output of the counter 22 is compared with the output of the threshold determination 22 which outputs a signal HotChb_thr. If the counter exceeds a calibratable threshold HotChb_thr, then a hot chamber is detected. Otherwise, if the counter drops under the threshold HotChb_thr, the combustion chamber 5 is considered to be cold. The threshold is used without a hysteresis.

Reference number list

[0032]

- 1 internal combustion engine
- 2 fuel injector
- 3 intake
- 5 combustion chamber
- 6 piston
- 7 crankshaft
- 8 exhaust passage
- 9 exhaust valve
- 10 exhaust
- 15 intake valve
- 20 step determination block
- 21 counter
- 22 threshold determination
- 23 comparator

Claims

1. Method for determining the temperature in a combustion chamber (5) of an internal combustion engine (1), comprising a step of estimating the temperature based on the quantity of fuel being injected in the internal combustion engine and on the ambient air temperature (T_{Air}).

2. Method according to claim 1 or 2,

characterized in that

the quantity of fuel being injected consists of a torque forming part and a non-torque forming part and that the estimation is based only on the torque forming part.

3. Method according to one of the claims 1 to 2,

characterized in that the step of estimating comprises the calculation steps of

- adding a value X to a stored value S if the torque forming quantity $Q_i > 0$ in the last time step and

- subtracting a value Y from the stored value S if the torque forming quantity $Q_i = 0$ in the last time step.

4. Method according to claim 3,

characterized in that

the stored value S is initialised at zero at the start of the internal combustion engine (1).

5. Method according to claim 3 or 4,
characterized in that

the step of adding comprises the calculation of S according to

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}}$$

whereby S_j and S_{j-1} are the values of S at the time points T_j and T_{j-1} and $Q(t)$ is the injected fuel quantity.

6. Method according to one of the claims 3 to 4,
characterized in that

the step of adding comprises the calculation of S according to

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \text{ if } S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} < UL$$

and

$$S_j = UL \text{ if } S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \geq UL$$

whereby S_j and S_{j-1} are the values of S at the time points T_j and T_{j-1} and $Q(t)$ is the injected fuel quantity and UL an upper limit for S.

7. Method according to one of the claims 3 to 6,

characterized in that the value Y depends on the ambient air temperature.

8. Method according to one of the claims 1 to 7,

characterized in that the stored value S is compared with a threshold value to determine if the combustion chamber is hot.

9. Apparatus for determining the temperature in a combustion chamber of an internal combustion engine, comprising

- a fuel determination block for determining the quantity of injected fuel,
- a temperature sensor for measuring the ambient temperature,
- and a calculator (20, 21) for estimating the temperature based on the outputs of the fuel determination block and on the output of the temperature sensor.

10. Apparatus according to claim 9,

characterized in that

the quantity of fuel being injected consists of a torque forming part and a non-torque forming part and that the estimation is based on the torque forming part.

11. Apparatus according to claim 9 or 10,

characterized in that
that the counter (21) is built for

- counting up by a value of X if a quantity $Q_i > 0$ of fuel was injected during in the last time step
- counting down by a value of Y from the stored value S if the quantity $Q_i \leq 0$ was injected in the combustion chamber in the last time step.

12. Apparatus according to claim 9 to 11,
characterized in that the counter is built for counting up from S_{j-1} to S_j according to

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}}$$

whereby S_j and S_{j-1} are the values of S at the time points T_j and T_{j-1} and $Q(t)$ is the injected fuel quantity.

13. Apparatus according to claim 9 to 11,
characterized in that
the counter is built for counting up from S_{j-1} to S_j according to

$$S_j = S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \text{ if } S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} < UL$$

and

$$S_j = UL \text{ if } S_{j-1} + \frac{\int_{T_{j-1}}^{T_j} Q(t) dt}{T_j - T_{j-1}} \geq UL ,$$

whereby S_j and S_{j-1} are the values of S at the time points T_j and T_{j-1} and $Q(t)$ is the injected fuel quantity and UL an upper limit for S.

14. Apparatus according to one of the claims 9 to 13,
characterized in that
the value Y depends on the ambient temperature (T_{Air}).

15. Apparatus according to one of the claims 9 to 14,
characterized in that
the apparatus further comprises a comparator (23) which is built for comparing the output of the counter (21) with a predefined threshold.

16. Apparatus according to one of the claims 9 to 15,
characterized in that
the apparatus is part of a control of an internal combustion engine.

17. Apparatus according to claim 16,
characterized in that

the internal combustion engine (1) is part of an automobile.

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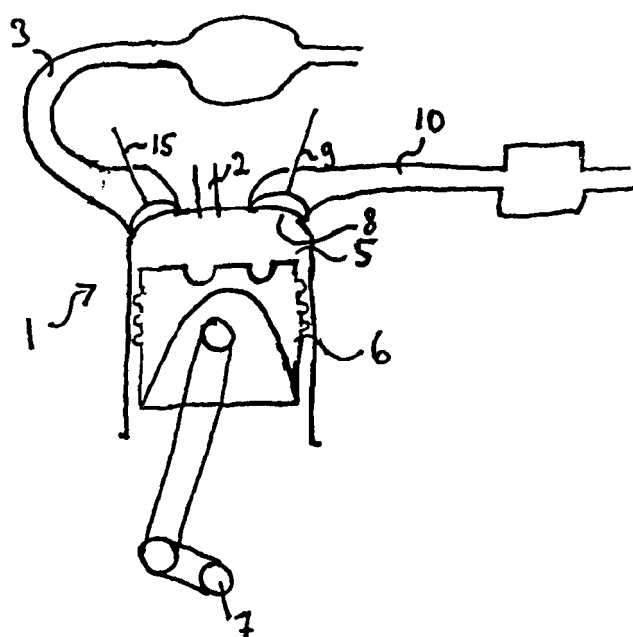


Fig.1

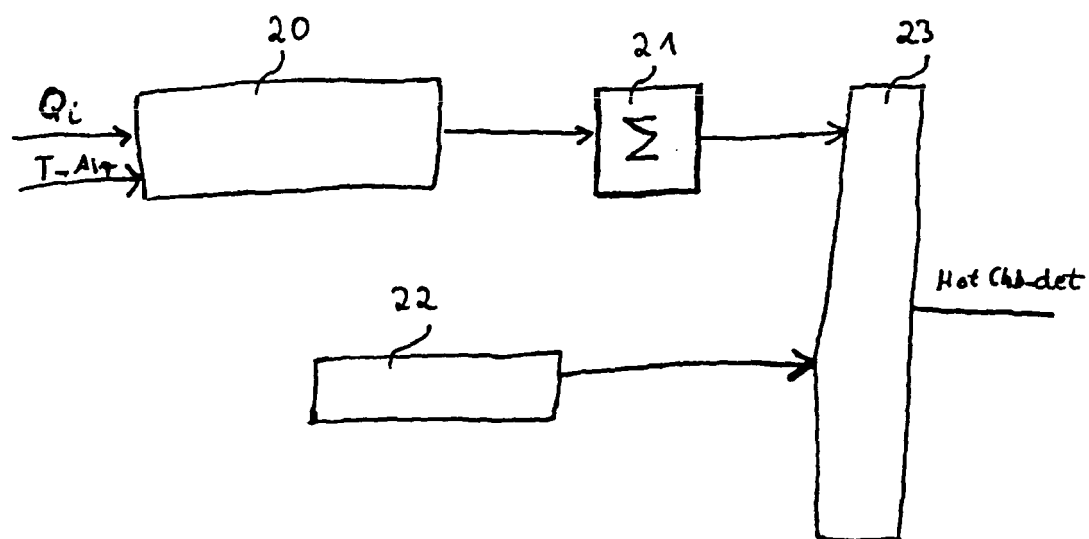


Fig. 2



European Patent
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EUROPEAN SEARCH REPORT

Application Number
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 07 01 8761

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