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(54) **METHOD FOR DETECTING A SWITCHING POINT OF A SWITCHABLE SOLENOID VALVE, ELECTRONIC CIRCUIT, PUMP AND MOTOR VEHICLE**

VERFAHREN ZUR ERKENNUNG EINER SCHALTSTELLE EINES SCHALTBAREN MAGNETVENTILS, ELEKTRONISCHE SCHALTUNG, PUMPE UND KRAFTFAHRZEUG

PROCÉDÉ POUR DÉTECTER UN POINT DE COMMUTATION D'UNE SOUPAPE À SOLÉNOÏDE COMMUTABLE, CIRCUIT ÉLECTRONIQUE, POMPE ET VÉHICULE À MOTEUR

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Description

[0001] The invention is concerned with a method for detecting a switching point of a switchable solenoid valve. The switching point is the time point at which the valve reaches a closing state during a closing phase. The invention is also directed to an electronic circuit for controlling a switchable solenoid valve. The invention also comprises a pump for an injection system of a motor vehicle and a motor vehicle comprising the injection system.

[0002] One of the most used actuators for controlling the flow of a fluid is the solenoid valve. There are two main types of solenoid valves, the proportional valve and the digital valve. As an example, in diesel and gasoline common rail fuel injection systems, the rail pressure can be controlled by a digital inlet valve (DIV).

[0003] The DIV is a solenoid valve which closes the inlet valve when it is energized, i.e. when an electric current is driven through the solenoid of the valve for closing the valve against a force of a spring. During a currentless state, the valve will open and be kept in open position by the DIV spring until the solenoid is energized again. The current profile for the DIV is a peak current and a hold current control. The peak current provides an actuation energy for moving the valve from the open position into the closed position. The hold current generates the magnetic field for keeping the valve in the closed position.

[0004] US 2012/0167993 A1 describes a method for reducing a noise generated when closing the inlet valve of a fuel pressure system. The duration of the peak current for providing the actuation energy is varied. However, this method implies that it is known, how far the acceleration or in general the actuation energy may be reduced without causing a failure of the actuation.

[0005] US 8 245 693 B2 describes a method for reducing the noise in the closing state of an inlet valve of a high pressure injection system by reducing the amplitude of the peak current and at the same time letting the peak current flow for a longer time such that the velocity of the accelerated valve is reduced. This slows the pump down.

[0006] The switch time of the valve is a vital information for the precise fuel metering of a DIV. The pump delivery is varied by changing the closing position or switch point of the valve relative to the pump top dead center (TDC). This is illustrated in Fig. 4. Fig. 4 provides two diagrams. One diagram shows the movement of the piston of the valve, i.e. the piston lift PL over time t. The other diagram shows the current profile of a current I that is applied to the solenoid current. The piston may be driven by a crank such that instead of measuring time t, the crank angle may be used to describe the position of the piston. The piston moves between the top dead center TDC and the bottom dead center BDC. The example shown in Fig. 4 provides two full piston movements from TDC to TDC within a 360° turn of the crank. In other words, one pump cycle or actuation cycle or stroke (STRK) is performed within 180° crank angle (180° CRK) . Within one actuation cycle, the pump performs a suction phase SUC, a refluxing phase RFLX and a pumping phase PMP. For switching from the refluxing phase to the pumping phase, the valve is actuated by driving the electric current I through the solenoid of the valve, wherein the actuation is achieved by the peak current IP and (after the valve has reached the switching point SP, at which the valve reaches the closed state) the electric current I may be reduced to a hold current IH. For opening the valve again, the current I is switched off, such that a spring may open the valve, once the pressure of the fuel inside the pump is low enough.

[0007] In order to have the valve close precisely at the required position or switching point SP, the electronic circuit providing the control unit needs to know how long the valve needs to reach its closed position, i.e. the switching point SP, once the peak current IP is started at a current begin B. This duration from current begin B until the switching point SP, at which the valve is completely closed for the first time, is the switch time T of the valve.

[0008] The switch time T of valves can be different due to production tolerances, e.g. two valves show a different switch time T although both are having the same boundary conditions. Moreover, the switch time T can also be influenced by other boundary conditions, e.g. battery voltage and/or engine speed.

[0009] Without knowing the switch time T of the valve, the pump delivery can deviate from the required fuel delivery in a fuel injection system. Although this might still be compensated by the control unit in a steady operating point, in dynamic operating points or dynamic boundary conditions, i.e. extreme conditions, this could lead to a bad fuel pressure control performance. Moreover, if the switch time assumed by the control unit is different from the real switch time T, small fuel quantity delivery and full load ability could be negatively influenced.

[0010] Besides for the precise fuel delivery, the switch time T is also an important parameter to be controlled at the production end-of-line (EOL) . A certain minimum and maximum tolerance range is defined at the EOL to ensure the quality of DIVs produced. Without knowing the actual switch time T of the DIVs, it is impossible to maintain the quality of the valves produced.

[0011] Document DE 42 37 706 A1 describes a method for detecting when a valve reaches the switching point by evaluating the switching rate of a controller that controls the current which drives the valve.

[0012] Document US 2011/149458 A1 describes a method for continuously observing the time point when a valve reaches the closing state.

[0013] Document US 5,592,921 A teachers to observe the time duration between two switching events of a two-point controller for sensing the position of a valve.

[0014] Document US 5, 053, 911 A describes a method and an apparatus for electronically detecting when a solenoid has closed. Time durations of switching events may be evaluated and if the time duration of two successive switching events changes, it is assumed that a solenoid has closed.

[0015] Document US 2016/186707 A1 describes how a crank of a combustion engine may be linked with a piston of a high-pressure pump for driving same.

[0016] It is an object of the present invention, to provide means for detecting a switching point of a solenoid valve.

[0017] The object is solved by the subject matter of the independent claims. Additional aspects of the invention are described by the dependent claims, the following description and the figures.

[0018] The invention provides a method for detecting a switching point of a switchable solenoid valve, particularly a digitally solenoid valve. In a closing phase of an actuation cycle of the valve, an electric current is driven through the electric coil or solenoid of the valve for generating a closing movement of the valve. The closing phase is the phase during which the peak current is applied as described. The closing phase moves a valve disk or in general a closing element of the valve from an open position to a closed position against a force of a spring until the switching point is reached, i.e. the time point at which the valve finally reaches the closed state. In a valve, the current increase of the peak current can be so fast that the current has to be limited to such a current level that can be accepted by the control unit. This is achieved by a two point current control or bang-bang closed-loop current control. In other words, during the closing phase, a control unit or controller controls the current strength value of the electric current by switching on a voltage source, if the value is smaller than a lower threshold value, and switching off the voltage source, if the value is greater than an upper threshold value. Switching off the voltage source means that the solenoid is disconnected from the voltage source such that an increase of the current is prevented. However, the current may continue flowing due to the induction of the electric circuit, especially the solenoid. To this end, a freewheeling diode may be provided.

[0019] For detecting the switching point, a switching frequency at which the controller switches the voltage source on and off is determined and if the switching frequency fulfills a predefined closed state criterion, a signal is generated, wherein the signal signals that the valve reached the switching point. In other words, a change of current control frequency of the controller in the closing phase is detected. The current strength or the dynamic change of the current strength or the current level during closing phase is controlled via the described to point control method or bang-bang closed current control. It includes an upper current threshold value and a hysteresis, which results in the lower threshold value. By observing the current frequency during the bang-bang current control, a significant change in control frequency is detected at the switch point when the valve reaches its closed position.

[0020] The frequency is mainly influenced by the current gradient which is dependent on the circuit induction. During the closing phase, the valve (i.e. its closing element) is accelerated from its open position towards its closed position. In other words, the closing element or valve disk moves towards the solenoid, as it is attracted by the magnetic force of the solenoid. The pole distance is getting smaller as the valve is approaching the closed position. This has an influence on the circuit induction. A change in current gradient is however not only due to the change in pole distance of the magnetic poles, but also due to the sudden stop of the movement of the valve, when the closed position is hit or reached. Before the valve reaches its closed position, the valve is in a state of movement. The movement of the valve also has an impact on the current gradient, i.e. it slows the current change down. This effect stops, once the closed position is reached. This can be used as a feedback to detect the switching point. The necessary degree of relative change can be defined by the said closed state criterion. The closed state criterion can be derived by simple experiments.

[0021] The described method is a core element that can be used for several different applications. One application is the measurement of the described switch time. To this end, switching point data can be generated to describe the switching point as a time duration that is measured starting from a predefined starting point and ending at the switching point. The starting point is the described current begin B.

[0022] According to the invention, a relative change of a rotation angle or crank angle of a crank that drives the piston of the valve is measured. Again, the relative change of rotation angle is measured starting from the predefined starting point and ending at the switching point. The switching point data thus describe the switch time T of the valve.

[0023] The switching point data are saved in an electronic circuit of the controller or control unit of the valve for controlling future closing phases on the basis of the switching point data. In other words, the switching point data can be used to calibrate the electronic circuit of the valve.

[0024] The method is especially useful for calibrating a high-pressure pump of a fuel injection system of a motor vehicle. Correspondingly, as the valve an inlet valve of the high-pressure pump of the injection system of the motor vehicle is controlled. "High-pressure" especially means that the pump generates a pressure greater than 100 bar.

[0025] The invention also comprises further aspects that provide additional technical advantages.

[0026] The switching point data can be determined during an End-of-line calibration procedure after producing the valve. As was already described, this allows to individually calibrate each valve. Additionally or alternatively, the switching point data may be determined during a self-calibration procedure after the valve has been used for at least a predefined amount of time. As a valve changes its mechanical and/or magnetic and/or electric behavior during its lifetime, this allows for adapting the switching point data during operation of the valve. The described predetermined amount of time can be more than one week, especially more than one year.

[0027] The closed state criterion that is used to detect the switching point may comprise that the switching frequency that results during the closing phase is above a predefined frequency threshold. In other words, an absolute value can be provided and the switching frequency is compared to this absolute value. Additionally or alternatively a relative or absolute change of the switching frequency compared to a switching frequency of a preceding actuation cycle may be detected and the closed state criterion may comprise that this relative or absolute change is greater than a predefined change threshold value. In other words, a step or jump of the switching frequency is detected with regard to a preceding actuation cycle. Determining the relative change provides the advantage that the method does not have to be adapted to a value of the switching frequency that is applied by the controller in the case that the valve is not closed yet.

[0028] For measuring the switching frequency, one aspect of the invention comprises sensing a current strength signal of the electric current and determining a time difference between at least two predefined characteristic points of the signal. For example, a time difference between peaks of the signal can be measured or determined. This can be repeated for each measurement.

[0029] For performing the inventive method, the invention also provides an electronic circuit for controlling a switchable solenoid valve. The electronic circuit is designed to perform an embodiment of the inventive method as described. The electronic circuit may comprise a microcontroller or a microprocessor for performing the steps of the method. The electronic circuit may provide said controller.

[0030] The invention also comprises a pump for a fuel injection system of a motor vehicle, wherein the pump comprises the described switchable solenoid valve, particularly a digital inlet valve, and an embodiment of the inventive electronic circuit.

[0031] Finally, the invention is concerned with a motor vehicle comprising an internal combustion engine with an injection system. The vehicle provides an injection system that comprises an embodiment of the inventive pump with the described electronic circuit.

[0032] In the following an exemplary implementation of the invention is described. The figures show:

Fig. 1 a schematic illustration of an embodiment of the inventive motor vehicle;

Fig. 2 a diagram illustrating a current strength signal of an electric current of a solenoid of a pump of the motor vehicle of Fig. 1;

Fig. 3 a diagram illustrating a switching frequency of a controller of a valve of the pump; and

Fig. 4 a diagram illustrating the switch time of the valve.

[0033] The embodiment explained in the following is a preferred embodiment of the invention. However, in the embodiment, the described components of the embodiment each represent individual features of the invention which are to be considered independently of each other and which each develop the invention also independently of each other and thereby are also to be regarded as a component of the invention in individual manner or in another than the shown combination. Furthermore, the described embodiment can also be supplemented by further features of the invention already described.

[0034] In the figures elements that provide the same function are marked with identical reference signs.

[0035] Fig. 1 shows a motor vehicle 10 that can be, e.g., a passenger vehicle or a freight vehicle. The vehicle may comprise an internal combustion engine 11 that may be operated on the basis of fuel 12 from a fuel tank 13. The fuel 12 may be pumped from the fuel tank 13 to the combustion engine 11 by a pump 14. The pump 14 may comprise a switchable solenoid valve 15, e.g. a digital inlet valve, DIV, with a closing element or valve disk 16 and an electric coil or solenoid 18. An electric current I for the solenoid 18 may be controlled by an electronic circuit 17 that provides a control unit or controller 17' for switching the current I. The operation of the valve 15 can be coordinated with the rotation of a crank 20 by measuring a crank angle 21 and switching current I according to crank angle 21. Crank angle 21 may be measured using a sensor 21'. Crank 20 moves a piston 22 for a pumping movement 23 for pumping the fuel 12 from a low pressure side 24 to a high-pressure side 25 where the fuel is injected by a fuel injection system. Outlet valve 26 may be a passive valve, e.g. a check valve, wherein the inlet valve is provided by the solenoid valve 15 with its valve disk 16. For closing the valve 15, current I is driven through solenoid 18 such that a pin 27 that holds the valve disk 16 is attracted against a spring force of a spring 28 towards a pole piece 29 and an armature such that valve disk 16 is moved from an open position 31 to a closed position 32. Current I may be provided by a voltage source U.

[0036] Switching off voltage source U results in an exponential decrease of current I. Once the spring force of the spring 28 is stronger than the magnetic field of solenoid 18, the valve 16 is moved back from closed position 32 to open position 31. This completes a full actuation cycle or pump cycle.

[0037] Fig. 2 shows a current strength signal 33 of current I over time t or over crank angle 21 (CRK) . During a pump cycle or actuation cycle 34 during an closing phase 35 a peak current 36 is provided that delivers an overall actuation energy for moving valve disk 16 from the open position 31 to the closed position 32. Once valve disk 16 is in closed position 32, a hold phase 37 follows with a hold current 38. After holding phase 37 an opening phase O may follow in which current I is allowed to fall to zero such that spring 28 may open valve 16 again.

[0038] Controller 17' controls current I during closing phase 35 using a bang-bang control method by switching on the voltage source U, if the value of current I is smaller than a lower threshold value 39, and switching off voltage source U, if the value of current I is greater than an upper threshold value 40.

[0039] Electronic circuit 17 may measure a time difference 41 between e.g. two consecutive peaks 42 of the signal 33. The inverse value of time difference 41 yields a switching frequency F, i.e. the frequency or rate at which controller 17' switches current I. The switching frequency F is dependent on the induction value of the magnetic system of solenoid 18 and the magnetic materials and their position within pump 15. It is also dependent on the fact whether elements of the magnetic circuit of the valve 16 are in motion or not. In other words, the position and motion of valve disk 16 and pin 27 influences switching frequency F.

[0040] Fig. 3 shows, how this can be used to detect the switching point SP during closing phase 35. During several consecutive measurements MS of the switching frequency F (measurement N, N+1, N+2, N+3), the switching frequency may vary due to the changing position of the valve disk 16 and pin 27. Fig. 3 shows that measurement 43 (N+2) yields a switching frequency F where a change of the value of the induction of the magnetic circle results and a relative change 44 of the switching frequency F from the preceding measurement 45 (N+1) to measurement N+2 is greater than a predefined threshold value 46. Threshold value 46 is a closed position criterion that is fulfilled in measurement N+2. In other word, switching point SP is reached.

[0041] Thus the time point or the crank angle at this parameter value used for generating switching point data that may describe the switch time T.

[0042] Thus, by measuring the control frequency or switching frequency before and after the switching point, a difference can be detected. This is a low-cost strategy to detect the switch point of a solenoid valve, especially a digital solenoid valve.

[0043] Overall, the example shows how the invention provides method for detecting a switching point of a switchable solenoid valve.

Claims

1. Method for detecting a switching point (SP) of a switchable solenoid valve (15), wherein in a closing phase of the valve (15) an electric current (I) is driven through the solenoid (18) of the valve (15) for generating a closing movement of the valve (15) against a force of a spring (28) until a switching point (SP) is reached at which the valve (15) finally reaches a closed state, wherein during the closing phase (37) a controller (17') of an electronic circuit (17) controls a current strength value of the electric current (I) by switching on a voltage source (U), if the value is smaller than a lower threshold value (39), and switching off the voltage source (U), if the value is greater than an upper threshold value (40), and wherein for detecting the switching point (SP) a switching frequency (F) at which the controller (17') switches the voltage source (U) is determined and if the switching frequency (F) fulfills a predefined closed state criterion (46), a signal is generated, wherein the signal signals that the valve (15) reached the switching point (SP), wherein as the valve (15) an inlet valve of a high pressure pump (14) of an injection system of a motor vehicle (10) is controlled and the operation of the valve (15) is coordinated with the rotation of a crank (20) by measuring a crank angle (21) and by switching the current (I) according to the crank angle (21), wherein the crank angle (21) is measured using a sensor (21') and wherein the crank (20) moves a piston (22) of the pump (14) for a pumping movement (23) between a top dead center (TDC) and a bottom dead center (BDC) for pumping fuel (12) from a low-pressure side (24) to a high-pressure side (25) where the fuel (12) is injected by a fuel injection system and wherein a pump delivery is varied by changing the switching point (SP) of the valve relative to the pump top dead center (TDC), wherein in order to have the valve close precisely at the required position or switching point (SP) the electronic circuit (17) providing the control unit (17') needs to know the switch time (T) of the valve (15), which is a duration from current begin (B) until the switching point (SP), at which the valve is completely closed for the first time, and wherein
switching point data are generated that describe the switching point (SP) as a relative change of a rotation angle of the crank (20) that drives the piston (21), wherein the relative change of rotation angle is measured starting from a predefined starting point, which is the current begin (B), and ending at the switching point (SP), and wherein
the switching point data are saved in the electronic circuit (17) of the valve (15) for controlling future closing phases on the basis of the switching point data.

2. Method according to claim 1, wherein the switching point data are determined during an end-of-line calibration procedure after producing the valve (15) and/or during a self-calibration procedure after the valve has been used for at least a predefined amount of time.

3. Method according to any of the preceding claims, wherein the closed state criterion (46) comprises that the switching frequency (F) is above a predefined frequency threshold value and/or that the switching frequency (F) changes by a relative or absolute change (44) greater than a predefined change

threshold value (46).

4. Method according to any of the preceding claims, wherein the switching frequency (F) is measured by sensing a current strength signal (33) of the electric current (I) and determining a time difference (41) between at least two predefined characteristic points (42) of the signal (33).

5. Electronic circuit (17) for controlling a switchable solenoid valve (15), wherein the electronic circuit (17) is configured to perform a method according to any of the preceding claims.

6. Pump (14) for an injection system of a motor vehicle (10), wherein the pump (14) comprises a switchable solenoid valve (15) and an electronic circuit (17) according to claim 5.

7. Motor vehicle (10) comprising an internal combustion engine (11) with a fuel injection system that provides a pump (14) according to claim 6.

Patentansprüche

1. Verfahren zur Erkennung eines Schaltpunkts (SP) eines schaltbaren Magnetventils (15), wobei in einer Schließphase des Ventils (15) ein elektrischer Strom (I) durch das Solenoid (18) des Ventils (15) getrieben wird, um eine Schließbewegung des Ventils (15) gegen eine Kraft einer Feder (28) zu erzeugen, bis ein Schaltpunkt (SP) erreicht ist, bei dem das Ventil (15) schließlich einen geschlossenen Zustand erreicht, wobei während der Schließphase (37) eine Steuereinheit (17') einer elektronischen Schaltung (17) einen Stromstärkewert des elektrischen Stromes (I) steuert durch Einschalten einer Spannungsquelle (U), falls der Wert kleiner als ein unterer Schwellenwert (39) ist, und Ausschalten der Spannungsquelle (U), falls der Wert größer als ein oberer Schwellenwert (40) ist, und wobei zur Erkennung des Schaltpunkts (SP) eine Schaltfrequenz (F), bei der die Steuereinheit (17') die Spannungsquelle (U) schaltet, bestimmt wird und, falls die Schaltfrequenz (F) ein vordefiniertes Kriterium (46) für den geschlossenen Zustand erfüllt, ein Signal erzeugt wird, wobei das Signal signalisiert, dass das Ventil (15) den Schaltpunkt (SP) erreicht hat, wobei als Ventil (15) ein Einlassventil einer Hochdruckpumpe (14) eines Einspritzsystems eines Kraftfahrzeuges (10) gesteuert wird und der Betrieb des Ventils (15) mit der Drehung einer Kurbel (20) durch Messen eines Kurbelwinkels (21) und durch Schalten des Stromes (I) gemäß dem Kurbelwinkel (21) koordiniert wird, wobei der Kurbelwinkel (21) unter Verwendung eines Sensors (21') gemessen wird und wobei die Kurbel (20) einen Kolben (22) der Pumpe (14) zum Zwecke einer Pumpbewegung (23) zwischen einem oberen Totpunkt (TDC) und einem unteren Totpunkt (BDC) zum Pumpen von Kraftstoff (12) von einer Niederdruckseite (24) zu einer Hochdruckseite (25), wo der Kraftstoff (12) durch ein Kraftstoffeinspritzsystem eingespritzt wird, bewegt und wobei eine spezifische Förderarbeit der Pumpe durch Ändern des Schaltpunkts (SP) des Ventils relativ zum oberen Totpunkt (TDC) der Pumpe variiert wird, wobei, um das Ventil genau an der erforderlichen Position oder Schaltpunkts (SP) schließen zu lassen, die elektronische Schaltung (17), die die Steuereinheit (17') bereitstellt, die Schaltzeit (T) des Ventils (15) kennen muss, die eine Zeitdauer vom Beginn des Stromes (B) bis zum Schaltpunkt (SP), bei dem das Ventil zum ersten Mal vollständig geschlossen wird, ist, und wobei
Schaltstellendaten erzeugt werden, die der Schaltpunkt (SP) als eine relative Änderung eines Drehwinkels der Kurbel (20), die den Kolben (22) antreibt, beschreiben, wobei die relative Änderung des Drehwinkels beginnend an einem vordefinierten Startpunkt, der der Beginn des Stromes (B) ist, und endend an dem Schaltpunkt (SP) gemessen wird, und wobei die Schaltstellendaten in der elektronischen Schaltung (17) des Ventils (15) zum Zwecke der Steuerung zukünftiger Schließphasen auf der Grundlage der Schaltstellendaten gespeichert werden.

2. Verfahren nach Anspruch 1, wobei die Schaltstellendaten während einer End-of-Line-Kalibrierprozedur nach der Produktion des Ventils (15) und/oder während einer Selbstkalibrierprozedur, nachdem das Ventil mindestens eine vordefinierte Zeitdauer lang verwendet worden ist, bestimmt werden.

3. Verfahren nach einem der vorangehenden Ansprüche, wobei das Kriterium (46) für den geschlossenen Zustand umfasst, dass die Schaltfrequenz (F) über einem vordefinierten Frequenzschwellenwert liegt und/oder dass sich die Schaltfrequenz (F) um eine relative oder absolute Änderung (44) ändert, die größer als ein vordefinierter Änderungsschwellenwert (46) ist.

4. Verfahren nach einem der vorangehenden Ansprüche, wobei die Schaltfrequenz (F) durch Abfühlen eines Stromstärkesignals (33) des elektrischen Stromes (I) und Bestimmen einer Zeitdifferenz (41) zwischen mindestens zwei vordefinierten charakteristischen Punkten (42) des Signals (33) gemessen wird.

5. Elektronische Schaltung (17) zur Steuerung eines schaltbaren Magnetventils (15), wobei die elektronische Schaltung (17) so konfiguriert ist, dass sie ein Verfahren nach einem der vorangehenden Ansprüche durchführt.

6. Pumpe (14) für ein Einspritzsystem eines Kraftfahrzeuges (10), wobei die Pumpe (14) ein schaltbares Magnetventil (15) und eine elektronische Schaltung (17) nach Anspruch 5 umfasst.

7. Kraftfahrzeug (10), umfassend eine Verbrennungskraftmaschine (11) mit einem Kraftstoffeinspritzsystem, das eine Pumpe (14) nach Anspruch 6 bereitstellt.

Revendications

1. Procédé pour détecter un point de commutation (SP) d'une soupape à solénoïde commutable (15), un courant électrique (I) étant appliqué au solénoïde (18) de la soupape (15), lors d'une phase de fermeture de la soupape (15), pour générer un mouvement de fermeture de la soupape (15) contre une force d'un ressort (28) jusqu'à ce qu'un point de commutation (SP) soit atteint, auquel la soupape (15) atteint définitivement un état fermé, lors de la phase de fermeture (37), un contrôleur (17') d'un circuit électronique (17) commandant une valeur d'intensité de courant du courant électrique (I) en allumant une source de tension (U) si la valeur est inférieure à une valeur de seuil inférieure (39), et en éteignant la source de tension (U) si la valeur est supérieure à une valeur de seuil supérieure (40), une fréquence de commutation (F) à laquelle le contrôleur (17') commute la source de tension (U) étant déterminée pour détecter le point de commutation (SP) et, si la fréquence de commutation (F) remplit un critère d'état fermé prédéfini (46), un signal étant généré, le signal indiquant que la soupape (15) a atteint le point de commutation (SP),
la soupape (15) commandée étant une soupape d'admission d'une pompe à haute pression (14) d'un système d'injection d'un véhicule à moteur (10) et l'actionnement de la soupape (15) étant coordonnée avec la rotation d'un vilebrequin (20) en mesurant un angle de vilebrequin (21) et en commutant le courant (I) conformément à l'angle de vilebrequin (21), l'angle de vilebrequin (21) étant mesuré en utilisant un capteur (21') et le vilebrequin (20) déplaçant un piston (22) de la pompe (14) pour un mouvement de pompage (23) entre un point mort haut (TDC) et un point mort bas (BDC) pour pomper du carburant (12) d'un côté à basse pression (24) vers un côté à haute pression (25) où le carburant (12) est injecté par un système d'injection de carburant et un débit de pompe étant varié en changeant le point de commutation (SP) de la soupape par rapport au point mort haut de la pompe (TDC), le circuit électronique (17) fournissant l'unité de commande (17') ayant besoin de connaître le temps de commutation (T) de la soupape (15) afin que la soupape soit fermée précisément à la position requise ou au point de commutation (SP), lequel temps est une durée à partir du début du courant (B) jusqu'au point de commutation (SP), auquel la soupape est complètement fermée pour la première fois, et
des données de point de commutation étant générées, décrivant le point de commutation (SP) comme un changement relatif d'un angle de rotation du vilebrequin (20) qui entraîne le piston (22), le changement relatif de l'angle de rotation étant mesuré en partant d'un point de départ prédéfini, qui est le début du courant (B), et en se terminant au point de commutation (SP), et les données de point de commutation étant enregistrées dans le circuit électronique (17) de la soupape (15) pour commander des phases de fermeture futures, sur la base des données de point de commutation.

2. Procédé selon la revendication 1, les données de point de commutation étant déterminées pendant une procédure d'étalonnage fin de ligne après la production de la soupape (15) et/ou pendant une procédure d'auto-étalonnage après que la soupape a été utilisée pendant au moins une période de temps prédéfinie.

3. Procédé selon l'une quelconque des revendications précédentes, le critère d'état fermé (46) comprenant le fait que la fréquence de commutation (F) est supérieure à une valeur de seuil de fréquence prédéfinie et/ou le fait qu'un changement relatif ou absolu (44) de la fréquence de commutation (F) est supérieur à une valeur de seuil de changement prédéfinie (46).

4. Procédé selon l'une quelconque des revendications précédentes, la fréquence de commutation (F) étant mesurée par la détection d'un signal d'intensité de courant (33) du courant électrique (I) et par la détermination d'une différence temporelle (41) entre au moins deux points caractéristiques prédéfinis (42) du signal (33).

5. Circuit électronique (17) pour commander une soupape à solénoïde commutable (15), le circuit électronique (17) étant conçu pour exécuter un procédé selon l'une quelconque des revendications précédentes.

6. Pompe (14) pour un système d'injection d'un véhicule à moteur (10), la pompe (14) comprenant une soupape à solénoïde commutable (15) et un circuit électronique (17) selon la revendication 5.

7. Véhicule à moteur (10) comprenant un moteur à combustion interne (11) avec un système d'injection de carburant qui fournit une pompe (14) selon la revendication 6.

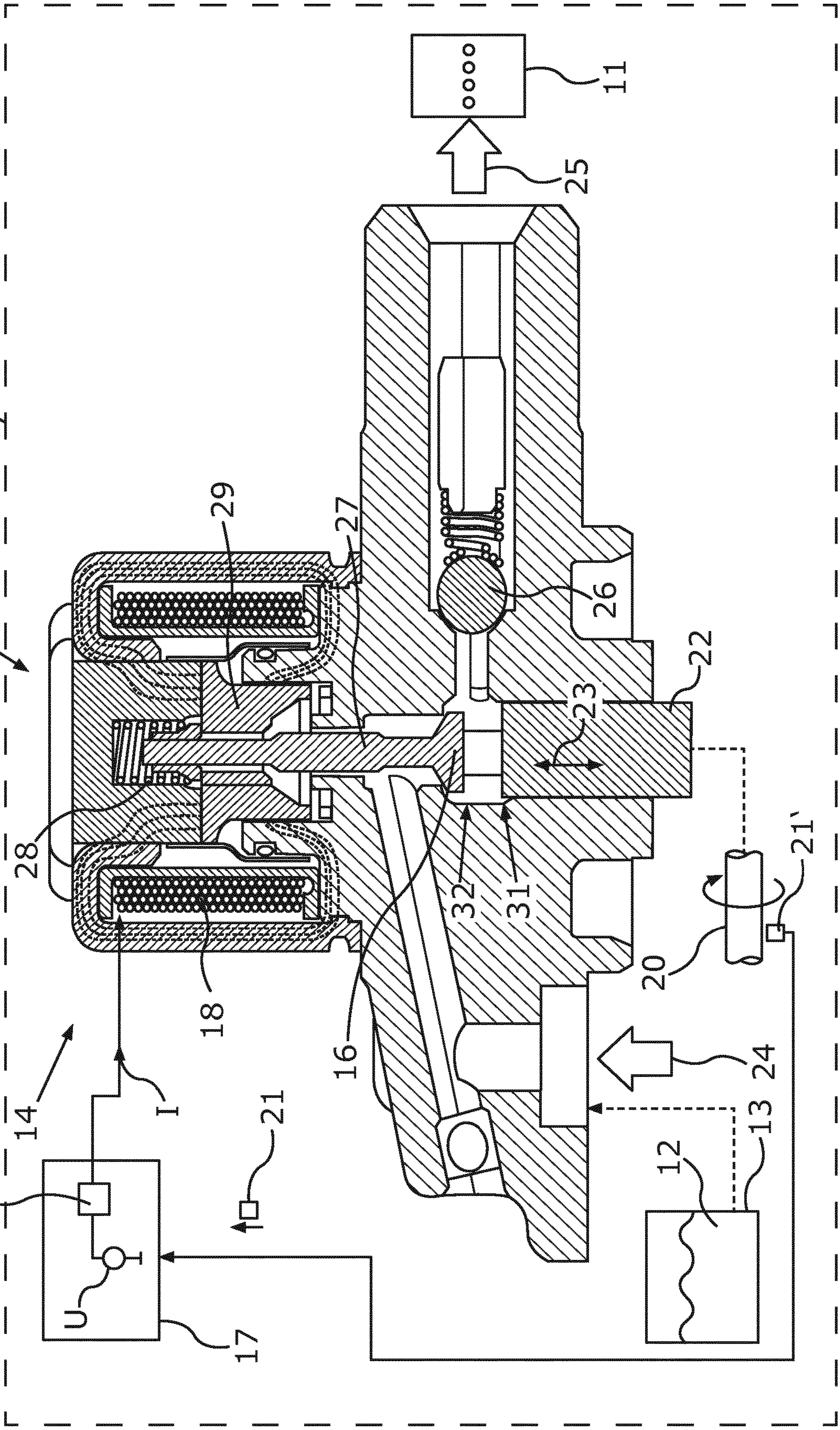

Fig.1

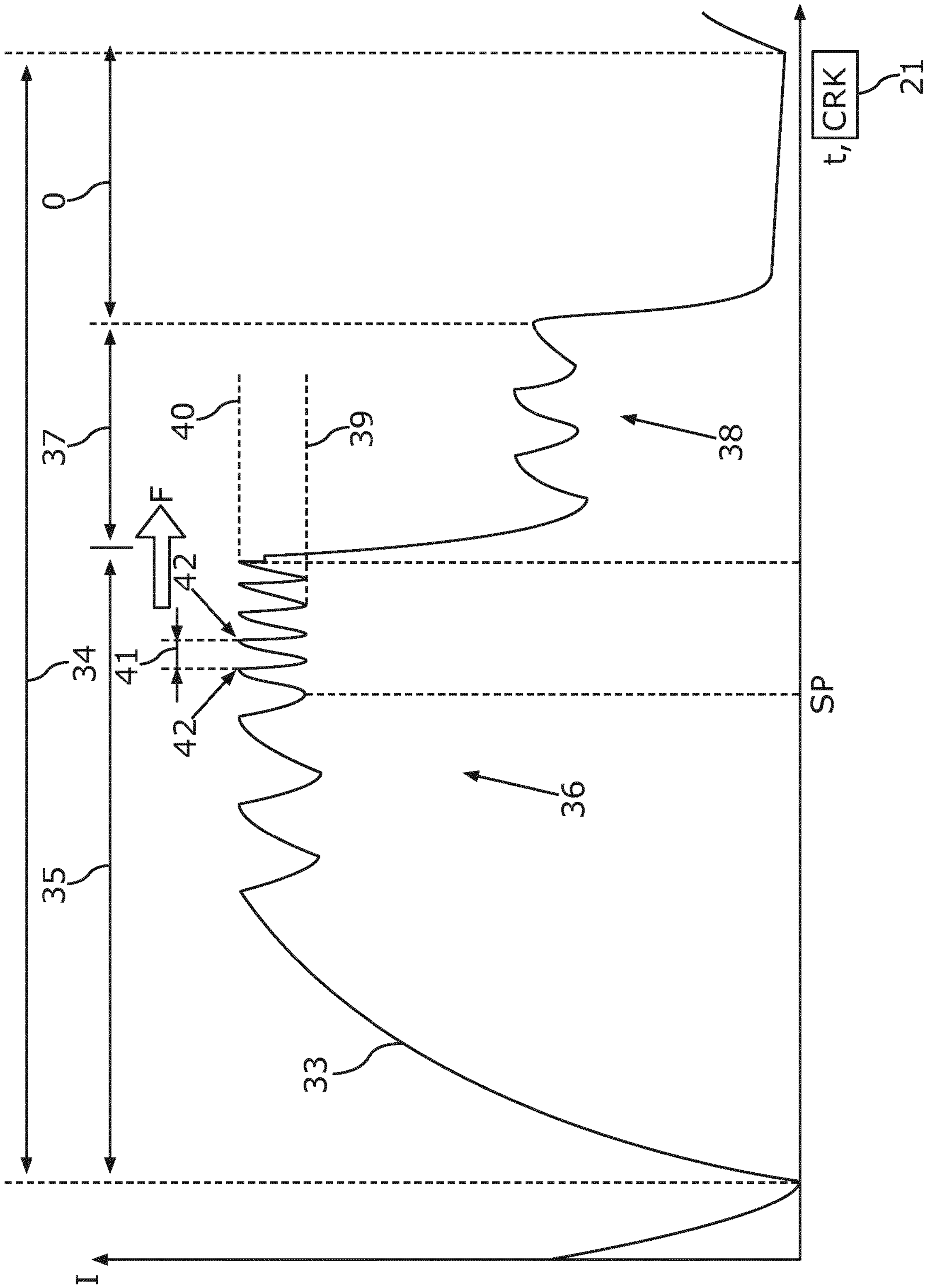

Fig.2

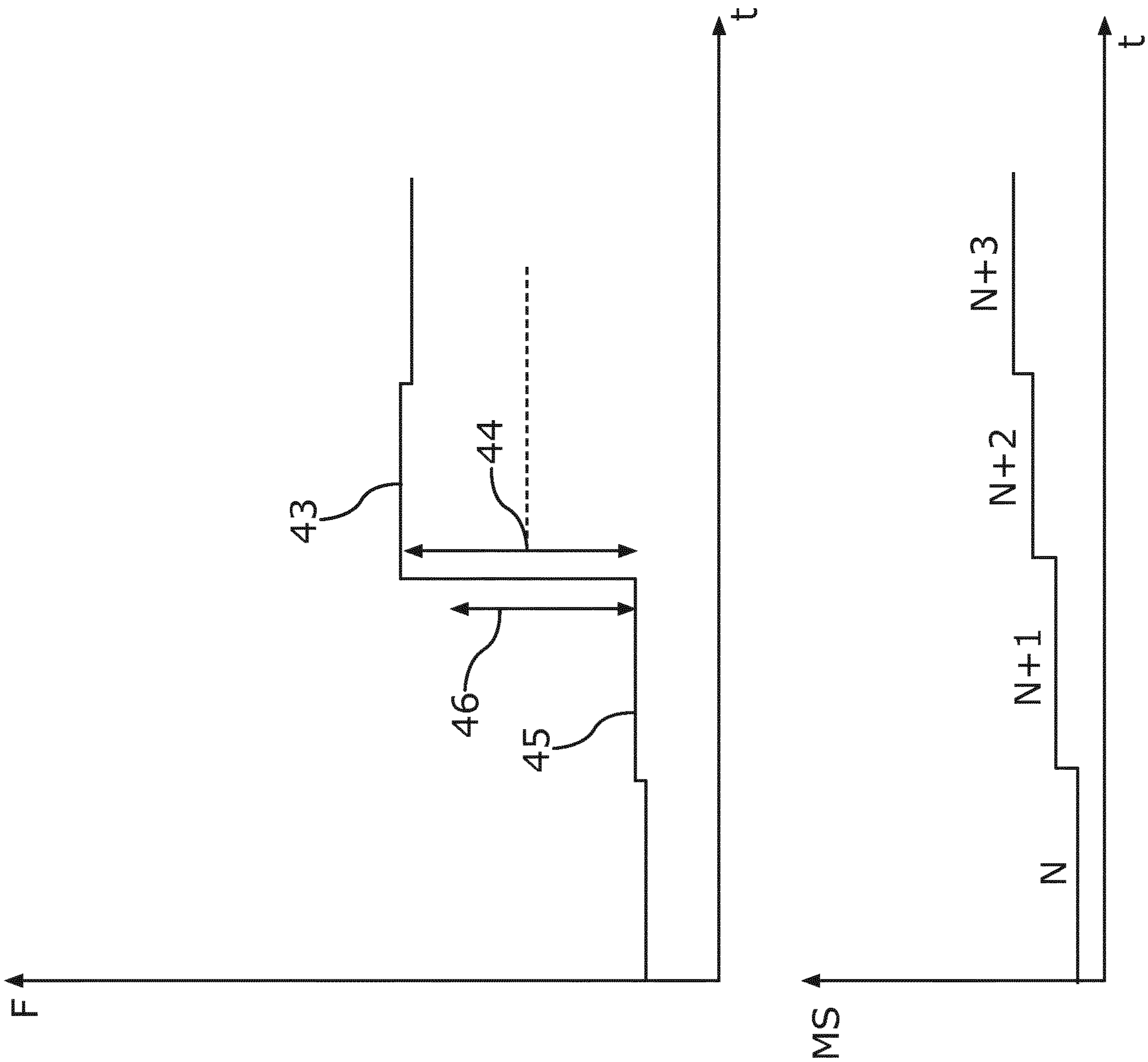

Fig.3

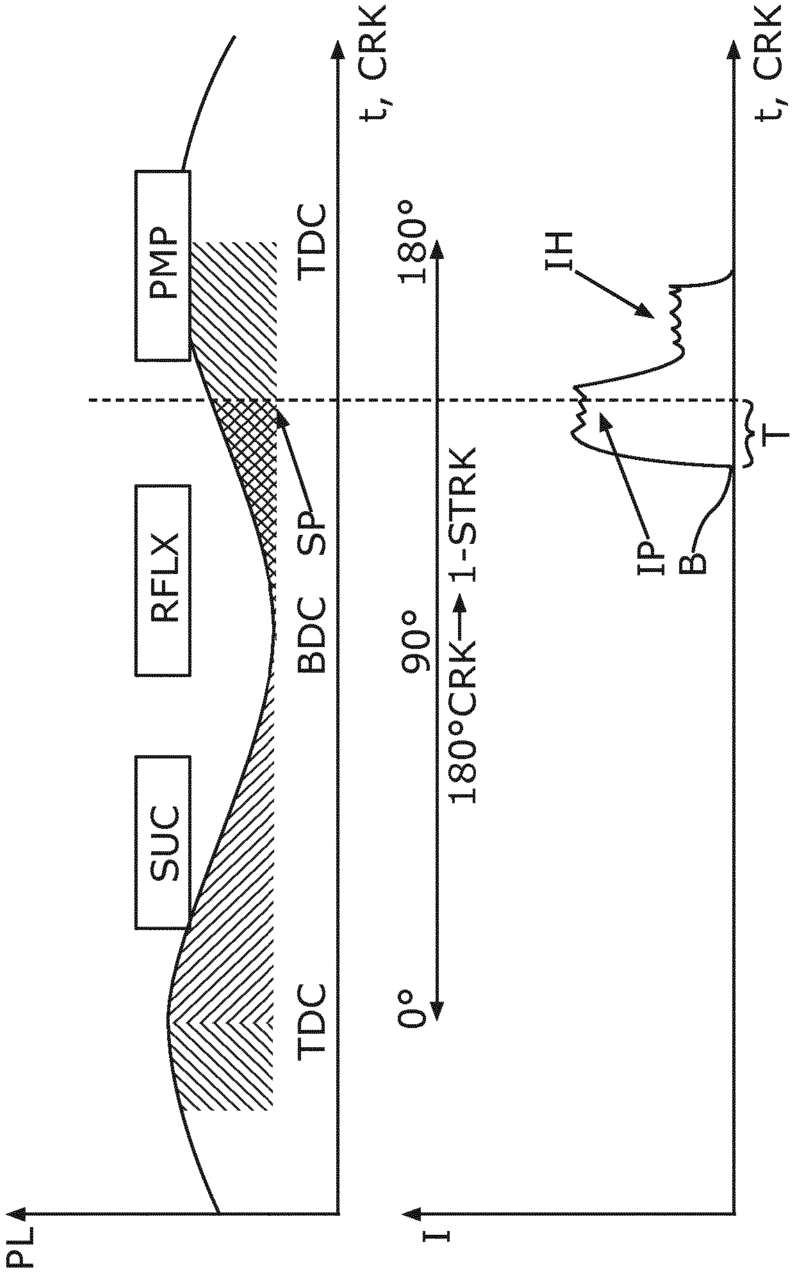
PL
PMP
RFLX
SUC
TDC
BDC
SP
TDC
t, CRK
0°
90°
180°
180°CRK⟶ 1-STRK
I
IH
IP
B
T
t, CRK

Fig.4

REFERENCES CITED IN THE DESCRIPTION

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