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

(11) EP 0 816 655 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.01.1998 Bulletin 1998/02

(51) Int. Cl.[6]: **F02D 41/08**, F02D 41/02

(21) Application number: 97110317.1

(22) Date of filing: 24.06.1997

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 27.06.1996 IT BO960355

(71) Applicant:
MAGNETI MARELLI S.p.A.
20145 Milano (IT)

(72) Inventor: Poggi, Pierluigi
40100 Bologna (IT)

(74) Representative:
Jorio, Paolo et al
STUDIO TORTA S.r.l.,
Via Viotti, 9
10121 Torino (IT)

(54) Method and device for controlling the speed of an internal combustion engine

(57) Device for controlling the speed of an internal combustion engine (1), the engine (1) being provided with a output shaft, with a cylinder (3), with an induction manifold (4) connected to the cylinder (3), with an injector (5) for carrying out the injection of fuel into the induction manifold (4), and with an encoder (14) for detecting the angle of rotation of the output shaft, the control device being provided with a unit (20) for controlling the injector (5), which unit is connected to the encoder (14), for activating the injector (5) for a preset interval defined by a mechanical angle, of given size, of rotation of the output shaft.

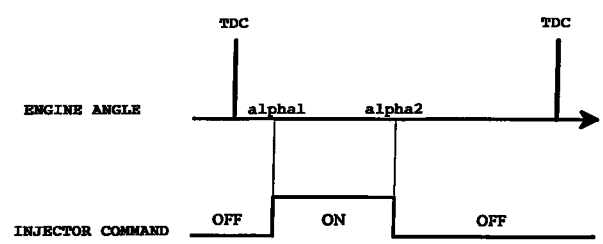

Fig. 2

EP 0 816 655 A1

Description

The present invention relates to a method for controlling the speed of an internal combustion engine.

The present invention also relates to a device for controlling the speed of an internal combustion engine, which incorporates the method according to the invention.

The method according to the invention finds advantageous application for controlling the idling speed in internal combustion engines, to which the description will make explicit reference without losing in universality as a result of this.

As is known, the purpose of a method for controlling the idling speed is the stabilization of this speed at a preset value. Methods of control which are currently used provide for the use of a closed-chain control. In these control systems, the value of the desired speed is given as an input; this value is compared with the value of the actual speed in order to obtain an error signal which is input to a control block which outputs the signal for controlling the engine speed.

In the methods of control currently used, the control of the engine speed is actuated by varying the cross section of the induction pipe (typically by varying the position of the throttle valve) and/or on the value of the advance, and consequently on the quantity of fuel injected in order to keep the mixture strength, that is the air/fuel ratio, constant.

However, these solutions have a number of disadvantages, mainly the complexity of the closed-chain system and in particular of the control block and the slowness of response of the system to variations in speed. This slowness is due essentially to two factors: the fact of controlling the section of the induction pipe, typically by varying the position of the throttle valve, the effects of which occur with a certain delay on the engine speed, and the delays introduced by the control chain, in particular by the control block. Control of the section of the induction pipe is necessary even if very slow, as controlling the advance is very fast but has a decidedly limited effect.

The aim of the present invention, therefore, is to produce a method for controlling the speed of an internal combustion engine, which does not have the disadvantages described above.

Another aim of the present invention is to produce a device for controlling the speed of an internal combustion engine, which implements said method.

According to the present invention, a method for controlling the speed of an internal combustion engine is produced, said engine operating with a succession of thermodynamic cycles in order to set in rotation at least one output shaft and comprising at least one injector for carrying out fuel injection, said method being characterized in that it comprises a phase in which said injector is activated in one of said cycles of said engine for an interval which is defined by a mechanical angle of rotation of said output shaft.

According to the present invention, a device for controlling the speed of an internal combustion engine is also produced, said engine comprising at least one output shaft, at least one injector for carrying out the injection of fuel, and a sensor for detecting the angle of rotation of said output shaft, said device being characterized in that it comprises a unit for controlling the injector, which unit is connected to said sensor, for activating the injector for an interval defined by a mechanical angle of rotation of said output shaft.

For better understanding of the present invention, a preferred embodiment will now be described, purely by way of non-limiting example, with reference to the attached drawings, in which:

- Figure 1 illustrates diagrammatically an internal combustion engine which operates according to the method of control according to the present invention;
- Figure 2 illustrates a multiple diagram of a number of quantities relating to the procedure according to the present invention, shown against time, and
- Figure 3 illustrates a diagram of a number of quantities relating to the engine in Figure 1.

In Figure 1, 1 indicates an internal combustion engine comprising a fuel supply system 2 with no return.

The engine 1 comprises a output shaft (not shown), a cylinder 3 which contains a piston connected mechanically to the output shaft and communicates with a respective induction manifold 4 which ends in an induction valve of said cylinder 3 and in which at least one injector 5 is present for carrying out the injection of the fuel into the induction manifold 4 itself, a fuel tank 6, a fuel pump 7 positioned substantially in the tank 6 for supplying the fuel to the injector 5 through a delivery pipe 8, a central control unit 9, a battery (not shown), and a cooling circuit (not shown).

The injector 5 is controlled by the central unit 9 by means of an ON/OFF type control, that is the injector 5 can assume only two states: on and off. In these states, the injector 5 carries out or does not carry out respectively the injection of fuel into the induction pipe 4. The delivery of fuel injected by the injector 5 depends partly on the construction characteristics of the injector 5 itself, and partly on the difference in pressure between the two ends of the injector 5. This pressure difference can be considered to a first approximation to be constant during normal operation of the engine, and it is therefore clear that the quantity of fuel injected is directly proportional to the time during which the injector is activated.

The fuel pump 7 comprises a pump 10 operating at a relative pressure which is typically between 4 and 6 bar, and a pressure regulator 11 for keeping the supply pressure of the fuel at a constant value (typically between 3 and 3.5 bar in relation to the pressure prevailing in the tank 6).

In the induction manifold 4, there is also a throttle valve 12, in addition to the injector 5. In the case of engines with multi-point injection, that is one injector for each cylinder 3, the injectors 5 are normally located (as illustrated in Figure 1) as close as possible to the induction valve whereas, in the case of engines with single-point injection, that is with a single injector for all the cylinders 3, the injector 5 is normally located immediately upstream of the throttle valve 12.

The central control unit 9 has various input and output connections for controlling all the functions of the engine 1: in Figure 1, the connections which are significant for the purposes of the description of the method according to the present invention and other connections as examples are illustrated.

In particular, 13 indicates the connection between the central control unit 9 and the injector 5, by means of which the central control unit controls the operation of the injector 5; 14a indicates the connection to a sensor 14, in particular an encoder, for detecting the angular position of the output shaft (by deriving this value, the central control unit 9 can calculate the value of the angular velocity of the output shaft), 15a indicates the connection to a sensor 15 for detecting the temperature of the cooling liquid, 16a indicates the connection to a sensor 16 for detecting the section of the induction pipe, typically by acting on the position of the throttle valve 12, 17a indicates the connection to a sensor 17 for detecting the temperature of the air present in the induction manifold 4, 18a indicates the connection to a sensor 18 for detecting the pressure of the air present in the induction manifold 4 (this pressure value is often indicated as the engine charging value), and 19a indicates the connection to a sensor 19 for detecting the voltage of the battery. The sensor 18 for detecting the pressure of the air present in the induction manifold 4 is normally positioned in the region of the injector 5 so as to be capable of detecting the value of the pressure in the zone of the manifold 4 close to the injector 5 itself.

The method of control forming the subject of the present invention will now be described, as applied to the engine 1 illustrated in Figure 1.

In the following description, the term cylinder 3 cycle is intended to mean all the typical operating phases of an internal combustion engine; in the case of a four-stroke internal combustion engine, these phases are: induction, compression, combustion and exhaust.

The central control unit 9 contains in its interior a unit 20 intended for controlling the idling speed of the engine 1. The unit 20 is activated by the central control unit 9 when the conditions for controlling the speed are met, typically when there is a lack of accelerator control and the speed of the engine is lower than a predetermined threshold value.

When it is activated, the unit 20 for controlling the idling speed receives as an input a desired speed value (this value is normally stored in a memory 21 of the central unit 9) and its task is to perform the operations necessary in order that the actual speed of rotation of the engine drifts as little as possible from this desired value.

According to the procedure according to the present invention, regulation of the idling speed is carried out by controlling the air/fuel mixture strength, that is the mass ratio of the mixture between parts of air and parts of fuel. The operation of a modern internal combustion engine normally takes place with an air/fuel mixture strength equal to the stoichiometric ratio for reasons of problems of containing pollutant emissions (essentially for good operation of the catalytic convertor on the exhaust).

It is known that, in a range centred on the stoichiometric strength, if the mixture strength is enriched, the torque produced by the engine is consequently increased, whereas, if the mixture strength is made leaner, the torque produced by the engine is consequently decreased. Outside this range, however, varying the strength of the mixture leads on the other hand essentially to a loss of torque in both cases because if the strength is excessively high, the combustion of the mixture in the cylinder worsens considerably, rendering the addition of further fuel fruitless or even harmful.

This situtation is clearly illustrated in the diagram in Figure 3, in which the maximum torque C of an internal combustion engine is entered on the axis of the ordinates (presented as a ratio to the maximum torque at stoichiometric operation), and a parameter LAMBDA inversely proportional to the strength is entered on the axis of the abscissae; a LAMBDA value equal to 1 corresponds to the stoichiometric strength, a LAMBDA value greater than 1 corresponds to a strength lower than the stoichiometric strength, and a LAMBDA value smaller than 1 corresponds to a strength higher than the stoichiometric strength.

It is therefore clear that, within certain limits, it is possible to control the speed of an engine by varying suitably the strength of the mixture.

This type of control lends itself very well to controlling the idling speed because, during control of idling speed, small variations in torque (of the order of a few per cent) are necessary because these variations do not have to compensate corresponding variations of load but only corresponding variations of resisting torques initiated by friction, ventilation, alternator and other causes. The limitation on the maximum value of torque increase which can be obtained by varying the strength does not, therefore, constitute a problem.

Varying the strength of the mixture from the stoichiometric value may lead to an overall rise in the pollutant emissions of the engine, which is normally small. In controlling the idling speed, this increase is negligible, however, because it occurs during an operating state, the idling speed, which in total produces a few per cent (up to 3%) of the total pollutant emissions of an engine.

There are essentially two types of action possible for controlling the mixture strength: varying the quantity of fuel or varying the quantity of air, by controlling the injector 5 or the throttle valve 12 respectively.

In general, control of the injector 5 is preferable because it is faster and more accurate, particularly for small variations such as those used in controlling the strength, compared with control of the throttle valve 12.

Controlling the idling speed by varying the mixture strength can be implemented using a simple closed-chain control, into which the desired idling speed is input; this value is compared with the value of the actual speed to obtain an error signal; this error signal is input to a control block which outputs the command signal to the member for controlling the mixture strength.

According to the present invention, an innovative method is disclosed for controlling the strength of the mixture, using the injector 5 as the control member.

Instead of using a common closed-chain control, it is possible to control the speed of the engine using an open chain by calculating, on the basis of the value of the desired idling speed, a preset interval for operation of the injector 5 which is calculated not, as already known, in terms of time interval but instead in terms of mechanical angle of rotation of the engine 1.

With particular reference to the diagram in Figure 2, on each cycle of the cylinder 3, the injector 5 is not activated starting from one moment in time to a second moment in time but is instead activated starting from a first mechanical angle alpha1 of the engine to a second mechanical angle alpha2 of the engine.

This solution can be implemented easily by means of the encoder 14 because the idling speed control unit of the central unit 9 receives as an input from the encoder 14 the value of the current engine angle and activates the injector 5 when the engine angle is between alpha1 and alpha2.

Operation of this method of control is simple: consider starting from a situation of equilibrium in which the engine 1 is rotating at the desired idling speed and the injector 5 is activated for an angular interval delta which is equal to the difference between alpha1 and alpha2.

If the engine 1 accelerates, that is increases the angular velocity of the output shaft, the time during which the injector 5 is activated is shorter because, as the engine is rotating more quickly, it will take less time to pass through the angular interval delta. Consequently, less fuel is injected into the cylinder 3, therefore the torque will be decreased, and consequently the engine 1 will tend to slow, that is to decrease the angular velocity of the output shaft, thereby returning to the initial conditions.

On the other hand, if the engine 1 slows, the time during which the injector 5 is activated is longer because, as the engine is rotating more slowly, it will take more time to pass through the angular interval delta. Consequently, more fuel is injected into the cylinder 3, therefore the torque will be increased, and consequently the engine 1 will tend to accelerate, thereby returning to the initial conditions.

Consider the following equations where: G indicates the delivery of the injector 5 which is assumed to be constant, t indicates the injection time interval, q indicates the quantity of fuel injected in one cycle of the cylinder 3, A indicates the angular interval of operation of the injector 5, n indicates the angular velocity of the engine, and c the torque of the engine:

$$q=G*t$$

$$t=A/n$$

Assuming that over a small interval the Torque/Strength function is linearized and that to a first approximation during this interval the torque is proportional to the strength; assuming also that the quantity of air, that is the position of the throttle 12, is constant: the strength, and consequently the torque, are then proportional to the quantity of fuel injected q:

$$c=K*q$$

$$c=K*G*t$$

$$c=K*G*A/n$$

from which is obtained by derivation:

$$dc=-(K*G*A)/(n*n)*dn$$

In other words it is clear that variation of the torque is, in a limited range about a working point and to a first approximation, proportional and opposite to the variation of the number of revolutions (that is if the engine 1 slows, the torque increases and vice versa). It is therefore clear that the method of control proposed by the present invention is effective and efficient in keeping the idling speed of rotation of the engine 1 constant. This effectiveness and efficiency have been confirmed by theoretical simulations and practical tests on the action of an internal combustion fuel engine.

It remains to be pointed out that the variation of the torque (dc) also depends on the square of the number of revolutions, and therefore if the engine speed is transitory, i.e. is varying in time, then for the same angular interval of opening of the injector, the quantity of fuel injected, and therefore the torque produced, varies as the moment of starting injection varies. For example, if the engine slows, starting the injection later, with the same angle of opening, makes it possible to obtain greater torque, because the engine is turning more slowly and therefore takes more time to pass through the angle of opening, and therefore more fuel is injected.

The method and the device according to the present invention have numerous advantages.

Principally, the device according to the present invention is of extremely simple construction and therefore highly economical. In fact, the only sensor required, that is the encoder, is already provided for other purposes in all internal combustion engines of the latest generation.

Moreover, the device and the method according to the present invention guarantee a very fast response speed. This speed is accounted for by two factors: the absence of control response delays and the rapidity of response of the engine speed to changes in the strength of the air/fuel mixture. The absence of response delays is intrinsic to the method itself because the quantity of fuel injected depends directly (that is without any intermediate stage and therefore without any delay) on the speed of the engine. Lastly, it is demonstrated that internal combustion engines respond much more quickly in terms of engine speed to variations of the strength of the mixture than to variations of the section of the induction pipe (typically achieved by varying the position of the throttle valve). This difference in response speed is considerable and can vary by a factor which varies from a minimum of 5 to a maximum of 10. Moreover, unlike control of the advance, controlling the strength makes it possible to achieve a substantial effect on the speed of the engine in addition to guaranteeing great rapidity of response.

Finally, it is clear that modifications and variations can be applied to the method of control described and illustrated here.

In particular, the method according to the present invention can advantageously be used for stabilizing any engine speed, not necessarily idling speed. It can therefore be used in controlling internal combustion engines which have to rotate at constant speeds such as, for example, electricity-generating engines.

In combination with the method according to the present invention, it would also be possible to provide a strategy for controlling the position of the throttle and/or the value of the advance, to maximize the efficiency of the engine under any conditions. The method according to the present invention could, for example, be used to respond rapidly to variations in engine speed with a subsequent, and much slower, adaptation of the other control variables (throttle, advance and others). In other words, the working point of the engine as a whole is determined by an optimized combination of all the control variables (injection, throttle, advance and others), while variations about this working point are carried out uniquely or mainly by means of controlling the strength of the mixture according to the procedure according to the present invention.

This combination proves to be particularly advantageous in the case of stabilizing working speeds of the engine where, unlike the idling speed, the efficiency of the engine and the reduction of pollutant emissions are fundamental requirements.

In calculating the interval delta, that is the angular interval of operation of the injector 5, it would be possible to provide a correction factor depending on an estimated value of the delivery of the injector 5 itself, so as to obtain the desired engine speed value in any given operating situation.

Claims

1. Method for controlling the speed of an internal combustion engine (1), said engine (1) operating with a succession of thermodynamic cycles in order to set in rotation at least one output shaft and comprising at least one injector (5) for carrying out fuel injection, said method being characterized in that it comprises a phase in which said injector (5) is activated in one of said cycles of said engine (1) for an interval which is defined by a mechanical angle, of given size, of rotation of said output shaft.

2. Method according to Claim 1, characterized in that said engine (1) comprises at least one cylinder (3) and an induction manifold (4) which is connected to said cylinder (3) and into which said injector (5) carries out the injection of fuel.

3. Method according to any one of Claims 1 and 2, characterized in that said interval depends only on a desired speed value for the engine (1).

4. Method according to any one of Claims 1 and 2, characterized in that said interval depends on a desired speed value for the engine (1) and on an estimated value of the delivery of said injector (5).

5. Method according to any one of Claims 1 and 2, characterized in that said interval depends on a desired speed value for said engine (1) and on a value of the delivery of oxidant into said engine (1).

6. Method according to any one of the preceding claims, characterized in that said controlled speed is the idling speed.

7. Method according to any one of the preceding claims, characterized in that said phase of activation of said injector (5) is combined with subsequent phases in which a value for delivery of oxidant and a value for advance of the engine (1) are adapted to the new operating conditions of the engine (1).

8. Device for controlling the speed of an internal combustion engine (1), said engine (1) comprising at least one output shaft, at least one injector (5) for carrying out the injection of fuel, and a sensor (14) for detecting the angle of rotation of said output shaft, said device being characterized in that it comprises a unit (20) for controlling the injector (5), which unit is connected to said sensor, for activating the injector (5) for an interval defined by a mechanical angle, of given size, of rotation of said output

shaft.

9. Device according to Claim 8, characterized in that said engine (1) comprises at least one cylinder (3) and an induction manifold (4) which is connected to said cylinder (3) and into which said injector (5) carries out the injection of fuel.

10. Device according to any one of Claims 8 and 9, characterized in that said sensor (14) is constituted by an encoder mechanically connected to said output shaft.

11. Device according to any one of Claims 8 to 10, characterized in that said control unit (20) comprises a calculating member for estimating a value of the delivery of said injector (5).

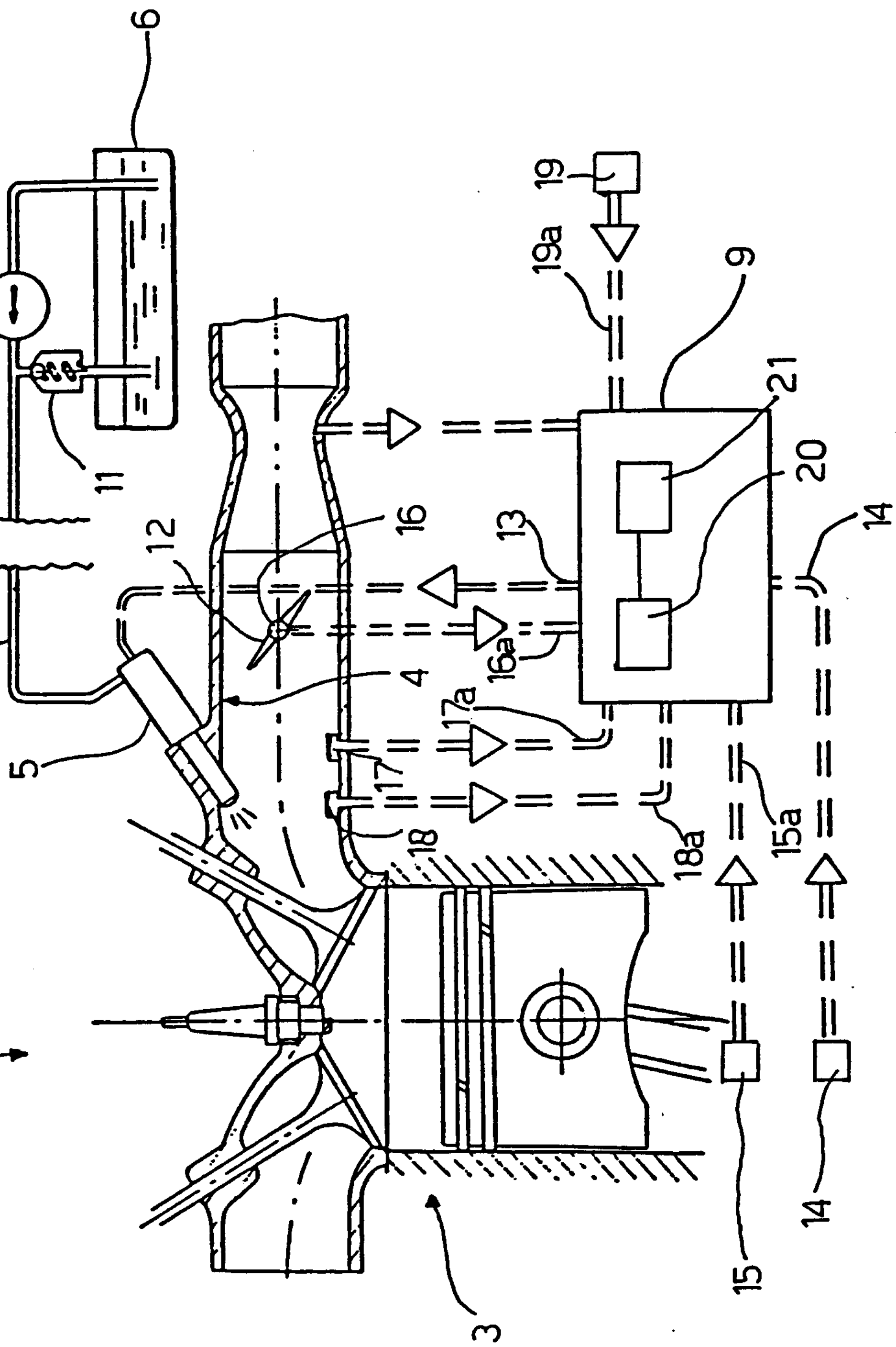

Fig. 1

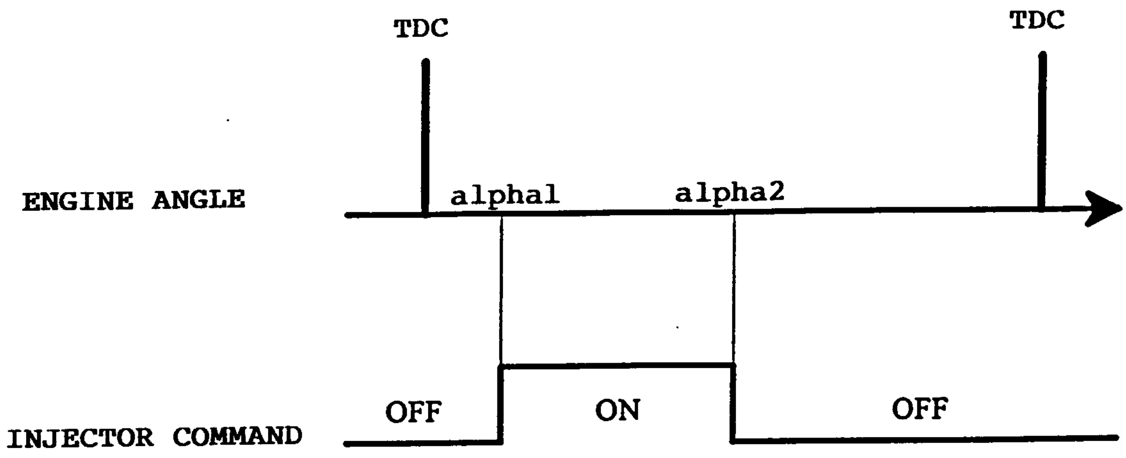
TDC
TDC
ENGINE ANGLE
alpha1
alpha2
INJECTOR COMMAND
OFF
ON
OFF

Fig. 2

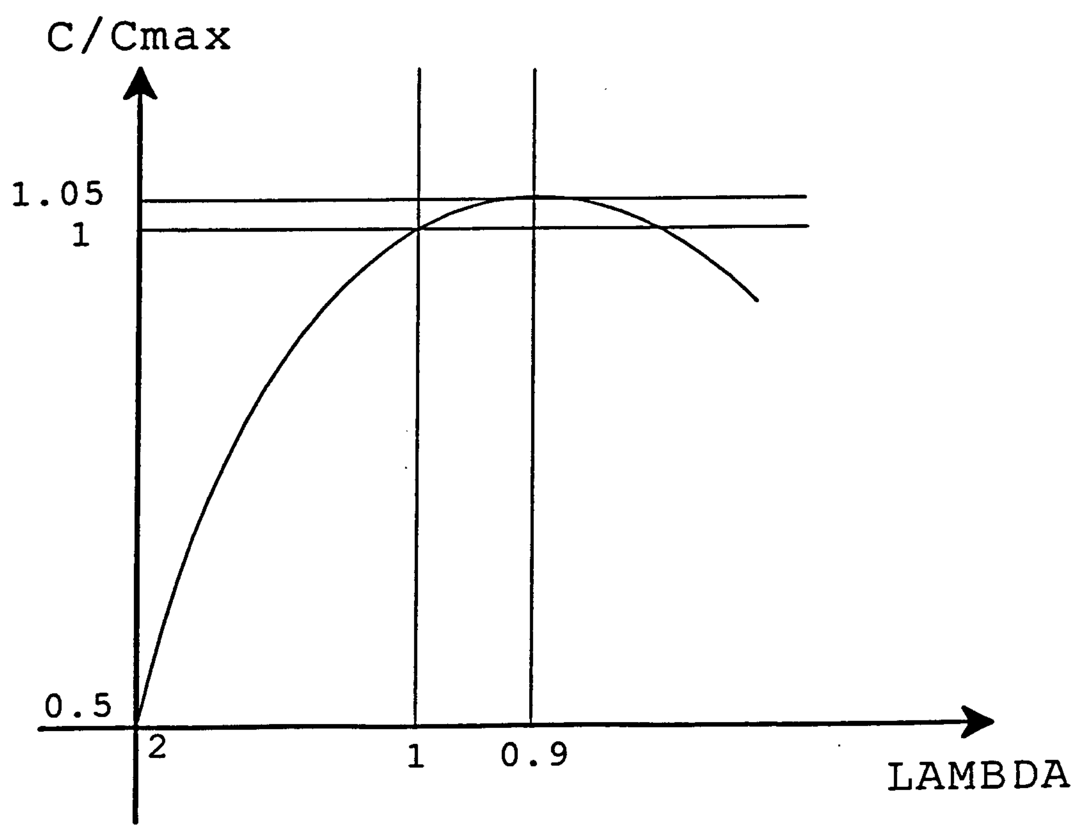
C/Cmax
1.05
1
0.5
2
1
0.9
LAMBDA

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 11 0317

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.6)
X	GB 2 257 806 A (VOLKSWAGENWERK AG) 20 January 1993 * page 7, line 6 - page 9, line 11 * * page 11, line 1 - page 13, line 21 * * page 14, line 1 - page 16, line 12 * ---	1,2,4-11	F02D41/08 F02D41/02
X	US 4 232 647 A (VAN SICLEN JR HOWARD E) 11 November 1980 * column 2, line 1 - column 4, line 11 * * column 4, line 30 - column 5, line 56 * ---	1,3,4,8,10	
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 003 (M-349), 9 January 1985 & JP 59 155540 A (NIHON DENSHI KIKI KK), 4 September 1984, * abstract * ---	1,8	
A	WO 91 17350 A (BOSCH GMBH ROBERT) 14 November 1991 * the whole document * ---	1,8	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 3 741 176 A (SCHMIDT P ET AL) 26 June 1973 * the whole document * -----	1,8	F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 October 1997	Moualed, R

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
P : intermediate document

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 (P04C01)