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(54) METHOD TO DETERMINE THE NEEDLE OPENING DELAY OF A FUEL INJECTOR

VERFAHREN ZUR BESTIMMUNG DER NADELÖFFNUNGSVERZÖGERUNG EINES KRAFTSTOFFINJEKTORS

PROCÉDÉ DE DÉTERMINATION DE RETARD D'OUVERTURE D'AIGUILLE D'INJECTEUR DE COMBUSTIBLE

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(73) Proprietor: **PHINIA Delphi Luxembourg SARL**
4367 Belvaux (LU)

(72) Inventors:
- **COCHET, Thierry**
  41190 Molineuf (FR)
- **GHIRLANDA, Alessio**
  54190 Villerupt (FR)

(74) Representative: **Office Freylinger**
P.O. Box 48
8001 Strassen (LU)

(56) References cited:
EP-A2- 1 544 446
US-A1- 2012 191 327
US-A1- 2013 312 709

EP 3 698 035 B1

Description

TECHNICAL FIELD

[0001] The invention relates to method to determine the needle opening delay (OD) of a fuel injector. The needle opening delay is the time lag between when an activation pulse is sent to fuel injector and the time that the needle starts to move away from its seat to dispense fuel.

BACKGROUND OF THE INVENTION

[0002] Modern fuel injectors typically use electrical actuators such as piezo or solenoid operated actuators which are used to activate a valve, the valve opening and closing in order to dispense fuel to a combustion chamber via movement of a needle away from a seat. Typically an activation pulse of certain duration is sent to the fuel injector to activate the fuel injector via activating the actuator. Modern fuel injectors are hydraulically operated in that rather than the actuator actuating the needle directly, the actuator used to operate a valve (system) so as to control pressure in the fuel injector, so as to indirectly operate the fuel injector by movement of a needle to or from a needle seat, using such pressures, so as to selectively dispense fuel. Thus there is a distinction between actuator operated valve opening and closing, and needle opening and closing.
[0003] There is typically a time delay between the leading edge of the pulse, i.e. start of activation and the needle valve opening; this is referred to as the opening delay.
[0004] Some designs of fuel injector typically also provide a switch signal, provided often by an extra wire, where a signal on the wire provides means to detect when two moving parts in the injector system are in or out of contact with each other. This may be for example detecting when the valve needle and nozzle/needle seat come into contact or are out of contact with each other, or when the needle after opening (moving away from the valve seat) comes to its end (fully open) stop. Many prior art systems use this switch signal to determine the opening time of the injector needle valve or other components. However the use of switch signals which determine the opening time of the needle are sometime unreliable.
[0005] US 2013/312709 A1 describes a method similar to the method of claim 1 without the separate utilisation of a Control Chamber filling time CCFT.

SUMMARY OF THE INVENTION

[0006] The invention is a method according to claim 1.
[0007] The control chamber filling time is found from the following equation

$$\mathrm{CCFT} = \mathrm{NFST} - \mathrm{VCT}$$

[0008] The needle closing delay (NCD) is found from the following equation;

$$\mathrm{NCD} = \mathrm{NCT} - \mathrm{VCT}$$

[0009] NFST and or NCT may be determined from the injector switch signal.
[0010] Said closing time of the solenoid actuated valve (VCT) may be determined by analyzing the voltage across the solenoid of the solenoid actuated valve and identifying a time of glitch.
[0011] The method may include storing a reference plot of NCD value against the sum Ton, VCD and CCFT for a reference injector, and providing a refined value of opening delay (Refined OD_injx) from the value found from step h) and the data from the reference plot.
[0012] The refined value of opening delay (refined OD_injx) may be determined from the following equation

$$\text{refined OD\_injx} = \mathrm{OD}_{\mathrm{injx}} + \left(\mathrm{OD}_{\mathrm{ref\_map}} - \mathrm{pseudo\_OD}_{\mathrm{ref\_map}}\right)$$

where $\mathrm{OD}_{\mathrm{injx}}$ is the initial estimate of opening delay found in step j);
$\mathrm{OD}_{\mathrm{ref\_map}}$ is a stored or determined value for a reference injector, representing the sum (Ton + VCD + CCFT) at a zero value of the NCD for the reference injector;
$\mathrm{pseudo\_OD}_{\mathrm{ref\_map}}$ is the value of the sum (Ton + VCD + CCFT) at the CCFT threshold value of the NCD with respect to the reference plot.

[0013] The method may include determining for each cycle the needle falling duration (NFD) from steps c) and d); where NFD is determined form the following equation: NFD= NCT-NFST, and wherein a needle closing delay NCD is determined form the following equations NCD= CCFT + NFD

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention is now described by way of example with reference to the accompanying drawings in which:

- Figure 1 shows a schematic diagram of a solenoid operated fuel injector system
- Figure 2a, 2b, 2c show three operational states of the fuel injector with reference to the needle position and the current which flows throught the additional wire to ground;
- Figure 3 shows the corresponding timeline of the activation pulse sent to the solenoid (top plot), the middle plot shows corresponding timeline of the injection period which is the time from needle opening to closing , and the bottom plot shows the corresponding states of the voltage on the switch signal with the various opening and closing and intermediate states corresponding to that of figure 2;
- Figure 4 shows corresponding timelines of activation pulse, valve lift, needle command (position) and needle lift respectively;
- Figure 5 shows the values of the sum of (Ton + VCD + CCFT) plotted against CCFT/NCD;
- Figure 6 and 7 shows further plots comparing the values of various parameters for ballistic and non-ballistic (full lift) operations of the fuel injector;
- Figure 8 illustrates an advanced method of refining the estimated value of opening delay.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Figure 1 shows a schematic diagram of a solenoid operated fuel injector system which includes a fuel injector 1 (shown in schematic cross section) and includes additional wiring 2 which allows detections of the operational state of the injector. The figure shows the ECU portion 3, the harness portion 4 and the injector portion 5. The injector portion shows the solenoid 6 of the actuator. The additional wiring 5 provides two current paths 7 and 8 to ground as shown depending on the position of the needle. The operational state of the injector can be monitored by measuring the voltage on line 9, which allows detection of the state of the needle contacts when it is fully closed fully open and partially open.

[0016] Figure 2a-c shows three operational states of the fuel injector with reference to the needle position and the current which flows throught the additional wire to ground. Figure 2a shows the needle in the closed state A where there is flow of current to ground when the needle contacts the needle seat (bottom contact) - the voltage on line 9 is 0V. Figure 2b shows where the needle is partially open in state B and there is no contact with ground through the additional wire and hence no current flow; the voltage on line 9 is high. Figure 2c shows the needle when it is in the open position C and there is flow throught the additional wire to ground via the top contact of (the needle is fully open) via pathway 7. The voltage on line 9 is 0V.

[0017] Figure 3 shows the corresponding timeline of the activation pulse 10 sent to the solenoid (top plot), the middle plot shows corresponding timeline of the injection period 11 which is the time from needle opening to closing , and the bottom plot shows the corresponding states of the voltage on the switch signal line 9 with the various opening and closing and intermediate states corresponding to that of figure 2. State A is where the needle is closed, the needle subsequently starts to lift at P1 and the signal on the switch line 9 goes high as there is no current path through the additional wire when the needle is partially open/closed in the transition state B. State C is where the needle reaches fully open point P2 and the signal on the switch line 9 goes to zero as current can flow through the additional wire due to the top contact. As the needle closes (is partially closed) during state D the voltage on the switch line goes high again at point P3 when the needle is in a transition state (partially open) and when the needle hits the needle seat and is closed the switch signal voltage goes to zero at state E at point P4.

[0018] So from the state of the switch signal (by monitoring the state of the voltage) the Needle Falling Start Time at point P3 can be determined. So the figure shows the various states when the needle is in full lift, the top switch is activated and the switch signal goes to 0V. When the needle is travelling back to the seat the short circuit in the top switch disappears and the switch signal is going from 0V to 5V. The needle closing time (NCT) is point P4. The NFD: Needle falling duration can also be computed from the switch signal also and is determined as the period D, between points P3 and P4 in figure 3 .

[0019] Figure 4 shows corresponding timelines of activation pulse 110, valve lift 111, needle command (position) 112 and needle lift 113 respectively. The following annotations are used in the figures and description:

NOT: Needle Opening Time
NCT: Needle closing time

VCT: Valve closing time
NFST: Needle Falling Start Time
CCFT: Control Chamber filling Time
OD: Needle Opening Delay
VCD: valve closing delay
NCD: Needle Closing Delay
NOL: needle opening length/duration
NFD: Needle falling duration

[0020] So the figure shows the corresponding timelines of various parameters in the operation of a solenoid injector. The top plot 110 shows the activation pulse which has a length (duration) of Ton. Underneath is shown the valve lift 111 and shows the valve starts to move/open at point P11 and closes at point P12. The assumed VCD is the time between the end of the activation pulse and the time of the VCT. The plot 12 below this shows needle effective command and the bottom plot 113 shows the actual movement of the needle and shows a small timespan where the needle lifts to allow injection of fuel and this show a small bell shaped pulse over a timespan of NOL. As can be seen there is a large time span between the start of the activation pulse and the (time the needle starts to lift) opening delay. The needle falling duration is as shown and is generally over the second half of the NOL. When looking at the plot the following equalities and equations apply:

$$\mathrm{OD} + \mathrm{NOL} = \mathrm{Ton} + \mathrm{VCD} + \mathrm{CCFT} + \mathrm{NFD}$$

$$\mathrm{CCFT} = \mathrm{NFST} - \mathrm{VCT}$$

$$\text{At NOL}= 0,\ \mathrm{NFD} = 0$$

$$\mathrm{OD} = \mathrm{Ton} + \mathrm{VCD} + \mathrm{CCFT}$$

$$\mathrm{NCD} = \mathrm{CCFT} + \mathrm{NFD} \quad \text{at NOL}=0\ \mathrm{NFD} = 0,\ \ \mathrm{NCD} = \mathrm{CCFT}$$

$$\text{AT NCD} = \mathrm{CCFT},\ \mathrm{Ton} + \mathrm{VCD} + \mathrm{CCFT}=\mathrm{OD}$$

Detailed Description of the Invention

[0021] In aspects of the invention the needle opening delay is determined from the following input parameters:

a) The (actuator) valve closing time (VCT). This parameter can be determined from analysis of the current/voltage across the solenoid actuator. Typically when the solenoid valve closes, there is a detectable glitch in the voltage plot which can be preferably determined by looking at the values of dV/dt and or the second derivative. The glitch is determined by observing a point of inflection in the current plot, and such techniques are well known in the art.

b) The needle closing time (NCT) information can be provided from a switch signal as described above, the time at point P4 at the end of the period D.. This provide the parameter NCT.

c) The NFD: Needle falling duration. This is computed from the switch signal also and is determined as the period D in figure 2, the time duration between point P3 and P4. This is optional and only needed in some embodiments (see *)

d) Injector (actuator) drive pulse length information. (Ton)

e) CCFT Threshold value. This will be explained in detail hereinafter.

[0022] Using the above information, for a number of injector actuation cycles of different durations of activation pulse, the values of the sum of (Ton + VCD + CCFT) is plotted against NCD.

[0023] The NCD is calculated by NCD = NCT - VCT. Figure 5 shows such a plot.

[0024] (It is to be noted that if in full lift, alternatively NCD may be calculated from the equation NCD=CCFT + NFD) * The Opening Delay according to aspects is determined by finding the intersection between this curve and the NCD value that corresponds; i.e. is equal to the CCFT threshold value; the later which will be explained hereinafter. So using the above input data, an NCD curve function is plotted by providing a plurality of injector operations (cycles) with different activation pulse lengths (Ton). This may be performed using a "sweep" where the fuel injector is activated with e.g. successively increasing pulse activation durations and subsequent measurements of the parameters referred to above. During such a sweep, Ton will increase, and then it will progressively open the valve then the needle. During this sweep, NCD, VCD, CCFT and NOL will progressively increase.

[0025] The value of Ton is the activation pulse duration. The value of VCD (valve closing delay) is determined from VCT (valve closing time), and is the time between the end of the activation pulse and the VCT. CCFT is determined as = NFST - VCT. NFST can be determined from the switch signal as described above. So to recap the value of (Ton + VCD + CCFT) is plotted against NCD and is shown in figure 5 as mentioned.

[0026] As mentioned the threshold value of CCFT is determined; this can be regarded as the maximum CCFT. If CCFT is plotted against pulse length (Ton), the value will increase (during the ballistic range)) and reach a plateau. This is the CCFT threshold and so this can be determined by looking at the plateau value thereof with increasing pulse length. So to recap CCFT against pulse length (Ton) will go up and reach a plateau and the value at the plateau will be used as the threshold value. The CCFT threshold value can be regarded as a NCD threshold value as will be explained below.

[0027] So to re-iterate, with respect to figure 5, a line is drawn horizontally on the y-axis (the NCD axis at the CCFT threshold value) i.e. the threshold value of CCFT on the NCD axis and the at this intersect point with the plot on the x-axis is determined as the opening delay OD.

[0028] Figure 6 and 7 shows further plots comparing the values of various parameters for ballistic and non-ballistic (full lift) operations of the fuel injector the reference numerals denote the activation pulse (in the case of full lift this is sufficient in length to operate out of ballistic mode) denotes the valve opening state signal denotes the needle signal and shows the needle lift state. This illustrates why OD = Ton + VCD + CCFT when NCD = CCFT (it is figure 4 that illustrates that). As CCFT cannot be measured in ballistic, the full lift CCFT is used. The NCD Threshold will be a value dependent on the full lift CCFT. NCD will be plotted function of (Ton + VCD + full lift CCFT). The full lift CCFT can be calculated as explained above as well as the valve closing time determined e.g. from a glitch in the voltage plot of the solenoid. CCFT = NFST - VCT, see fig.3

Refinement

[0029] In the above an estimate of the OD is determined. However in order to provide more accurate result, this initial estimate is refined to provide a more accurate estimate. This refined methodology will be explained with reference to figure 8. If we refer to the initial estimate as a "pseudo" OD of the injector under test such (Pseudo OD_{injx}), this will be higher than the real OD (ODinjx) because the NCD Threshold used (full lift CCFT) is higher than the CCFT corresponding to very small quantity (typically 0.1 mg/stroke) Furthermore the data on NCD = (Ton + VCD + CCFT) is not available at low values. The curve 21 in figure 8 is that obtained from the above methodology and is the same as in figure 5. Thus the data or portion of the curve shown dotted of plot 21 in figure 8 is usually unavailable.

[0030] In a refined embodiment there is provided a stored map of NCD against Ton+VCD+CCFT for an ideal i.e. reference injector. This stored (ref injector OD) reference map can be provided from data recorded on hydraulic rig /from an injection rate measurement device, and can be stored on an ECU. Figure 8 shows a graph/plot of (Ton + VCD + CCFT) 20 plotted against NCD for an ideal/reference injector, along with the plot 21 for the injector under test as obtained by the above described method, and shows that determined for the above methodology, the plot for the test injector Inj_x 20 should be generally parallel to the curve for the reference injector of Inj_{Ref}. 21. It is again to be noted that data regarding the test injector is not available at low levels. Thus the intersection of the test plot with the X-axis never appears because even for very small quantity, NCD is not null (it is very small but not null), it corresponds to the CCFT value for small quantity. This delay depends on the hydraulic behaviour of the injector. However this data is usually available. The following method steps are then taken:

i) From the reference injector plot, i.e., on the stored map/chart, the 0 (y-axis) crossing is used to get a value of the parameter $OD_{ref\ map\ zero}$ (where NCD is zero) . As this is fixed, this may be stored on a table.

ii) Also the current NCD threshold (current threshold CCFT) which is variable and as explained above is used to find initially estimated value of OD for the test injector (Pseudo) OD_{injx} for the test injector is also used to determine the equivalent Pseudo OD_{ref} for the reference injector designated Pseudo OD_{ref_map}.

iii) These two parameters are used along with the value of the NCD threshold crossing for the test injector which as previously described is Pseudo OD_{injx}, to get real $OD_{inj\ x}$ (using the formula) below:

$$\text{Estimated\_refined OD\_injx} = OD_{ref\_map} + ((\text{pseudo})\_OD_{injx} - \text{pseudo\_}OD_{ref\_map})$$

[0031] So in summary the real OD of the reference injector will be stored as a calibration in the ECU, it will be called OD_{Ref_map}. The pseudo OD of the reference injector will also be stored as a calibration dependent on the level of NCD for test injector, it will be called $Pseudo\_OD_{Ref\_map}$. The difference between $(pseudo)OD_{injx}$ and $pseudo\_OD_{ref\_map}$ will be added to the OD_{Ref_map} to have the estimated OD of the injx.

[0032] The present invention is an indirect way to determine the OD of a fuel injector. The old system was a direct measurement of the needle opening thanks to the switch signal. But this system was sometimes not reliable.

Claims

1. A method, carried out in an ECU (3), for determining the needle opening delay ODinjx of a solenoid actuated fuel injector (5) thereof, said fuel injector including a solenoid actuated valve (6) adapted to actuate a needle valve, said needle valve comprising a needle adapted to move from an closed state to an open state and to a closed state during an operational cycle of said injector, said needle opening delay being the time between when an activation pulse is sent and when the needle starts to move, comprising the following steps:

    a) providing, for a series of test injection cycles, respective solenoid actuator drive pulse duration information Ton; for each test injection cycle, performing the following b) to g):

        b) determining, the closing time of the solenoid actuated valve VCT;
        c) determining, the needle closing time NCT;
        d) determining, the needle falling start time NFST;
        e) determining a Control Chamber filling Time CCFT value from the values determined from step d) and step b), where CCFT = NFST - VCT;
        f) determining, a needle closing delay NCD from the values at steps b) and c), where NCD = NCT -VCT;
        g) determining a Valve Closing Delay VCD; said Valve Closing Delay being the time between the end of the drive pulse and the valve closing time;

    h) providing a test plot by plotting the value of needle closing delay NCD for each cycle against the respective sum of the values of (i) drive pulse duration information Ton, (ii) Valve Closing Delay VCD, and (iii) Control Chamber filling Time CCFT;
    i) determining a threshold value of CCFT, being the maximum value of CCFT obtainablethrough the use of the series of test injection cycles with different respective drive pulse duration information Ton;
    j) from the determined plot, determining the value of said sum at the intersect of said plot of the CCFT threshold on the NCD axis;
    k) determining the opening delay ODinjx as the determined sum value at the intersect.

2. A method as claimed in claim 1 where NFST and or NCT are determined from the injector switch signal.

3. A method as claimed in claim 1 to 2 wherein said closing time of the solenoid actuated valve VCT is determined by analyzing the voltage across the solenoid of the solenoid actuated valve and identifying a time of glitch from a point of inflection.

4. A method as claimed in any preceding claim including storing a reference plot of NCD value against the sum Ton, VCD and CCFT for a reference injector, and providing a refined value of opening delay "refined OD_injx" from the value found from step i) and the data from the reference plot.

5. A method as claimed in claim 4 the refined value of opening delay "refined OD_injx"

    is determined from the following equation

$$\text{refined OD\_injx} = OD_{injx}\,(OD_{ref\_map} - pseudo\_OD_{ref\_map})$$

    where OD_{injx} is the initial estimate of opening delay found in step j);
    OD_{ref_map} is a stored or determined value for a reference injector, representing the sum (Ton + VCD + CCFT) at a zero value of the NCD for the reference injector;
    $pseudo\_OD_{ref\_map}$ is the value of the sum (Ton + VCD + CCFT) at the CCFT threshold value of the NCD with

respect to the reference plot.

Patentansprüche

1. Verfahren, das in einer ECU (3) ausgeführt wird, zum Bestimmen der Nadelöffnungsverzögerung ODinjx einer durch ein Solenoid betätigten Kraftstoffeinspritzdüse (5) von dieser, wobei die Kraftstoffeinspritzdüse ein durch ein Solenoid betätigtes Ventil (6) einschließt, das dazu geeignet ist, ein Nadelventil zu betätigen, wobei das Nadelventil eine Nadel umfasst, die dazu geeignet ist, sich während eines Arbeitszyklus der Einspritzdüse von einem geschlossenen Zustand in einen offenen Zustand und in einen geschlossenen Zustand zu bewegen, wobei die Nadelöffnungsverzögerung die Zeit zwischen dem Zeitpunkt, wenn ein Aktivierungsimpuls gesendet wird, und dem Zeitpunkt ist, wenn sich die Nadel zu bewegen beginnt,
umfassend die folgenden Schritte:

    a) Bereitstellen, für eine Reihe von Testeinspritzzyklen, von jeweiligen Informationen über die Ansteuerungsimpulsdauer des Solenoidstellantriebs Ton für jeden Testeinspritzzyklus, Ausführen der folgenden Schritte b) bis g):

        b) Bestimmen der Schließzeit des durch das Solenoid betätigten Ventils VCT,
        c) Bestimmen der Nadelschließzeit NCT,
        d) Bestimmen der Nadelfallstartzeit NFST,
        e) Bestimmen eines Wertes einer Steuerkammerfüllzeit CCFT anhand der Werte, die in Schritt d) und Schritt b) bestimmt worden sind, wobei CCFT = NFST - VCT;
        f) Bestimmen einer Nadelschließverzögerung NCD anhand der Werte in den Schritten b) und c), wobei NCD = NCT - VCT;
        g) Bestimmen einer Ventilschließverzögerung VCD, wobei die Ventilschließverzögerung die Zeit zwischen dem Ende des Ansteuerungsimpulses und der Ventilschließzeit ist;

    h) Bereitstellen eines Testdiagramms durch Eintragen des Wertes der Nadelschließverzögerung NCD für jeden Zyklus gegenüber der jeweiligen Summe der Werte von (i) Informationen über die Ansteuerungsimpulsdauer Ton, (ii) der Ventilschließverzögerung VCD und (iii) der Steuerkammerfüllzeit CCFT;
    i) Bestimmen eines Schwellenwertes von CCFT, der der maximale Wert von CCFT ist, der durch die Verwendung der Reihe von Testeinspritzzyklen mit verschiedenen jeweiligen Informationen zur Ansteuerungsimpulsdauer Ton erhältlich ist;
    j) anhand des bestimmten Diagramms, Bestimmen des Wertes der Summe an der Kreuzungsstelle des Diagramms des CCFT-Schwellenwertes auf der NCD-Achse,
    k) Bestimmen der Öffnungsverzögerung ODinjx als der bestimmte Summenwert an der Kreuzungsstelle.

2. Verfahren nach Anspruch 1, wobei NFST und/oder NCT anhand des Einspritzdüsenschaltsignals bestimmt werden.

3. Verfahren nach Anspruch 1 bis 2, wobei die Schließzeit des durch das Solenoid betätigten Ventils VCT durch Analysieren der Spannung über das Solenoid des durch das Solenoid betätigten Ventils und Identifizieren einer Zeit eines Störimpulses von einem Wendepunkt bestimmt wird.

4. Verfahren nach einem der vorstehenden Ansprüche, einschließend das Speichern eines Referenzdiagramms des NCD-Wertes gegenüber der Summe Ton, VCD und CCFT für eine Referenzeinspritzdüse, und das Bereitstellen eines verfeinerten Wertes der Öffnungsverzögerung "refined OD_injx" anhand des Wertes, der in Schritt i) festgestellt wurde, und der Daten von dem Referenzdiagramm.

5. Verfahren nach Anspruch 4, wobei der verfeinerte Wert der Öffnungsverzögerung "refined OD_injx" anhand der folgenden Gleichung bestimmt wird

$$\text{refined OD\_injx} = OD_{injx}\,(OD_{ref\_map} - \text{pseudo\_}OD_{ref\_map})$$

wobei OD_{injx} die anfängliche Schätzung der in Schritt j) festgestellten Öffnungsverzögerung ist; OD_{ref_map} ein gespeicherter oder bestimmter Wert für eine Referenzeinspritzdüse ist, der die Summe (Ton + VCD + CCFT) an einem Nullwert der NCD für die Referenzeinspritzdüse darstellt; pseudo_OD_{ref_map} der Wert der Summe (Ton + VCD

+ CCFT) an dem CCFT-Schwellenwert der NCD in Bezug auf das Referenzdiagramm ist.

Revendications

1. Procédé, exécuté par une unité de commande électronique (ECU) (3), permettant de déterminer le retard d'ouverture d'aiguille ODinjx d'un injecteur de combustible (5) actionné par solénoïde en faisant partie, ledit injecteur de combustible comprenant une valve (6) actionnée par solénoïde conçue pour actionner une valve à pointeau, ladite valve à pointeau comprenant une aiguille conçue pour se déplacer d'un état fermé vers un état ouvert et vers un état fermé pendant un cycle opérationnel dudit injecteur, ledit retard d'ouverture d'aiguille étant le temps écoulé entre le moment où une impulsion d'activation est envoyée et le moment où l'aiguille commence à bouger, comprenant les étapes suivantes :

a) fourniture, pour une série de cycles d'injection test, d'une information de durée d'impulsion de commande d'actionneur à solénoïde respective Ton ;
pour chaque cycle d'injection test, exécution des actions b) à g) suivantes :

b) détermination du temps de fermeture de la valve actionnée par solénoïde VCT ;
c) détermination du temps de fermeture d'aiguille NCT ;
d) détermination de l'instant de début de retombée de l'aiguille NFST ;
e) détermination d'une valeur de temps de remplissage de chambre de commande CCFT à partir des valeurs déterminées lors de l'étape d) et de l'étape b), où CCFT = NFST -VCT ;
f) détermination d'un retard de fermeture d'aiguille NCD à partir des valeurs des étapes b) et c), où NCD = NCT - VCT ;
g) détermination d'un retard de fermeture de valve VCD ; ledit retard de fermeture de valve étant le temps écoulé entre la fin de l'impulsion de commande et le temps de fermeture de valve ;

h) fourniture d'une courbe test obtenue en rapportant la valeur du retard de fermeture d'aiguille NCD pour chaque cycle en fonction de la somme correspondante des valeurs (i) de l'information de durée d'impulsion de commande Ton, (ii) du retard de fermeture de valve VCD et (iii) du temps de remplissage de chambre de commande CCFT ;
i) détermination d'une valeur seuil de CCFT, celle-ci étant la valeur maximale de CCFT pouvant être obtenue en utilisant la série de cycles d'injection test avec différentes informations de durée d'impulsion de commande respectives Ton ;
j) à partir de la courbe tracée, détermination de la valeur de ladite somme à l'intersection de ladite courbe du seuil CCFT avec l'axe NCD ;
k) détermination du retard d'ouverture ODinjx en tant que valeur de la somme déterminée à l'intersection.

2. Procédé selon la revendication 1, dans lequel NFST et/ou NCT sont déterminés à partir du signal de commutation d'injecteur.

3. Procédé selon la revendication 1 ou 2, dans lequel ledit temps de fermeture de la valve actionnée par solénoïde VCT est déterminé en analysant la tension aux bornes du solénoïde de la valve actionnée par solénoïde et en identifiant un instant de pointe de tension à partir d'un point d'inflexion.

4. Procédé selon l'une quelconque des revendications précédentes, comprenant l'enregistrement d'une courbe de référence de la valeur NCD en fonction de la somme de Ton, VCD et CCFT pour un injecteur de référence, et la fourniture d'une valeur affinée (*refined*) de retard d'ouverture « refined OD_injx » à partir de la valeur trouvée lors de l'étape i) et des données de la courbe de référence.

5. Procédé selon la revendication 4, dans lequel la valeur affinée de retard d'ouverture « refined OD_injx » est déterminée à l'aide de l'équation suivante :

$$\text{refined OD\_injx} = OD_{injx}\,(OD_{ref\_map} - \text{pseudo\_}OD_{ref\_map}),$$

où OD_{injx} est l'estimation initiale du retard d'ouverture trouvé à l'étape j) ;

OD_{ref_map} est une valeur enregistrée ou déterminée pour un injecteur de référence, représentant la somme (Ton + VCD +CCFT) pour une valeur nulle du NCD pour l'injecteur de référence ;
$pseudo\_OD_{ref\_map}$ est la valeur de la somme (Ton + VCD +CCFT) à la valeur seuil de CCFT du NCD par rapport à la courbe de référence.

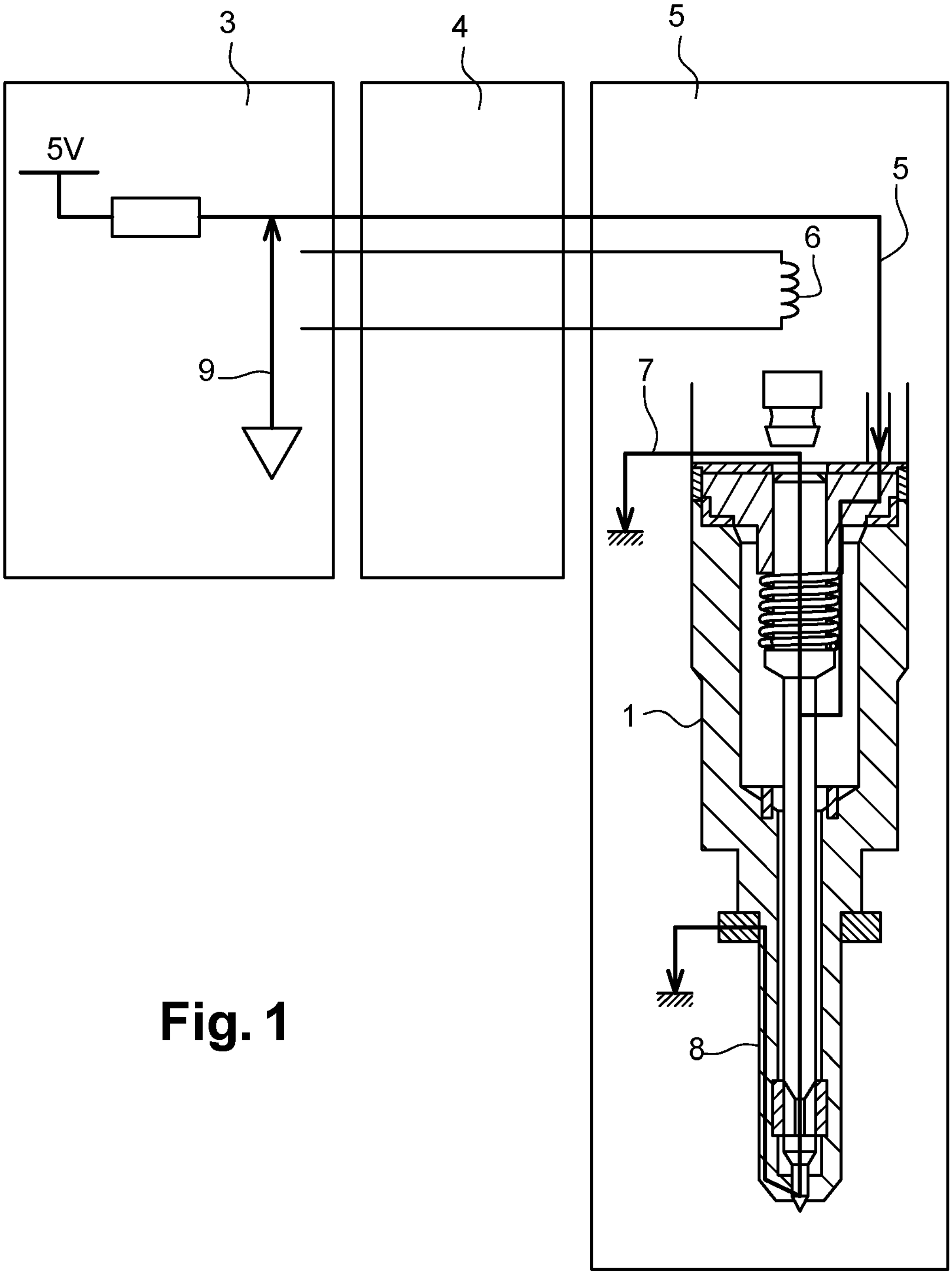


Fig. 1

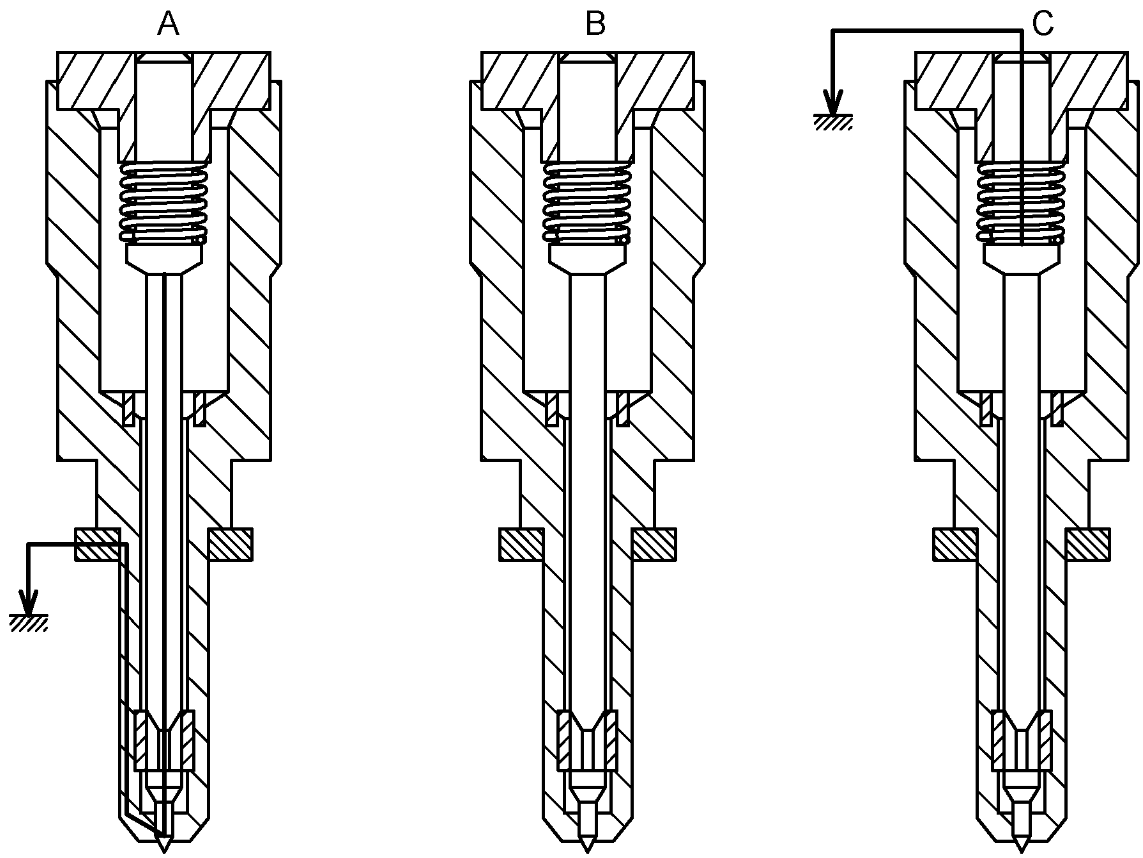


Fig. 2a Fig. 2b Fig. 2c

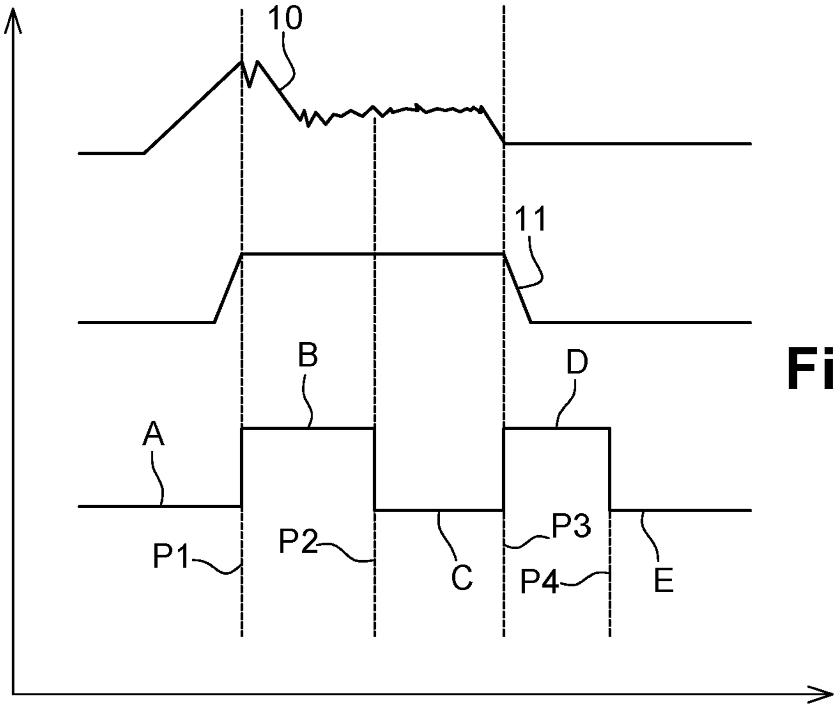


Fig. 3

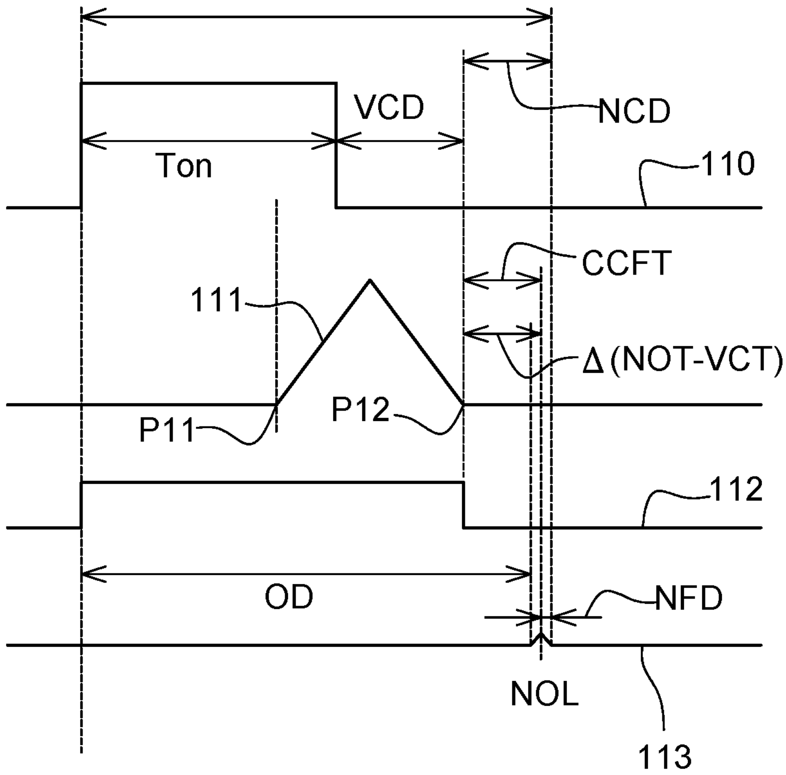

VCD
NCD
Ton
110
CCFT
111
Δ(NOT-VCT)
P11
P12
112
OD
NFD
NOL
113

Fig. 4

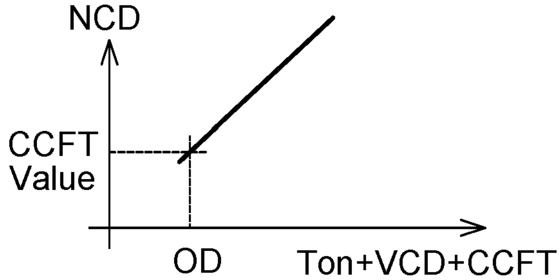
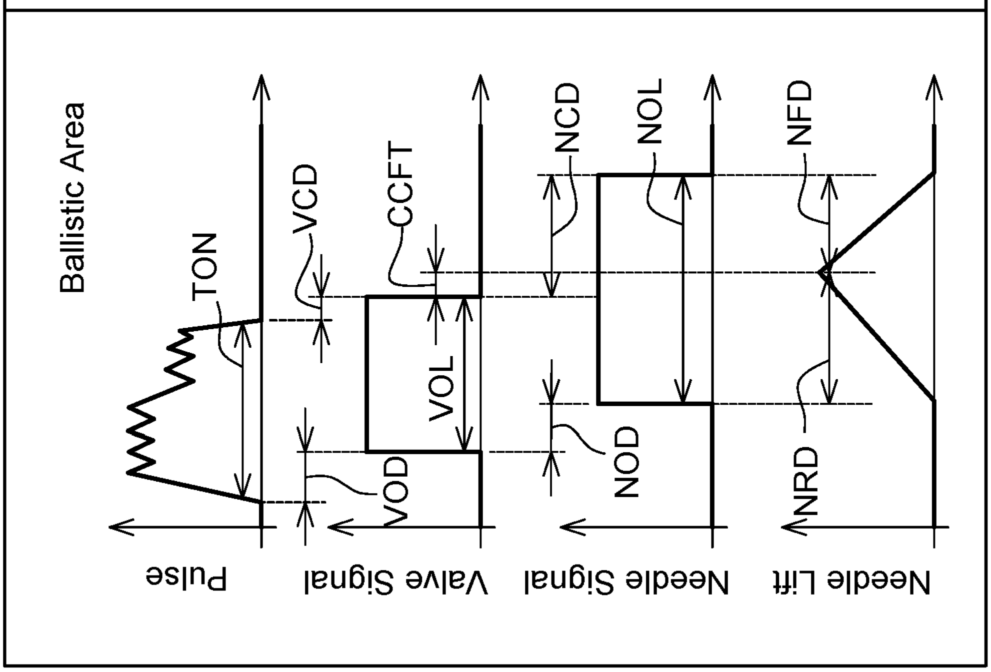
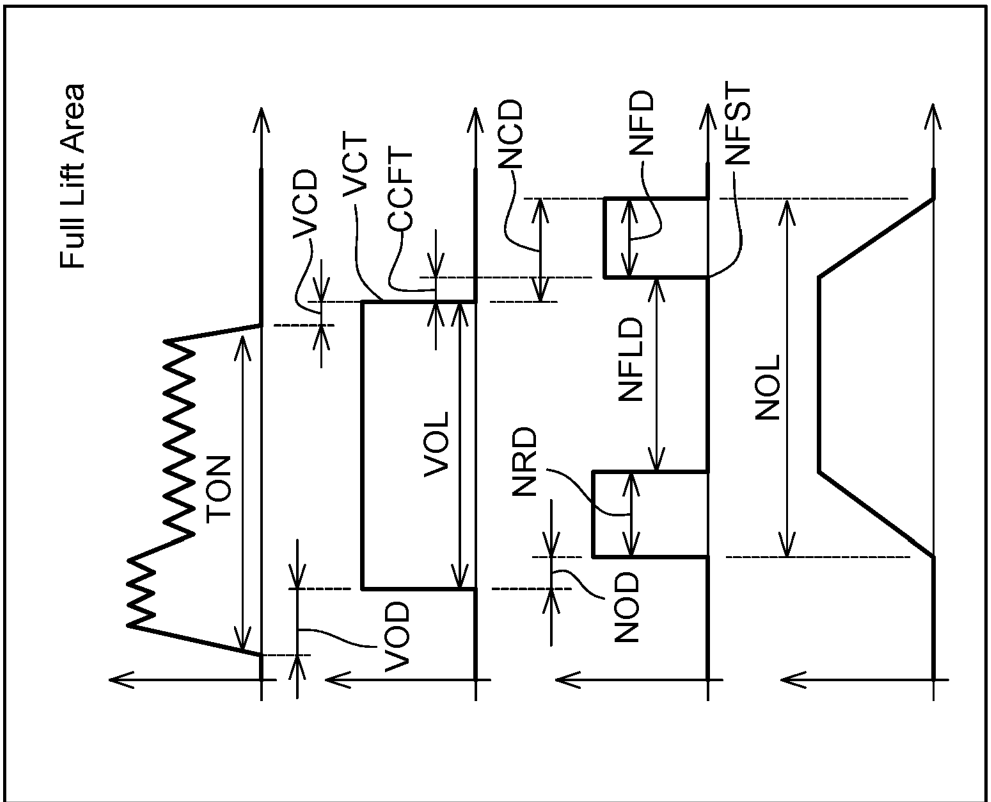

NCD
CCFT
Value
OD
Ton+VCD+CCFT

Fig. 5



Ballistic Area
Pulse
Valve Signal
Needle Signal
Needle Lift
TON
VCD
CCFT
VOL
VOD
NCD
NOL
NOD
NFD
NRD

Fig. 6



Full Lift Area
TON
VCD
VCT
CCFT
VOL
VOD
NCD
NFD
NFST
NRD
NFLD
NOD
NOL

Fig. 7

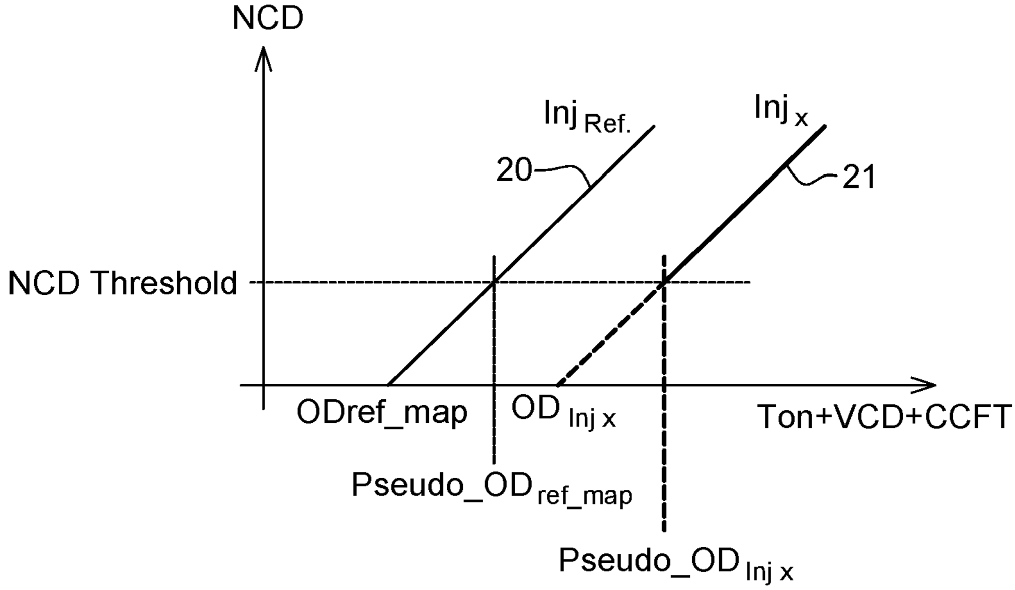

NCD
Inj Ref.
Inj x
20
21
NCD Threshold
ODref_map
OD Inj x
Ton+VCD+CCFT
Pseudo_OD ref_map
Pseudo_OD Inj x

Fig. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2013312709 A1 **[0005]**