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(19)

(11) Publication number: **0 400 172 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **89109805.5**

(51) Int. Cl.[5]: **F02D 41/14**

(22) Date of filing: **31.05.89**

(43) Date of publication of application: **05.12.90 Bulletin 90/49**

(84) Designated Contracting States: **DE ES FR GB IT**

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(54) **Method for determining the air/fuel ratio of an internal combustion engine.**

(57) A method and apparatus for automatically adjusting the air/fuel ratio of an internal combustion engine provided with a knock control comprises monitoring changes in value of the ignition angle of an engine at the knock limit in response to changes in the air/fuel ratio of the mixture supplied to the engine, noting two equal values of ignition angle at the knock limit with two difference values of the air/fuel ratio in order to compute the current optimum air/fuel ratio and adjusting the supply of fuel and/or of air to provide the optimum ratio.

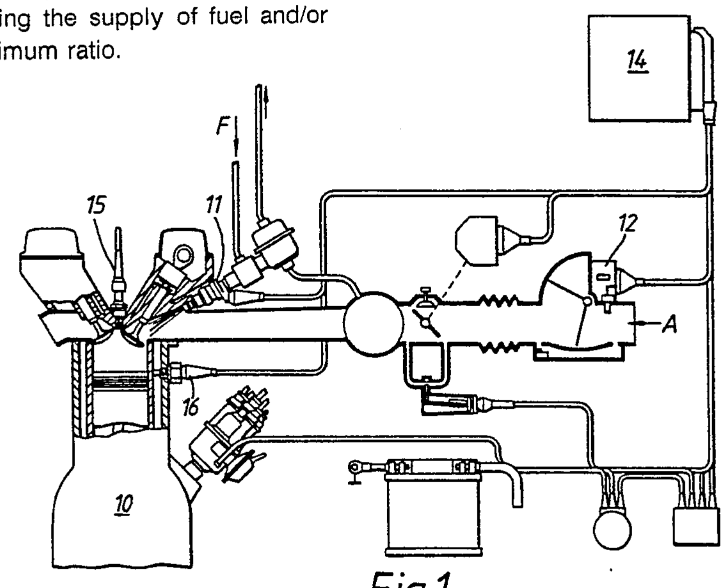

Fig.1

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Method and apparatus for determining the air/fuel ratio of an internal combustion engine

The present invention relates to the monitoring of the air/fuel ratio of an internal combustion engine which is provided with knock control.

It is known that the air/fuel ratio of an internal combustion engine should be maintained at a predetermined value throughout the life of the engine. With engines fitted with emission control equipment using a λ - sensor, the air fuel ratio of the engine can be maintained on the basis of signal derived from the sensor. For all other engines, adjustment of the air/fuel ratio has required trained technicians using special equipment.

The present invention provides a method of automatically adjusting the air/fuel ratio of an engine by monitoring changes in an operating parameter of the engine in response to a knock control circuit.

Preferably the operating parameter is ignition angle but it could also be ignition timing and/or duration.

The advantage of this arrangement is that any change of the air/fuel ratio from its nominally ideal value can be automatically compensated without the need of trained personnel.

In order that the present invention be more readily understood, an embodiment thereof will now be described by way of example with reference to the accompanying drawings in which:-

Fig. 1 shows diagrammatically a part of an engine fitted with fuel injection;

Fig. 2 shows a diagram indicating the variation in knock limit with variations of ignition angle and air/fuel ratio; and

Fig. 3. shows a block diagram of a part of an electronic control unit suitable for use in the arrangement shown in Fig. 1.

It is known that the air/fuel ratio of an engine varies as the engine ages but also with changes in climatic conditions and/or altitude. Ideally the air/fuel ratio should be constant for maximum engine efficiency.

In engines fitted with knock control, such as that shown in Fig. 1, the knock limit is influenced by the compression ratio, fuel quality of the engine and air/fuel ratio. In Fig. 1, an engine generally represented by the reference numeral 10 is fitted with a fuel injection system including inter alia a fuel injector 11, the fuel flow to which is indicated by arrow F, and an air supply flow system including an air flow sensor 12 for detecting air flowing in the direction of the arrow A. An electronic control unit (ECU) 14 controls the injector 11 and also controls the timing of voltage pulses to ignition device such as a spark plug 15. A knock sensor 16 is connected to the ECU 14 and the engine will operate in the normal manner. In view of this, further explanation of the operation will be omitted. The knock control circuitry in the ECU 14 will cause a reduction in spark advance in the situation where risk of knocking is determined. This is known as the knock limit.

The present invention makes use of signals derived from the knock control circuity to indicate that the air/fuel ratio is no longer optimized and to alter the air/fuel ratio by, for example altering the injection timing.

Fig. 2 of the drawings shows a diagram which will assist in understanding one way in which the optimum air/fuel ratio can be determined at any desired time using knock control circuitry. The line in the diagram represents the knock limit for difference combinations of ignition angle and air fuel ratio. It will be seen that the ignition angle at which the knock limit is reached decreases with increasing air/fuel ratio until a minimum ignition angle is reached and then increases with further increased of air/fuel ratio. It has been found that at the minimum ignition angle Z the air/fuel ratio is at or near the stoichiometric ratio λ for that engine. It is this stoichiometric ratio λ which it is wished to maintain.

In order to determine the stoichiometric ratio at any desired time, it is proposed to monitor the ignition angle at which the knock limit is reached as the air/fuel ratio is altered by changing for example the injection timing. The air/fuel ratio is continuously altered in one direction and the resultant changes in ignition angle at the knock limit stored until two equal values of ignition angle at the knock limit are produced by different air fuel ratios. These are indicated by the points a and b on the drawing. From this, the air/fuel ratio of the greatest low-octane rating can be inferred by, for example taking the average of the two air/fuel ratios at a and b and the appropriate adjustment can then be made to the injection timing to ensure continued operation at or near the current stoichiometric ratio.

The air fuel ratio will normally not alter appreciably in a short space of time so that the monitoring and adjustment procedure outlined above need not be done continuously. Further it is best done periodically.

Fig. 3 shows, in block diagram form, an arrangement for carrying out the method described above. It is assumed for the purposes of simplicity that a single ECU 14 will control both the injection and ignition if the engine is well as carrying out knock control function. This need not be the case and any one or indeed all the individual functions of injection, ignition and knock control can have a dedicated ECU in which case there must be communication between them.

The ECU 14 comprises a processor 20 for controlling the various devices connected thereto and for performing arithmetic calculations on data supplied to it. Connected to the processor 20 in an air/fuel ratio control circuit 21 which is arranged to control means for altering the air/fuel ratio 22. An indication of the air/fuel ratio set by the control circuit 21 is stored in a first store 23 which is updated with each new fuel ratio setting. The processor 20 receives data from the store 23.

An ignition control circuit 25 is also connected to the processor 20 and is arranged to control an ignition angle setting means 26. An indication of the ignition angle set by the circuit 25 is held in a further store 27 which is updated with each new ignition angle setting.

Thc knock sensor 16 shown in Fig. 1 is connected to a knock control circuit 30 which is used to modify the ignition angle set by setting means 26 in the event that knocking is detected by the sensor 16. This in turn updates the value in the store 27.

When optimising the air/fuel ratio, the processor 20 forces the control circuit 21 to alter the air/fuel ratio in a step wise or continuous manner and it samples the values held in the stores 23 and 27 until the required conditions are satisfied that enable the processor to determine the current optimum air/fuel ratio for the engine. That air/fuel ratio is then set using the control circuit 21.

Although only injection timing is described above as being altered in order to change the air/fuel ratio, it will be understood that alternatively or additionally, the amount of air supplied could also be altered by adjusting the position of an air valve (not shown)

Other methods of determining the minimum ignition angle may also be used. For example, a sample and hold arrangement can be used for both the ignition angle and the injector/air valve setting used by adjust the air/fuel ratio. With this arrangement, ignition angle values are stored and updated successively until it is determined that the current ignition angle is larger than the immediately preceding angle. In that case either the immediately preceding value can be used to recover the setting for the air/fuel ratio at that point or interpolation can be used on the settings for the air/fuel ratio at these to points.

If an air/fuel ratio unequal the stoichiometric ratio λ is needed (for example ratio A), the new calculated $\lambda = 1$ injection time is divided with the ratio A. In this case the calculated $\lambda = 1$ is the basic for the $\lambda \neq 1$ (A).

Claims

1. A method of determining the air/fuel ratio of an internal combustion engine fitted with knock control comprises the steps of changing in one direction the air/fuel ratio of the mixture supplied to the engine, monitoring the ignition angle of the engine when the knock limit is reached for each different air/fuel ratio, determining the minimum ignition angle at the knock limit to indicate the optimum air/fuel ratio, and altering the fuel and/or air supply to maintain the optimum ratio.

2. A method according to claim 1, wherein the minimum ignition angle is determined by storing each value of ignition angle until two equal values are obtained and then interpoling between the two values.

3. A method according to claim 1, wherein the minimum ignition angle is determined by storing values of ignition angle until it is determined that the current value is larger than the immediately proceeding value and the optimum air/fuel ratio is derived.

4. A method according to claim 3, wherein the optimum air/fuel ratio is derived by interpolating between stored parameters determining the air/fuel ratios at the current and preceding value.

5. A method according to claim 3, wherein the parameters of air/fuel ratio of the immediately preceding values are used as the optimum air/fuel ratio.

6. A method according to claim 1-5, wherein the parameters of air/fuel ratio not equal to the stoichiometric ratio is calculated from the result of claim 1-5.

7. Apparatus for determining the air/fuel ratio of an internal combustion engine comprising means (21, 22) for changing in one direction the air/fuel ratio of the mixture supplied to the engine, means (16 for detecting knocking of the engine, means (26) for monitoring the ignition angle of the engine when the knock limit is reached for each different air/fuel ratio, means (20) for determining the minimum ignition angle at the knock limit to indicate the optimum air/fuel ratio, and means (21) altering the fuel and/or air supply to maintain the optimum ratio.

8. A method according to claim 1, and comprising a store (27) for storing each value of the ignition angle, the determining means (20) monitoring the store (27) until two equal values are obtained and then interpoling between the two values.

9. A method according to claim 1, and comprising a store (27) for storing values of ignition angle, the determining means (20) monitoring the store (27) until it is determined that the current value and the optimum air/fuel ratio is derived.

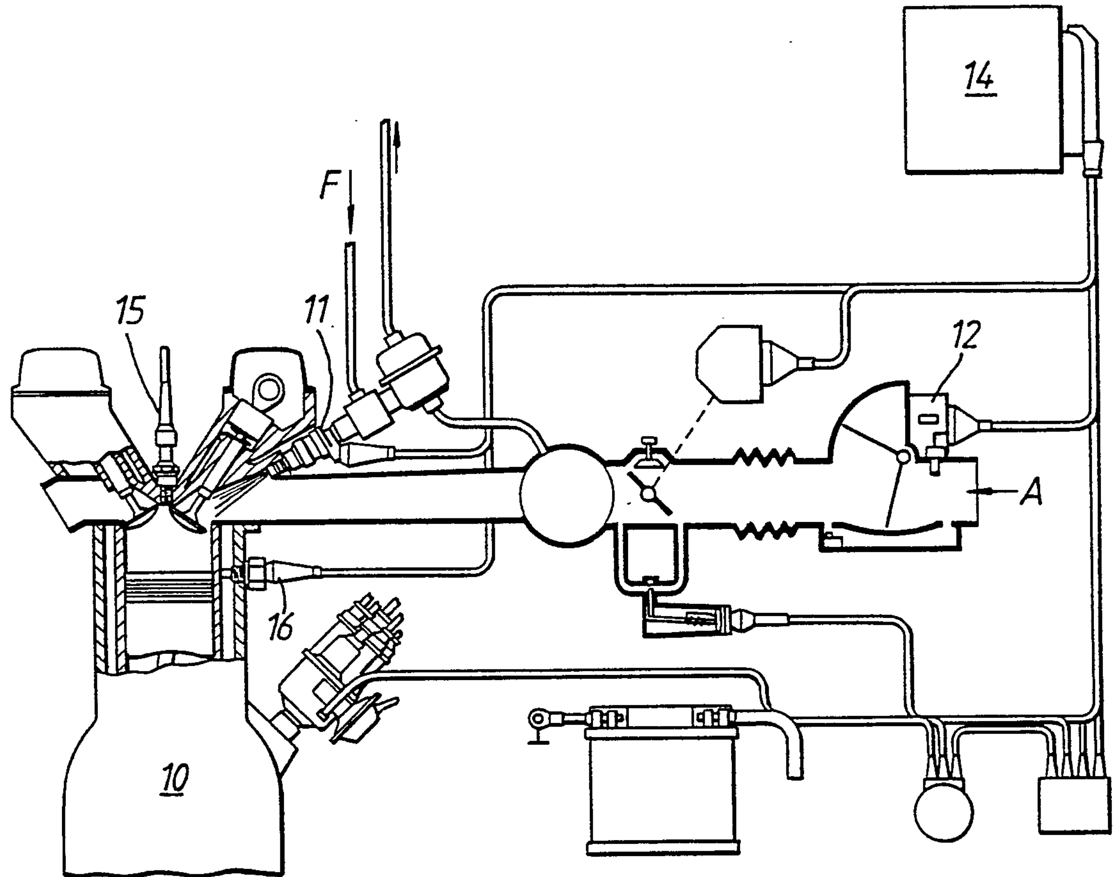

Fig.1.

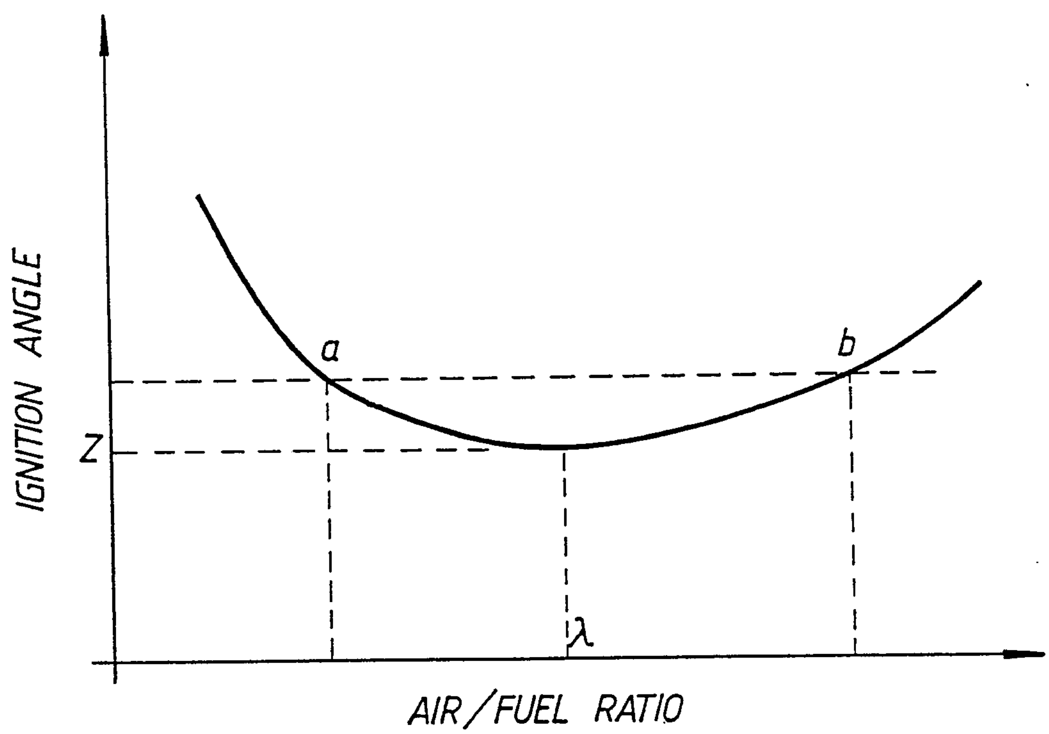

Fig.2.

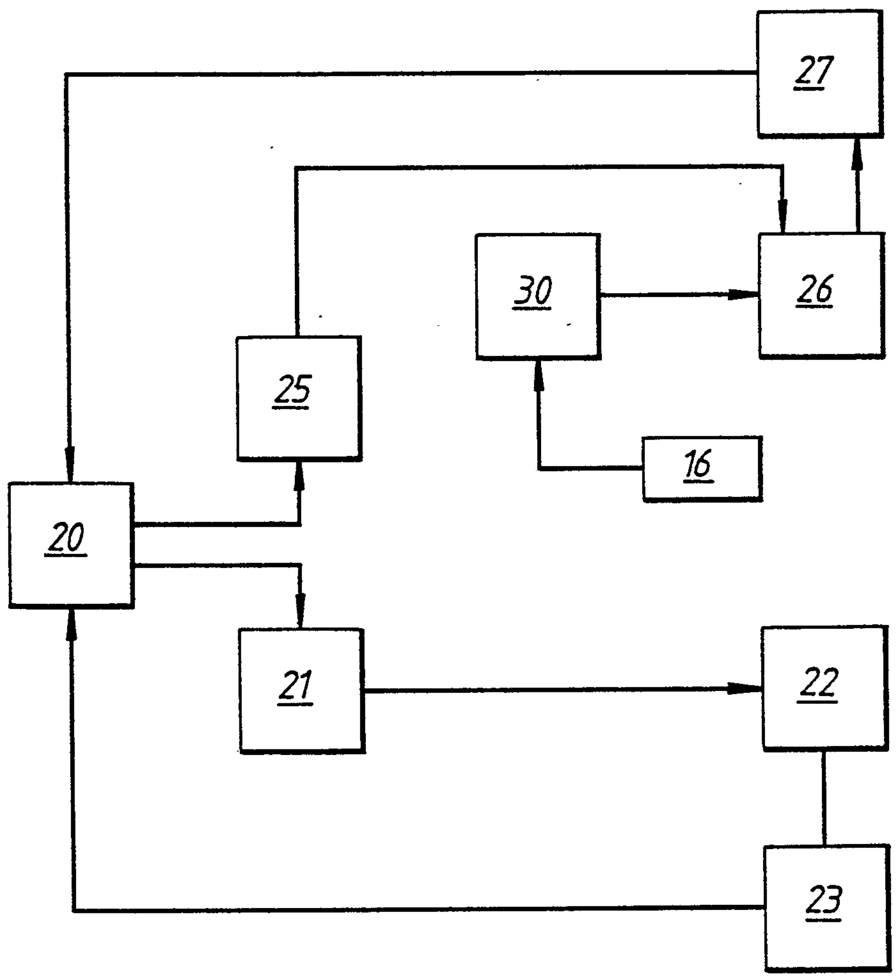

Fig.3.

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EUROPEAN SEARCH REPORT

Application Number

EP 89 10 9805

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	JP-A-62 197 656 (NIPPON DENSO) ---	1,7 2-6,8,9	F 02 D 41/14
A	US-A-4 745 553 (RAVEN et al.) * Whole document * ---	2-6,8,9	
A	US-A-4 403 584 (SUZUKI et al.) * Anspruch 1 * -----	8,9	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
F 02 D F 02 P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-01-1990	GAGLIARDI P.

CATEGORY OF CITED DOCUMENTS

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