

(12) UK Patent Application (19) GB (11) 2 318 390 (13) A

(43) Date of A Publication 22.04.1998

(21) Application No 9721792.1

(22) Date of Filing 14.10.1997

(30) Priority Data

(31) 19642653 (32) 16.10.1996 (33) DE

(71) Applicant(s)

Daimler-Benz AG

(Incorporated in the Federal Republic of Germany)

Epplestrasse 225, D-70546 Stuttgart,
Federal Republic of Germany

(72) Inventor(s)

Klaus Roessler
Stephen Kraemer
Guenter Karl

(51) INT CL⁶

F02D 41/40, F02M 51/06 61/06 61/16

(52) UK CL (Edition P)

F1B BBA BB102 BB220 BB228 BB300 BB318 B2JCB
B2JCBA B2JCE B2JCN B2JCP B2J10 B2J15B3 B2J5
B2P4

(56) Documents Cited

GB 2152135 A US 5518184 A US 5479902 A
US 5341783 A US 5280773 A US 4798188 A
US 4327695 A

(58) Field of Search

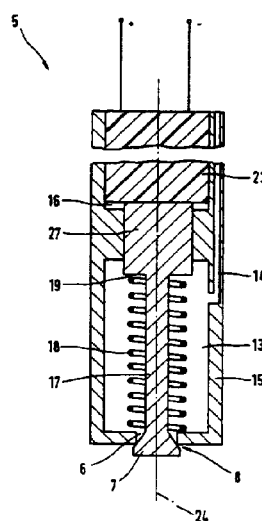
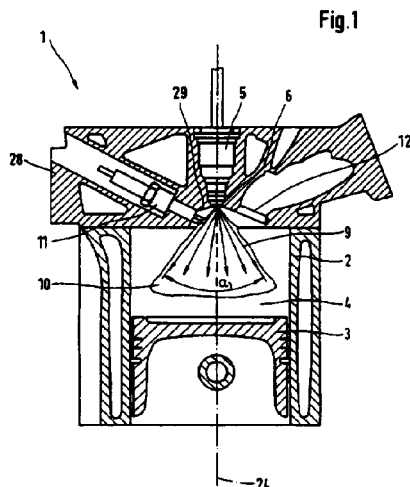
UK CL (Edition P) F1B BB102 B2P4
INT CL⁶ F02D 41/40, F02M 51/06 61/06 61/16
Online: WPI

(74) Agent and/or Address for Service

Jensen & Son
70 Paul Street, LONDON, EC2A 4NA, United Kingdom

(54) Forming an ignitable fuel/air mixture in a direct-injection i.c. engine using an injector with adjustable stroke and injection time

(57) An ignitable fuel/air mixture can be formed in the cylinders 2 of direct-injection internal combustion engines 1 by injecting fuel by means of an injector 5 into each combustion space 4 delimited by a piston 3, when a nozzle orifice 6 is opened by the lifting-off of a valve member 7 from a valve seat 8 surrounding the nozzle orifice 6. In order to optimize fuel consumption and emissions under all operating conditions, in particular the stratified charge mode, the invention provides for the opening stroke of the valve member and the injection time (duration) to be adjusted variably. For example, at 2000 rpm the stroke may be 0.02mm and the injection time may be 0.75ms while at 6000 rpm the corresponding figures may be 0.03mm and 0.375ms. The injector 5 may be of the outwardly-opening type which produces a conical spray pattern the cone angle α of which depends on the stroke of the valve element 7. The valve stem 17 is connected to a piston 27 which is displaceable by a piezoelectric element 23 to open and close the valve, the opening stroke of the valve being proportional to the applied voltage. For each operating point of the engine determined by engine speed and load the respective optimal values of injection time and opening stroke are filed in a map (20, fig 3) which is read by the injector control (25).



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 318 390 A

Fig.1

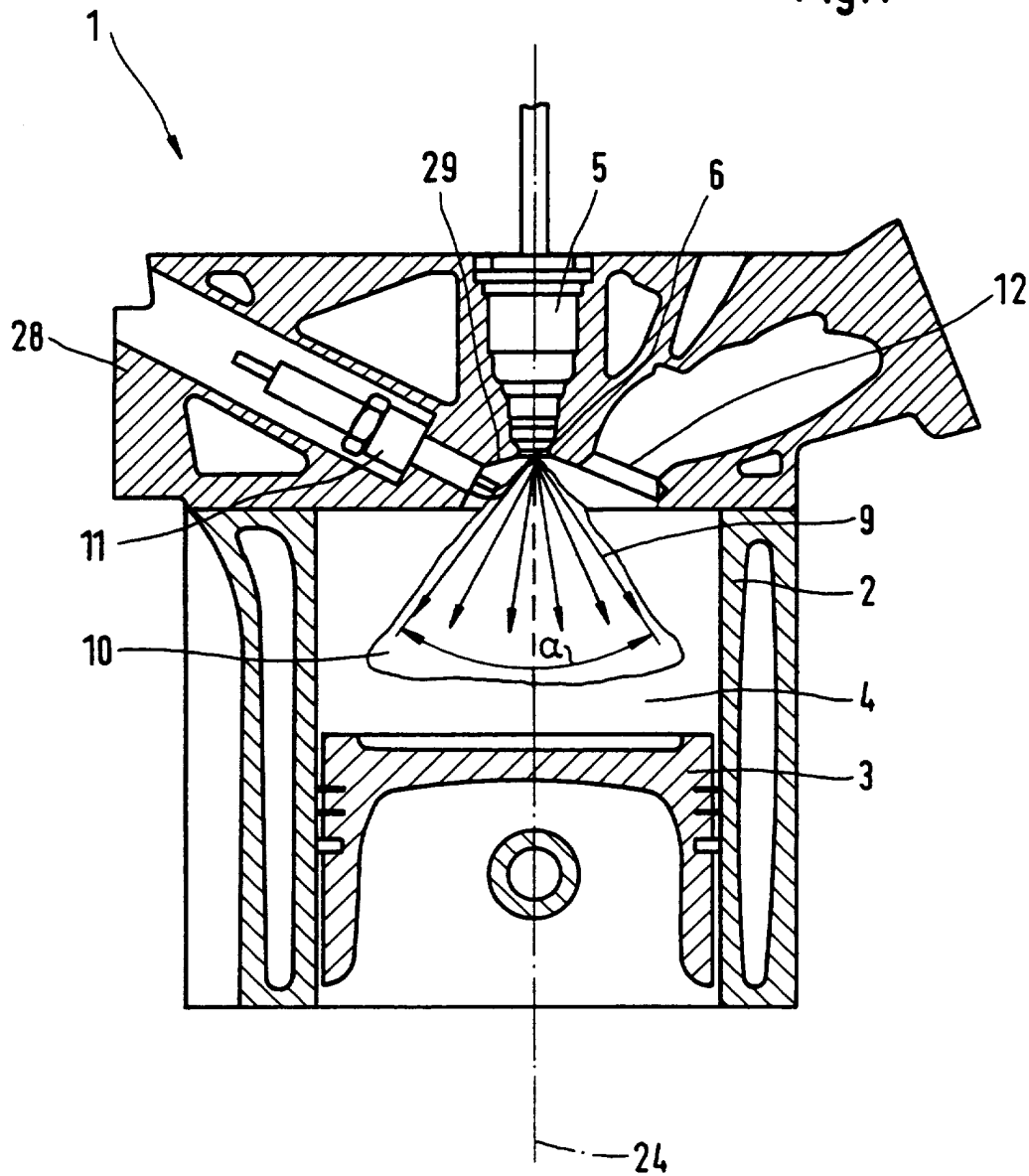


Fig.2

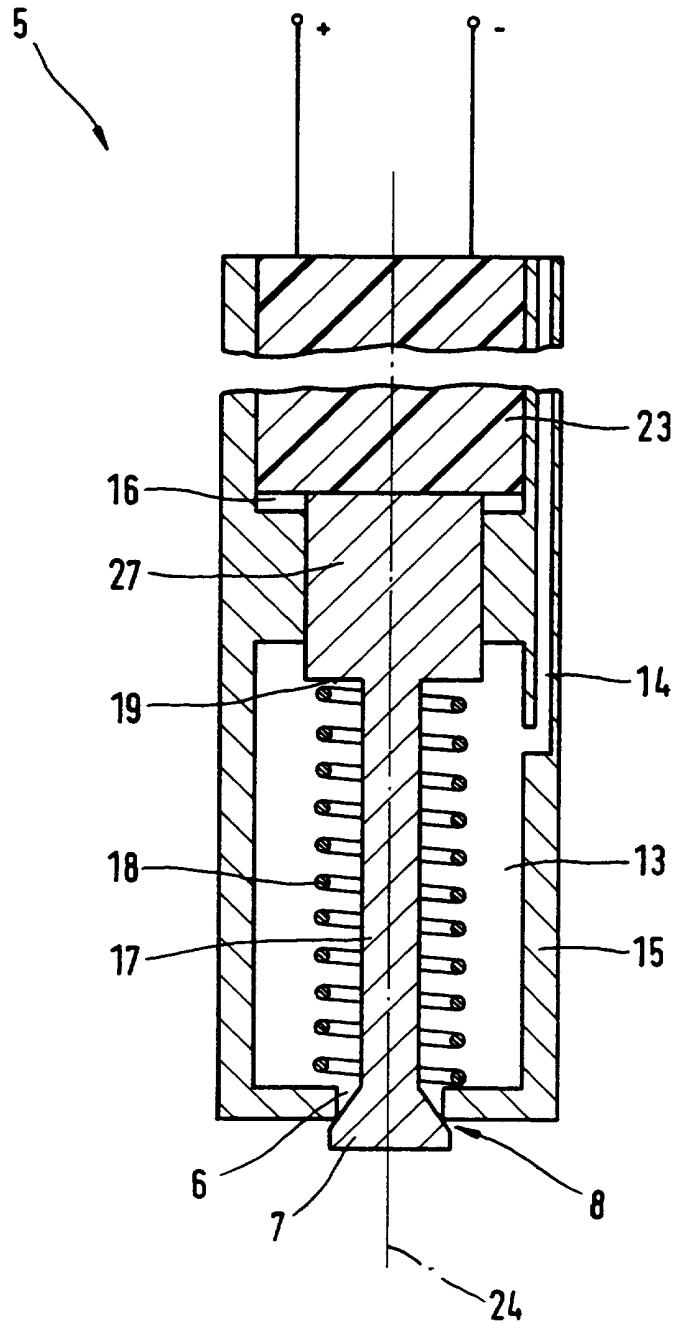


Fig.3

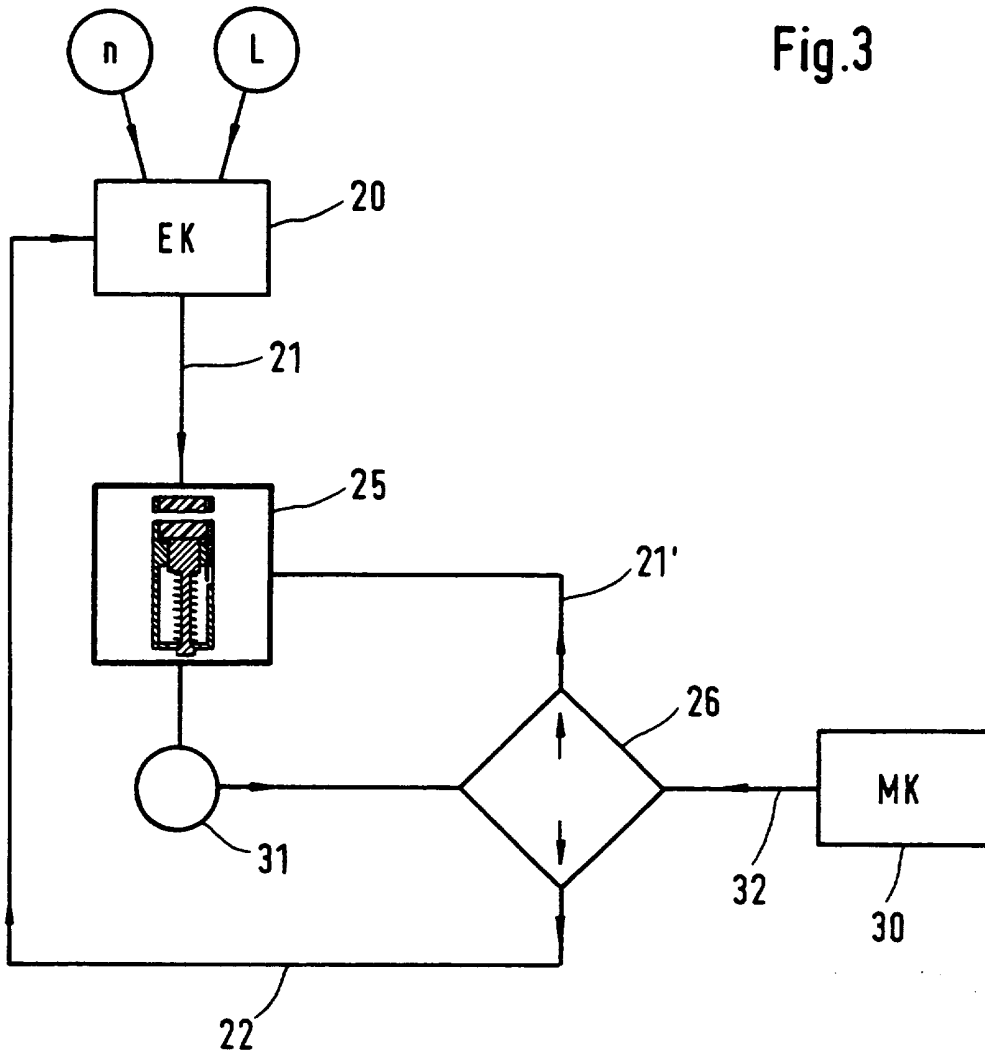


Fig.4

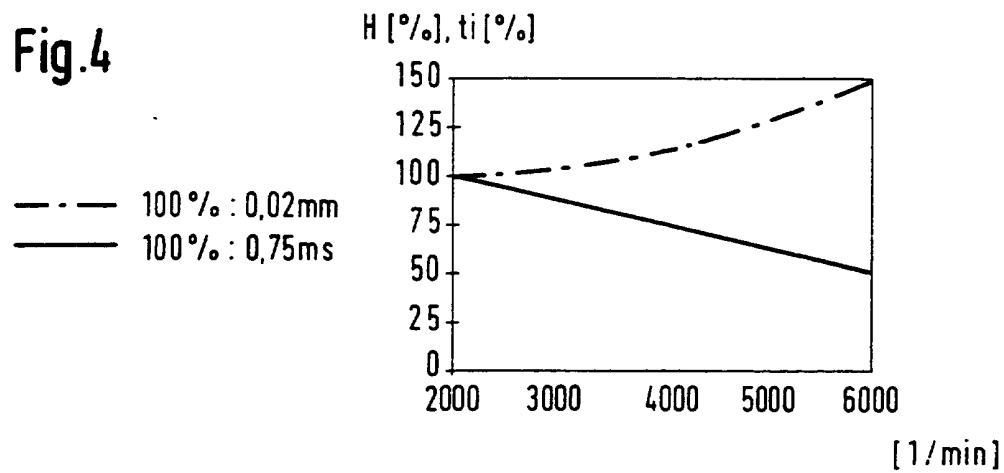


Fig.5

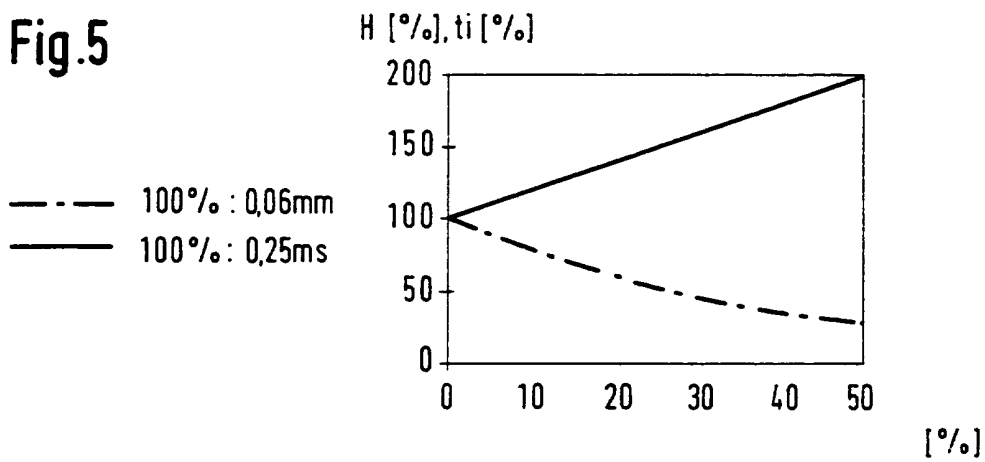
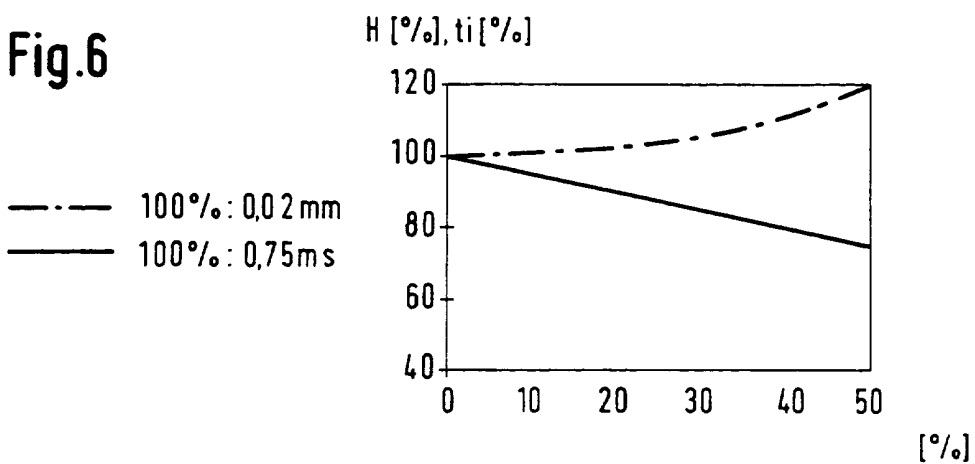


Fig.6



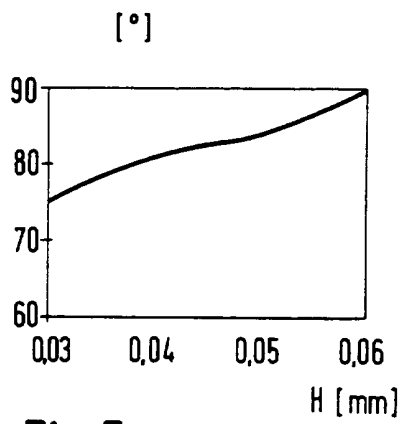


Fig. 7

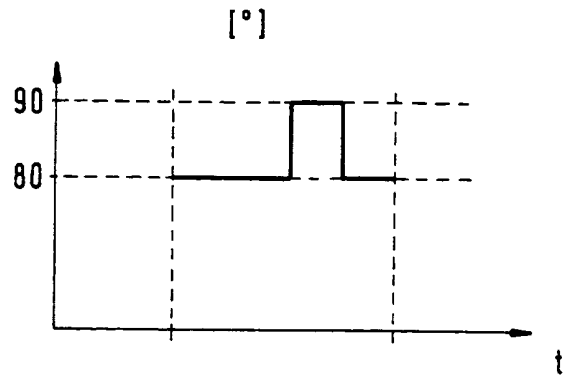


Fig. 8

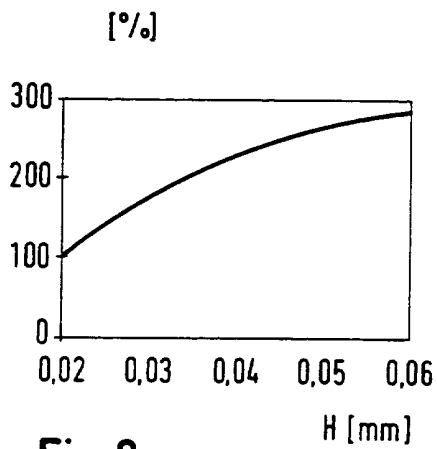


Fig. 9

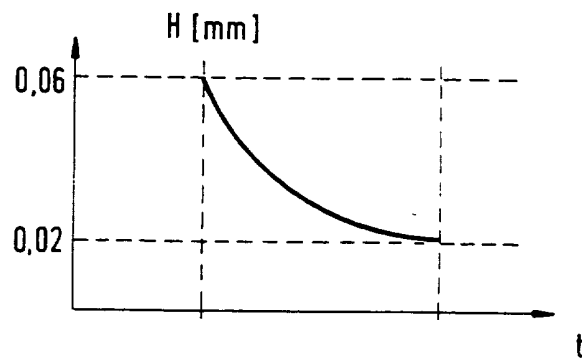


Fig. 10

Method for forming an ignitable fuel/air mixture

The invention relates to a method for forming an ignitable fuel/air mixture in a direct-injection internal combustion engine.

DE-A-43 24 642 A1 already discloses a direct-injection internal combustion engine, in which, in each cylinder, a piston delimits a combustion space, into which an injector arranged centrally in the roof of the combustion space injects fuel for the internal formation of an ignitable fuel/air mixture. The electrodes of a spark plug project into the fuel jet in the vicinity of the nozzle orifice of the injector, with the result that, in the low-load range of the internal combustion engine with stratified charge, the stable combustion of an altogether lean mixture takes place as a result of the ignition of a richer mixture in the vicinity of the electrodes of the spark plug, the said mixture being provided by the injection of fuel in a later phase of the compression stroke of the piston. The internal combustion engine comprises an electronic control unit which controls optimally in terms of operating point the fuel quantity injected by the injector, the injection time point and the ignition time point of the spark plug, with the result that the combustion characteristic can be influenced over and above the fixed factors, such as injection pressure, shape and size of the nozzle orifice, shape of the combustion space, compression ratio, etc.

However, under many operations conditions of the internal combustion engine, these possibilities for varying the injection parameters are not sufficient in order, in the stratified charge mode, to ensure that the internal mixture formation is optimized, along with low fuel consumption and emissions, over wide ranges of the characteristic map of the internal combustion engine.

The present invention seeks, therefore, to provide a method for forming an ignitable fuel/air mixture in direct-injection internal combustion engines, which makes it possible, under all the operating conditions of the internal combustion engine, to optimize the internal mixture formation at each operating point, especially in the stratified charge mode.

According to the present invention there is provided a method for forming an ignitable fuel/air mixture in the cylinder(s) of a direct-injection internal combustion engine, fuel being injected by means of an injector valve into the or each

combustion space delimited by a piston, when a nozzle orifice of the injector valve is opened by the lifting-off of a valve member from a valve seat surrounding the nozzle orifice, wherein the opening stroke of the valve member and the injection time are adjustable variably.

Since, during fuel injection, the opening stroke of the valve member in relation to the valve seat of an injector and the injection time can be adjusted variably, several advantages are afforded. In principle, it is possible, by means of an appropriate opening stroke of the valve member, to inject a specific fuel quantity into the combustion space for a variable duration of the injection time and thereby control the internal mixture formation, that is to say, in the stratified charge mode, the fuel concentration or the air ratios (λ values) of the mixture cloud formed in the combustion space by the injected fuel jet, via the factor of the injection time. In this case, the fuel is advantageously injected into the combustion space by the injector in a widening conical jet, with the result that, in the stratified charge mode of the internal combustion engine, depending on the injection time point, a mixture cloud having different λ values according to the injection angle of the conical jet in the combustion space is formed. Due to the possibilities of varying the opening stroke of the valve member, the injection angle of the conical jet can likewise be adjusted variably.

Advantageously, the injection angle of the conical jet is larger with an increasing opening stroke of the valve member, with the result that the conical jet characteristic, which may be different in the case of individual injectors, can be adapted in order to achieve an optimal operating behaviour of the internal combustion engine. The different jet characteristics occur due to production tolerances in the mass production of injectors or even cylinder heads, etc., but also due to wear or deposits, as the operating period of the internal combustion engine increases and may lead, for example as a consequence of jet bunching, to λ values unfavourable for ignition, above all in the region of the spark plug, on account of an unfavourable position of the mixture cloud in the combustion space. The variably adjustable opening stroke of the valve member makes it possible, at each operating point of the internal combustion engine, to provide the ignitable fuel/air mixture at the electrodes of the spark plug by injection at a suitable injection angle.

Advantageously, the opening stroke of the valve member of each cylinder can be adjusted individually, so that with injection angles which may be different, the jet characteristics of the individual injectors in the cylinders can be adapted optimally in order to achieve an optimal operating behaviour of the internal combustion engine.

Advantageously, the opening stroke of the valve member can be adjusted during the injection operation, with the result that it is possible for the injection angle and also the mass flow of fuel through the nozzle orifice to be influenced dynamically. Increasing the injection angle during injection ensures that the start of combustion is freely selectable, in that mixture which is combustible at this time point is brought into the region of the electrodes of the spark plug. Wetting of the electrodes with fuel and, consequently, carbonization due to the combustion of the fuel are minimized and the life of the spark plug is thus increased. Reducing the opening stroke of the valve member and therefore decreasing the mass flow of fuel through the nozzle orifice make it possible to form mixture clouds with optimal lambda gradients or else approximately constant air ratios, in contrast to a constant mass flow of fuel, along with a constant opening stroke of the valve member, where lean mixtures with high lambda values are formed in the nozzle-distant regions of the mixture cloud and rich mixtures with low lambda values are formed in the near-nozzle regions.

For the internal combustion engine to operate with optimized consumption and emission, the opening stroke of the valve member and the injection time are adjusted on the basis of the adjustment parameters for the opening stroke and injection time which are filed for the respectively existing operating point in an injection characteristic map. When the internal combustion engine is operating with the adjusted parameters for the opening stroke of the valve member and for the injection time, engine parameters, for example the smooth running of the internal combustion engine, are measured and are compared with the desired values filed for the respectively existing operating point of the internal combustion engine in an engine characteristic map. Deviations of the measured engine parameters from the filed desired values may occur, for example, during the first commissioning of the internal combustion engine as a result of production spreads in the manufacture of the components involved in injection or else, after a long operating period, on account of

wear or deposits. If the smooth running of the internal combustion engine is unsatisfactory, a variation in the opening stroke of the valve member takes place until an optimal operating behaviour, with the measured engine parameters and the desired values of the engine characteristic map corresponding to one another, is achieved. The ideal parameters determined are filed in the injection characteristic map and replace the previous adjustment parameters for this operating point, and, if this operating point is approached repeatedly, the ideal parameters now filed for the adjustment of the opening stroke of the valve member and the injection time are taken as a basis.

The method according to the invention is suitable, in particular, for internal mixture formation in Otto internal combustion engines. In this case, the opening stroke of the valve member advantageously amounts to a maximum of 0.1 mm, with the result that short opening times become possible due to small stroke travels, whilst at the same time a high throughput of fuel is ensured. In the stratified charge mode of the internal combustion engine, the opening stroke of the valve member can be adjusted between about 0.02 mm and about 0.06 mm and makes it possible to form mixture clouds in the combustion space which have a wide variety of air ratios, with the result that stratified combustion optimized in terms of consumption and emission can be carried out. The injection angle of the conical jet which depends on the opening stroke of the valve member is advantageously between about 70° and 100° and ensures that, in the stratified charge mode, electrodes of a spark plug which are arranged outside the core zone of the combustion space project into the mixture cloud and, deposits as a consequence of fuel wetting being insignificant, ignite reliably. The factor of injection time during the opening of the nozzle orifice of the injector makes it possible to control the internal mixture formation, that is to say, in the stratified charge mode, the air ratios of the mixture cloud, at each operating point of the internal combustion engine due to the injection of a definite fuel quantity by means of a specific opening stroke of the valve member. If a plurality of fuel injections into the combustion space take place in one work cycle of the piston, a further possibility for influencing internal mixture formation is afforded.

The method for forming an ignitable fuel/air mixture in a direct-injection internal combustion engine can be carried out, for example, by using the injector which is the subject of German Patent Application DE 195 48 526.2.

Exemplary embodiments and examples of the use of the invention are explained in more detail below with reference to the drawing in which:

- Figure 1 shows a cylinder cross-section of a direct-injection internal combustion engine,
- Figure 2 shows a cross-section of an injector,
- Figure 3 shows a flow diagram of the control of an injector,
- Figure 4 shows a graph of the adjustment parameters of the injector as a function of the engine speed,
- Figure 5 shows a graph of the adjustment parameters of the injector as a function of the exhaust-gas recirculation rate or the throttling of the internal combustion engine,
- Figure 6 shows a graph of the adjustment parameters of the injector as a function of the charging of the internal combustion engine,
- Figure 7 shows a graph of the injection angle of the conical jet as a function of the opening stroke,
- Figure 8 shows a graph of the variation in the injection angle during the injection time,
- Figure 9 shows a graph of the throughput of the nozzle orifice as a function of the opening stroke,
- Figure 10 shows a graph of the change of the opening stroke during the injection time.

Figure 1 shows a cylinder 2 of a direct-injection internal combustion engine 1, in which cylinder a piston 3 arranged so as to be longitudinally moveable delimits a combustion space 4 with a cylinder head 28 closing the cylinder 2. An injector 5 passes through the cylinder head 28 in a central position on the longitudinal axis 24 of the cylinder 2 and is guided with its nozzle orifice 6 into the combustion space 4 through a conically widening combustion space roof 29. A control unit (not illustrated) determines, specifically for each operating point of the internal combustion engine 1, that time point for the opening of the nozzle orifice 6 which is associated with the position of the piston 3 in the cylinder 2 and from which fuel is injected in a conical jet 9 into the combustion space 4. In this case, the injection angle α of the conical jet 9 is determined by the opening stroke of a valve member in the nozzle

orifice 6. An ignitable fuel/air mixture can be formed in the combustion space 4 by means of the fresh air capable of being supplied through an inlet port 12 in the cylinder head 28 and the injected fuel, and, in the stratified charge mode of the internal combustion engine 1 with fuel injection in the compression stroke of the piston 3, the said mixture is in the form of a mixture cloud 10 which is formed with the opening angle α of the conical jet 9 and which has sectionally different air ratios (λ values).

A spark plug 11, passing through the cylinder head 28, projects through a conical leg of the combustion space roof 29 into the combustion space 4, in such a way that the electrodes penetrate into the mixture cloud 10 and, by triggering an ignition spark, ignite the mixture cloud 10 at the edge. If no ignitable mixture is present due to the bunching of the conical jet 9 or as a result of the production tolerance spread of the injector 5, nozzle orifice 6, cylinder head 28, etc., or on account of wear or deposits on the electrodes of the spark plug 11 or on the nozzle orifice 6 at the electrodes of the spark plug 11, then the position of the mixture cloud 10 in the combustion space 4 can be varied by varying the injection angle α and an ignitable mixture can be provided at the electrodes.

Figure 2 shows diagrammatically, in cross-section, the design of an injector 5 for carrying out the method according to the invention for internal mixture formation. A fuel chamber 13, through which a valve stem 17 passes, is designed in an injector housing 15 designed cylindrically about a longitudinal axis 24. The valve stem 17 terminates in a tapered or conical valve member 7 which bears from outside on a valve seat 8 in the interior of a nozzle orifice 6. When the valve stem 17 is displaced axially, the valve member 7 lifts off from the valve seat 8, with the result that the latter opens the nozzle orifice 6 for the outlet of the fuel which is under pressure in the fuel chamber 13. In this case, within the framework of internal mixture formation, the opening stroke of the valve member 7 and the duration of the opening of the nozzle orifice 6 (injection time) determine both the throughput of fuel through the nozzle orifice 6 and the total injection quantity as well as the injection angle of the conical jet which emerges from the nozzle orifice 6 and which, in particular, influences mixture formation in the stratified charge mode of the internal combustion engine by forming a mixture cloud in the combustion space.

Opposite the valve member 7, the valve stem 17 is connected, to form a wide annular shoulder 19, to a pressure piston 27 which is guided by an inwardly directed guide portion 33 of the injector housing 15, the said guide portion delimiting the fuel chamber 13. In this case, the pressure piston 27 projects into an elongation space 16 which is formed in the injector housing 15 on that side of the guide portion 33 located opposite the fuel chamber 13 and in which a mechanical transducer device for electrical pulses is arranged. The transducer device may, for example, be a piezoelectric element 23 which bears positively on that end portion of the pressure piston 27 projecting into the elongation space 16 and which, due to its own elongation, displaces the pressure piston 27 when an electrical voltage is applied and, consequently, opens the nozzle orifice 6 for the injection of fuel out of the fuel chamber 13. According to the piezoelectric effect, the elongation of the piezoelectric element 23 is proportional to the applied voltage, with the result that the opening stroke of the valve member 7 can be controlled exactly and adjusted variably by applying a corresponding electrical voltage.

To close the nozzle orifice 6, the electrical voltage is reduced on the piezoelectric element 23 which is consequently shortened. A compression spring 18 in the fuel chamber 13, which is supported on the annular shoulder 19 of the pressure piston 27, on the one hand, and on the inside of the injector housing 15 at a point adjacent to the nozzle orifice 6, on the other hand, forces the valve member 7 back into the valve seat 8. If the internal combustion engine is equipped with a common-rail injection system, the fuel chamber 13 being under high pressure in the injector housing 15 via the fuel supply conduit, then the return force forcing the valve member 7 into the valve seat 8 in order to close the nozzle orifice 6 is exerted due to the fact that the pressure piston 27 has a larger diameter than the nozzle orifice 6. The larger pressure-loaded surface of the pressure piston 27 causes the pressure piston 27 together with the valve stem 17 to be displaced into the closing position. Electrical voltages necessary for controlling the opening stroke of the valve member 7 are higher by the amount of an electrical voltage which is necessary for overcoming the pressure force which is exerted in the fuel chamber 13 on the pressure piston 27 by the differential pressure surface and which forces the valve member into the closing position.

Figure 3 illustrates diagrammatically the sequence of the control of the

opening stroke of a valve member and the injection time for optimal mixture formation at any operating point of an internal combustion engine by means of an injector control 25. For each operating point of the internal combustion engine, which is determined by the engine speed n and the load L , the respectively optimal adjustment parameters 21 of the opening stroke of the valve member and the injection time are filed in an injection characteristic map 20. When any desired operating point of the internal combustion engine is approached, the corresponding adjustment parameters 21 are retrieved from the characteristic map 20 and are used by the injector control 25 as a basis for adjusting the opening stroke and the injection time during fuel injection for the internal combustion engine to operate with optimized consumption and emission. The adjustment parameters 21, filed in the injection characteristic map 20, of a plurality of injectors of various cylinders of a multi-cylinder internal combustion engine may be different and, in this case, lead to cylinder-specific mixture formations in the individual combustion spaces. After the injector has been adjusted by means of the injector control 25, engine parameters 31 are measured, for example the smooth running of the internal combustion engine, and are compared with desired values 32 in a controller unit 26 which are filed in an engine characteristic map 30 and which are specific to the operating point. If the measured engine parameters 31 deviate from the desired values 32 filed in the engine characteristic map 30, that is to say if the smooth running of the internal combustion engine is not satisfactory, the controller unit 26 causes a variation in the adjustment parameters 21 which are used by the injector control 25, in the subsequent work cycles of the internal combustion engine, as a basis for the adjustment of the injectors. If, after a continuing comparison of measured engine parameters 31 with the desired values 32 of the engine characteristic map 30, correspondence is finally achieved in the case of an optimal operating behaviour of the internal combustion engine, then the parameter variation of the controller unit 26 is terminated. The ideal parameters 22 determined for optimal mixture formation at the specific operating point of the internal combustion engine are filed in the injection characteristic map 20 and replace the previous adjustment parameters 21 for this operating point, with the result that, when this operating point of the internal combustion engine is next approached, the corrected ideal parameters 22 can be provided for the injector control 25.

Such corrections of the adjustment parameters 21 may be necessary, for example during the first commissioning of the internal combustion engine, on account of tolerance spreads in the mass production of injectors, cylinder heads, etc., which, in the stratified charge mode of the internal combustion engine, prevent an ideal mixture cloud from being formed by influencing the conical fuel jet, or else on account of variations in the behaviour of the conical jet as a result of wear or deposits as the operating period of the internal combustion engine increases. In this case, during the correction of the adjustment parameters 21, an increase in the opening stroke leads to an increase in the injection angle of the conical jet. In the stratified charge mode of the internal combustion engine, deviations of the air ratios (λ values) and of the position of the mixture cloud in the combustion space from the adjustment values for optimal mixture formation can thereby be compensated. The check of the operating behaviour of the internal combustion engine, that is to say the comparison of the measured engine parameters 31 (smooth running) with the desired values 32 of the engine characteristic map 30, may be carried out continuously or at predetermined intervals during the running time of the internal combustion engine.

Figure 4 illustrates a graph of the adjustment parameters of the opening stroke and injection time as a function of the speed of a direct-injection Otto internal combustion engine. In the stratified charge mode of the internal combustion engine, the speed influences the position of the mixture cloud in the combustion space, so that the adjustment parameters for the opening stroke and injection time must be adapted in order to achieve optimal mixture formation in the entire characteristic map. In this case, mixture preparation is carried out, as the speed increases, by an exponential increase in the opening stroke along with a linear reduction in the injection time. In the case of an operating point with an engine speed of 2000 revolutions per minute, the optimal injection time is about 0.75 ms for an opening stroke of 0.02 mm, whilst, at an engine speed of 6000 revolutions per minute, the optimal adjustment parameters are 0.375 ms for the injection time and 0.03 mm for the opening stroke.

Figure 5 illustrates a graph of the profile of the adjustment parameters for optimal mixture formation in the characteristic map of an internal combustion engine, in the combustion space of which there is a reduced oxygen concentration. An internal combustion engine works under these operating conditions when exhaust-gas

recirculation is provided or part throttling, for example for the free burn of the combustion space or to improve the conditions for the retreatment of the exhaust gas. The reduced mass flow of fresh air and its temperature and also the changed pressure conditions in the combustion space necessitate an adaptation of the mixture formation by a variation of the injection parameters in the characteristic map. In this case, with an increasing exhaust-gas recirculation rate or part throttling, the injection time is increased linearly and the opening stroke is reduced inversely exponentially. At the operating point without exhaust-gas recirculation or in the non-throttled mode, the optimal adjustment parameters are 0.25 ms for the injection time and 0.06 mm for the opening stroke, whilst, at the operating point with an exhaust-gas recirculation rate or part throttling of 50%, the injection time is 0.5 ms and the opening stroke 0.025 mm.

Figure 6 shows a graph of the optimal adjustment parameters in the characteristic map of a supercharged internal combustion engine, in which it is important to distribute the injected fuel in a small region of the combustion space. Accordingly, with an increasing charge, the opening stroke is increased exponentially and the injection time is reduced linearly, with the result that a mixture cloud having optimal lambda values is formed in the entire characteristic map of the internal combustion engine. In this case, the opening stroke is increased from 0.02 mm in the case of a 0% charge to about 0.025 mm in the case of a 50% charge of the engine, whilst the injection time in the same region of the characteristic map is reduced from 0.75 ms to about 0.6 ms.

Figure 7 shows a graph of the increase in the injection angle of a conical fuel jet from about 75° to about 90° with an increasing opening stroke of a valve member during the opening lifting-off from a valve seat in the nozzle orifice of an injector about 0.03 mm to 0.06 mm. It is thereby possible to ensure that, at each operating point of the internal combustion engine in the stratified charge mode, an ignitable fuel/air mixture is provided for ignition to the electrodes of a spark plug projecting into the combustion space. After the end of injection, the mixture cloud moves in the combustion space in the direction of the piston head, so that there is the risk that, in the region of the electrodes, the mixture will become leaner to the point of non-ignitable lambda values. In order, when the electrodes are slightly wetted with fuel so as to cause carbonization, to bring mixture combustible at a determinable

moment into the region of the electrodes and consequently select the ignition time point, there is provision, as illustrated graphically in Figure 8, for briefly increasing the injection angle during the injection time by increasing the opening stroke. Due to the dynamic variation in the injection angle during the injection time, a rich fuel/air mixture provided for ignition is present for a short time at the electrodes. Outside the ignition interval with a large injection angle of about 90° , during the injection time electrodes have fuel due to the small injection angle of about 80° and there is therefore a reduction in deposits.

Figure 9 illustrates a graph of the inversely exponentially increased throughflow rate of an opened nozzle orifice as a function of the increasing opening stroke of the valve member. In the case of a constant opening stroke, as a result of which a uniform mass flow of fuel would be injected into the combustion space, in the stratified charge mode of the internal combustion engine there would be a relatively rich fuel/air mixture in the near-nozzle regions of the mixture cloud formed and a relatively lean mixture in the nozzle-distant regions. In order to prevent the mixture cloud from becoming leaner in the nozzle-distant regions and consequently incomplete oxidation of the fuel as a result of too high an excess of air, there is provision for reducing the mass flow of fuel through the nozzle orifice during injection. As illustrated in Figure 10, this is carried out by a dynamic reduction in the opening stroke from about 0.06 mm at the start of fuel injection to 0.02 mm at the end of fuel injection shortly before the closing of the nozzle orifice. In this case, the reduction in the opening stroke takes place inversely exponentially during fuel injection, with the result that a large part of a metered fuel quantity is injected at a high throughflow rate through the nozzle orifice into the combustion space at the start of the injection time.

Claims

1. A method for forming an ignitable fuel/air mixture in the cylinder(s) of a direct-injection internal combustion engine, fuel being injected by means of an injector valve into the or each combustion space delimited by a piston, when a nozzle orifice of the injector valve is opened by the lifting-off of a valve member from a valve seat surrounding the nozzle orifice, wherein the opening stroke of the valve member and the injection time are adjustable variably.
2. A method according to Claim 1, wherein the opening stroke of the valve member is adjustable during the injection operation.
3. A method according to Claim 1 or 2, wherein the opening stroke of the valve member of each cylinder is adjustable individually.
4. A method according to any one of Claims 1 to 3, wherein the injector valve injects the fuel in a widening conical jet into the combustion space.
5. A method according to Claim 4, wherein, in the stratified charge mode of the internal combustion engine, the conical jet forms a conical mixture cloud carrying a fuel/air mixture and having air ratios dependent on the adjustment of the opening stroke of the valve member, the electrodes of a spark plug projecting into the said mixture cloud.
6. A method according to Claim 4 or 5, wherein the injection angle (α) of the conical jet is larger with an increasing opening stroke of the valve member.
7. A method according to any one of Claims 1 to 6, wherein the opening stroke of the valve member and the injection time are adjusted at each operating point of the internal combustion engine on the basis of adjustment parameters filed for the respectively existing operating point in an injection characteristic map.

8. A method according to Claim 7, wherein, if the measured engine parameters deviate from desired values in an engine characteristic map, a variation in the opening stroke of the valve member takes place at the respective operating point of the internal combustion engine during each injection, until an optimal operating behaviour, with the measured engine parameters and the desired values of the engine characteristic map corresponding to one another, is achieved, the ideal parameters determined being filed in the injection characteristic map so as to replace the previous adjustment parameters.

9. A method according to any one of Claims 1 to 8, wherein the opening stroke of the valve member is a maximum of 0.1 mm.

10. A method according to Claim 9, wherein, in the stratified charge mode of the internal combustion engine, the opening stroke of the valve member is adjustable between about 0.02 mm and about 0.06 mm.

11. A method according to Claim 10, wherein the injection angle (α) of the conical jet is between about 70° and 100°, depending on the opening stroke of the valve member.

12. A method according to any one of the preceding claims, wherein a plurality of injections take place in one work cycle of the piston.

13. A method for forming an ignitable fuel/air mixture in the cylinder(s) of a direct-injection internal combustion engine, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.



14

Application No: GB 9721792.1
Claims searched: 1 to 13

Examiner: John Twin
Date of search: 7 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B (BB102, B2P4)

Int Cl (Ed.6): F02M 51/06, 61/06, 61/16; F02D 41/40

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2152135 A (Toyota Chuo)	1
X	US 5518184 (Robert Bosch)	1
X	US 5479902 (Daimler-Benz) - see eg column 1, line 45 to column 2, line 12	1
X	US 5341783 (Servojet) - see eg column 23, line 50 to column 27, line 23	1
X	US 5280773 (Henkel)	1
X	US 4798188 (Aisan)	1
X	US 4327695 (Ford)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.