ORIGINAL

ABSTRACT

METHOD AND CONTROL DEVICE FOR OPERATING A VALVE

The present subject matter describes a method for operating a valve (18a) actuated by means of an actuator (26, 30), in particular a fuel injection valve of an internal combustion engine (10) of a motor vehicle. The actuator (26, 30) is actuated by means of an actuating current (I) having an actuating duration (ET). The actuating duration (ET) is formed as a function of a target value (t2*) for a closing delay time (t2) of the valve (18a), characterizing a time differential between an end (tET1) of the actuating duration (ET) and a closing time point (ts) of the valve (18a).

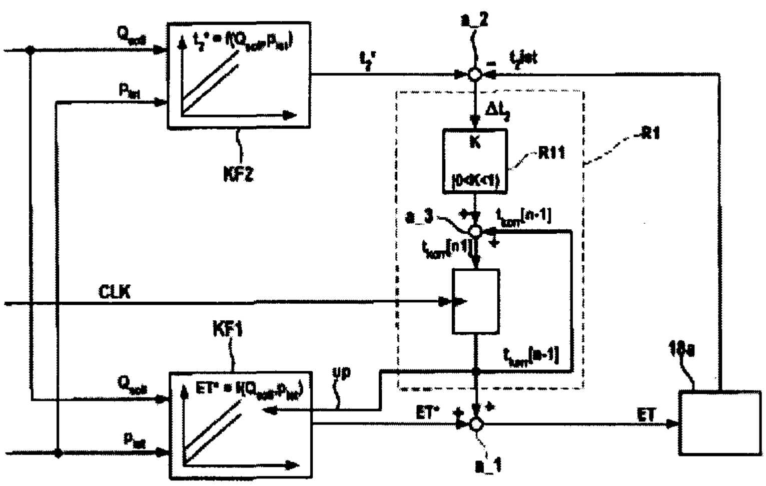

Fig. 4a

I/We claim:

1. A method for operating a valve (18a) actuated by means of an actuator (26, 30), in particular a fuel injection valve of an internal combustion engine (10) of a motor vehicle, wherein the actuator (26, 30) is actuated by means of an actuating parameter (I) comprising an actuating duration (ET);

characterized in that, the method comprising:

forming the actuating duration (ET) as a function of a target value (t2*) for a closing delay time (t2) of the valve (18a), characterizing a time differential between an end (tET1) of the actuating duration (ET) and a closing time point (ts) of the valve (18a);

determining an actual value (t2ist) of the closing delay time (t2), particularly determining in a measurement technological manner;

forming an actuation variable (Δt2, Δt) between the target value (t2*) and the actual value (t2ist) for the closing delay time (t2); and

modifying the target value (ET*) for the actuation duration (ET) as a function of the actuation variable (Δt2), wherein the actuation variable (Δt2) is multiplied with a feedback factor (K) having a value range of $K = 0$ to $K = 2$, particularly $K = 1$.

2. The method as claimed in claim 1, the modifying the target value (ET*) for the actuation duration (ET) is carried out as a function of the target value (t2*) for the closing delay time (t2) in order to obtain the actuation duration (ET).

3. The method as claimed in claim 2, further comprising determining both the target value (t2*) for the closing delay time (t2) and the target value (ET*) for the actuation duration (ET) as a function of a target injection quantity (Q_{soll}) and at least an operating parameter of the valve (18a), in particular as a function of a fuel pressure (pist).

4. The method as claimed in claim 1, wherein a correction parameter for modification of the target value (ET*) for the actuation duration (ET) is configured by means of an actuation/control structure (R1, R2) of the actuation variable (Δt2), wherein the control/actuation structure (R1, R2) in particular has an actuator/controller as an integral part.

5. The method as claimed in claim 4, wherein during the configuration of the actuation variable (Δt), the target value (ET*) for the actuation duration (ET), in particular weighted

about a preset weight factor (G1), is considered, in particular by addition of the target value (ET*) weighted about the weight factor (G1) to the target value (t2*) for the closing delay time (t2).

6. The method as claimed in one of the preceding claims, wherein the method is used for the operation of valves (18a), and wherein one component (28) driven by the actuator (26, 30), in particular a valve needle (28), at least partially carries out a ballistic trajectory due to actuation provided from the actuation current (I).

7. A control device (22) for operating a valve (18a) actuated by means of an actuator (26, 30), in particular a fuel injection valve of an internal combustion engine (10) of a motor vehicle;

characterized in that,

the control device (22) is configured for execution of the method as claimed in one of the preceding claims.

8. A computer program with program code means, to execute a method as claimed in one of the claims 1 to 6, when the computer program is executed in a computer or a corresponding computing unit, in particular in the control device (22) as claimed in claim 7.

9. A computer program product with a program code means, which is stored on a computer readable medium data carrier, executes a method as claimed in one of the claims 1 to 6, when the computer program is executed on a computer or a corresponding computing unit, in particular in the control device (22) as claimed in claim 7.

Dated this 19th day of January 2012

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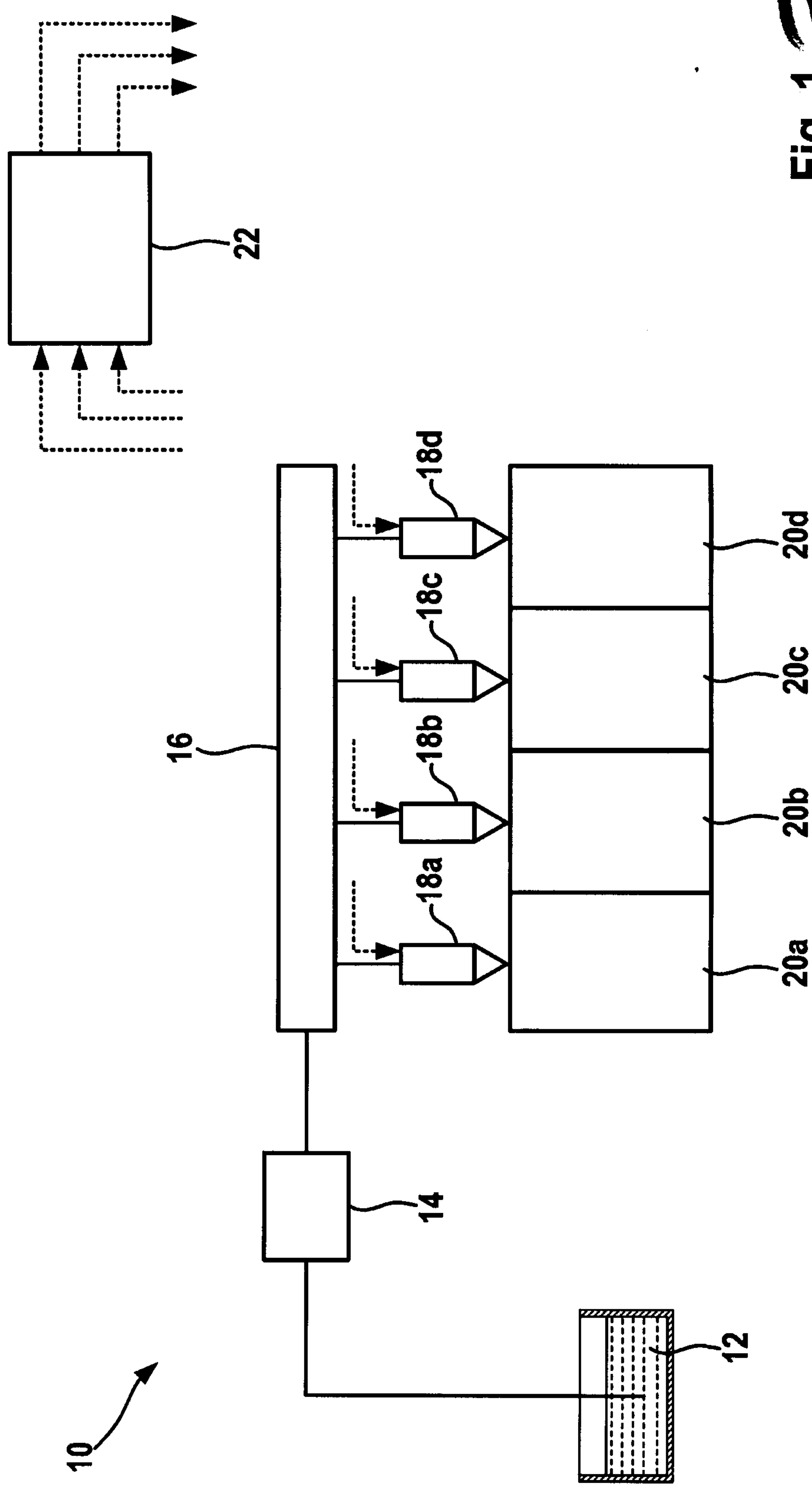
AGENT FOR THE APPLICANT

To
The Controller of Patents
The Patent office at New Delhi

Applicant(s) Name: **ROBERT BOSCH GmbH** Sheet No.: 1

Application No.: Total No. of Sheets: 7

Fig. 1



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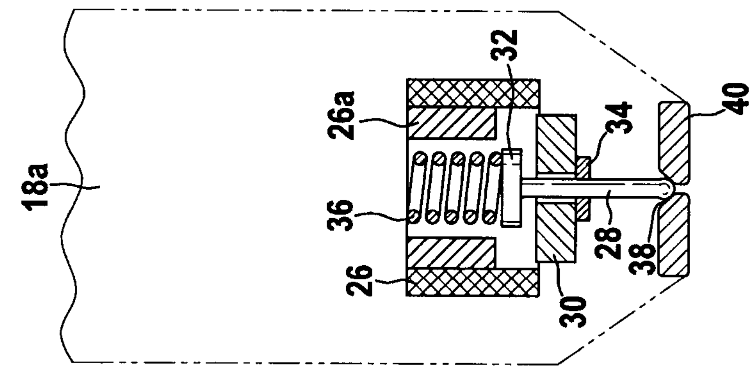

Fig. 2A

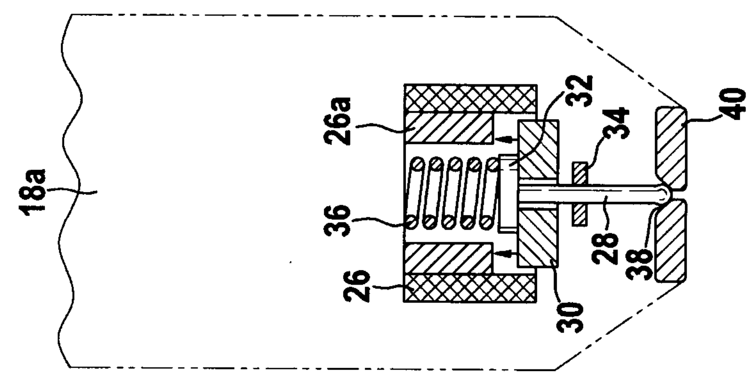

Fig. 2B

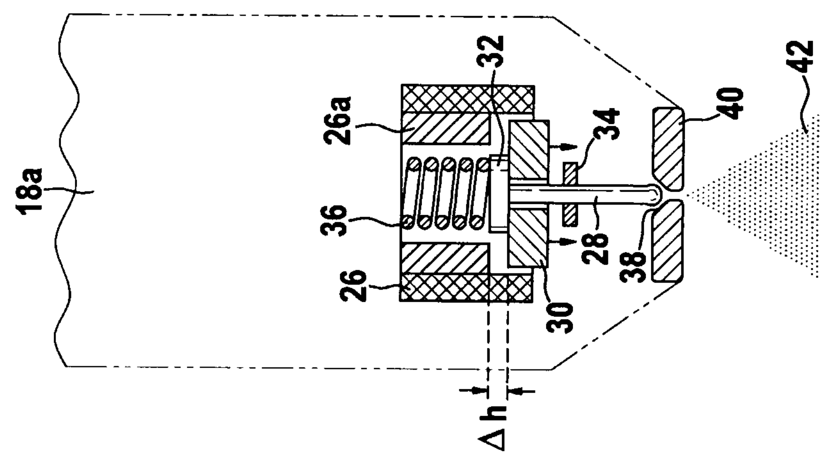

Fig. 2C

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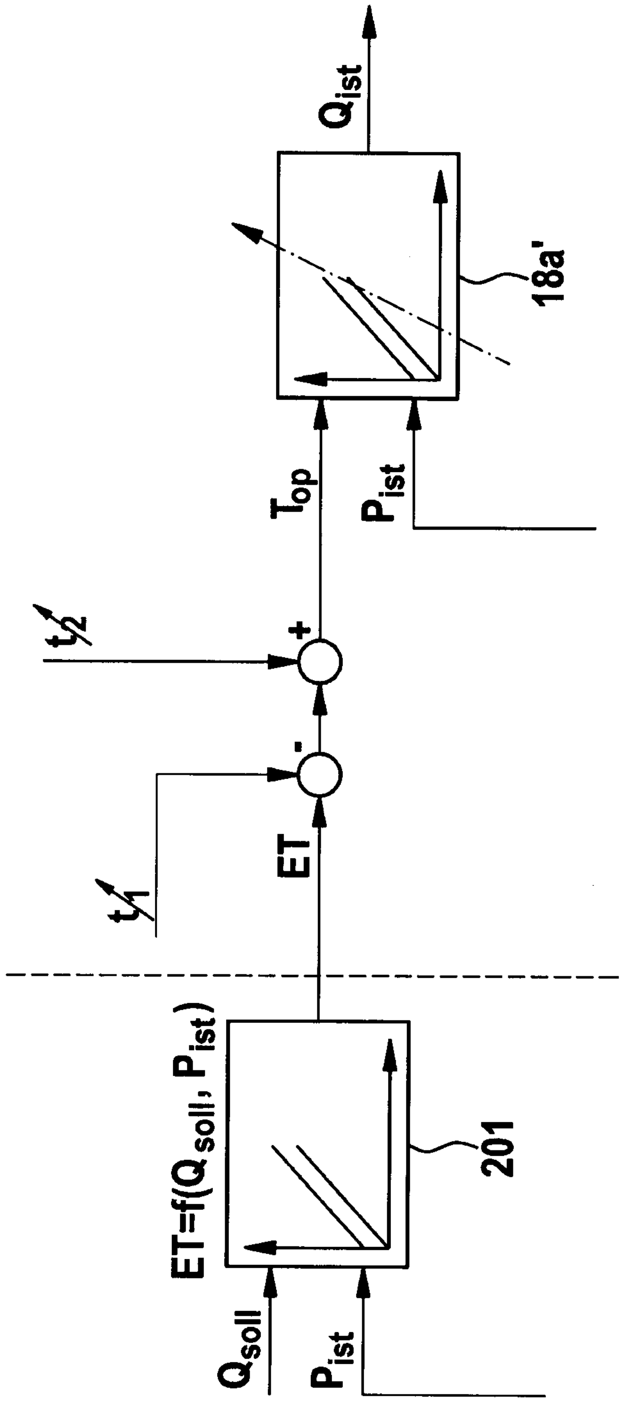

Fig. 3a
(STATE OF THE ART)

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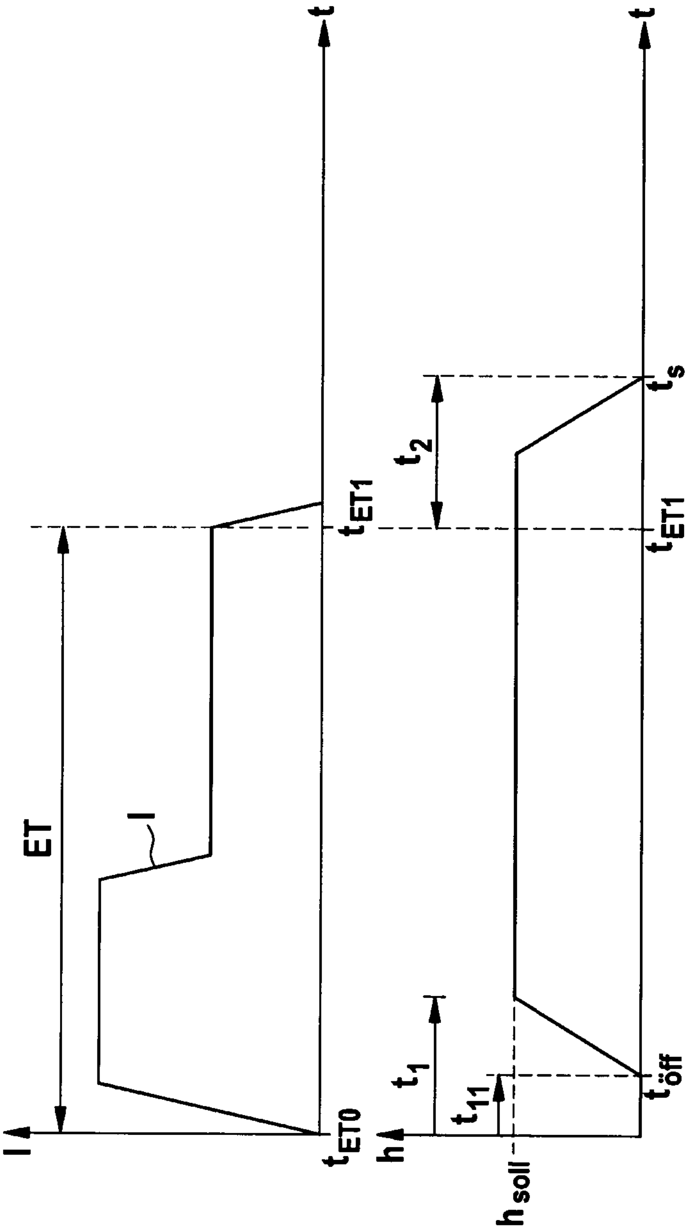

Fig. 3b

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Fig.

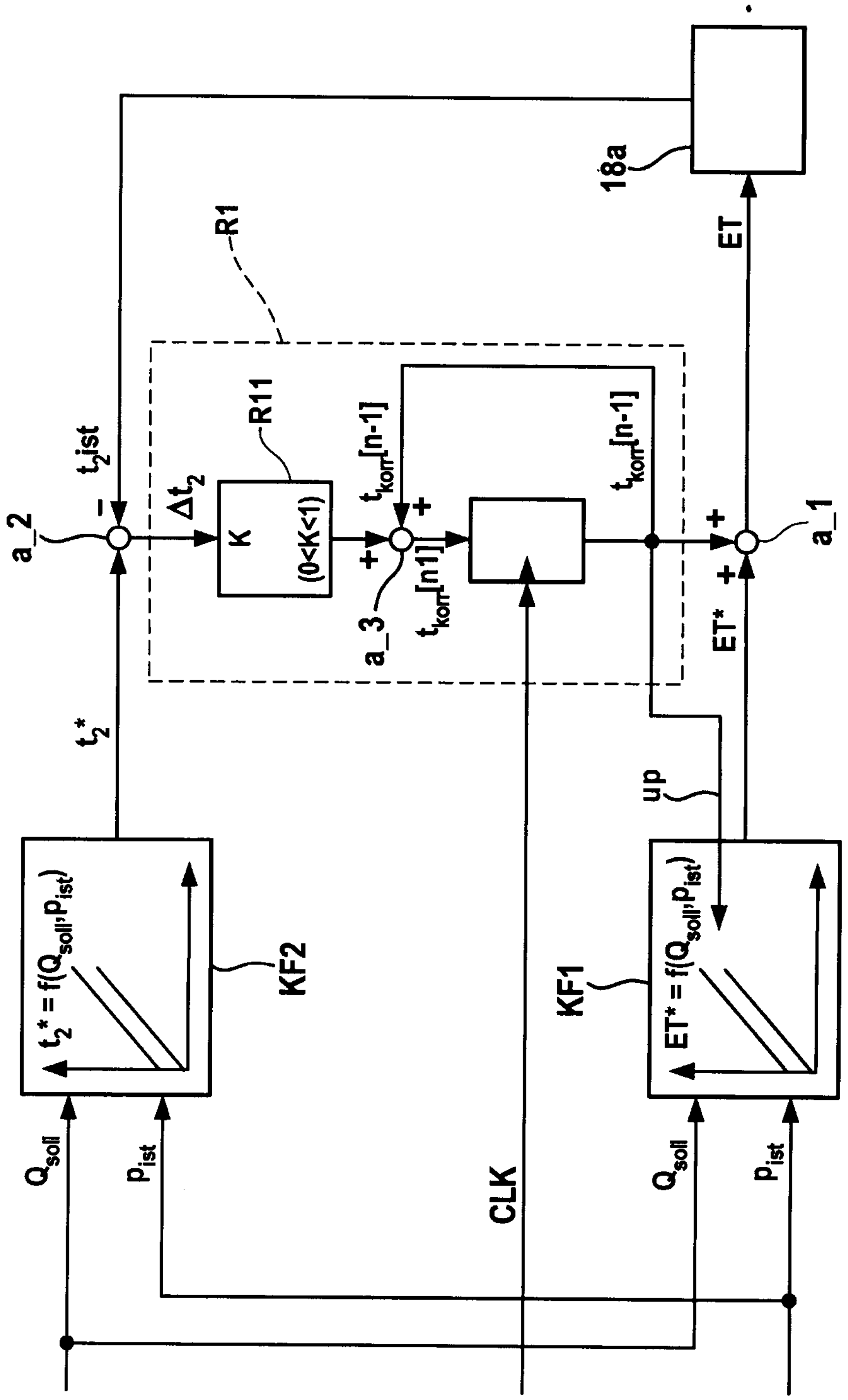

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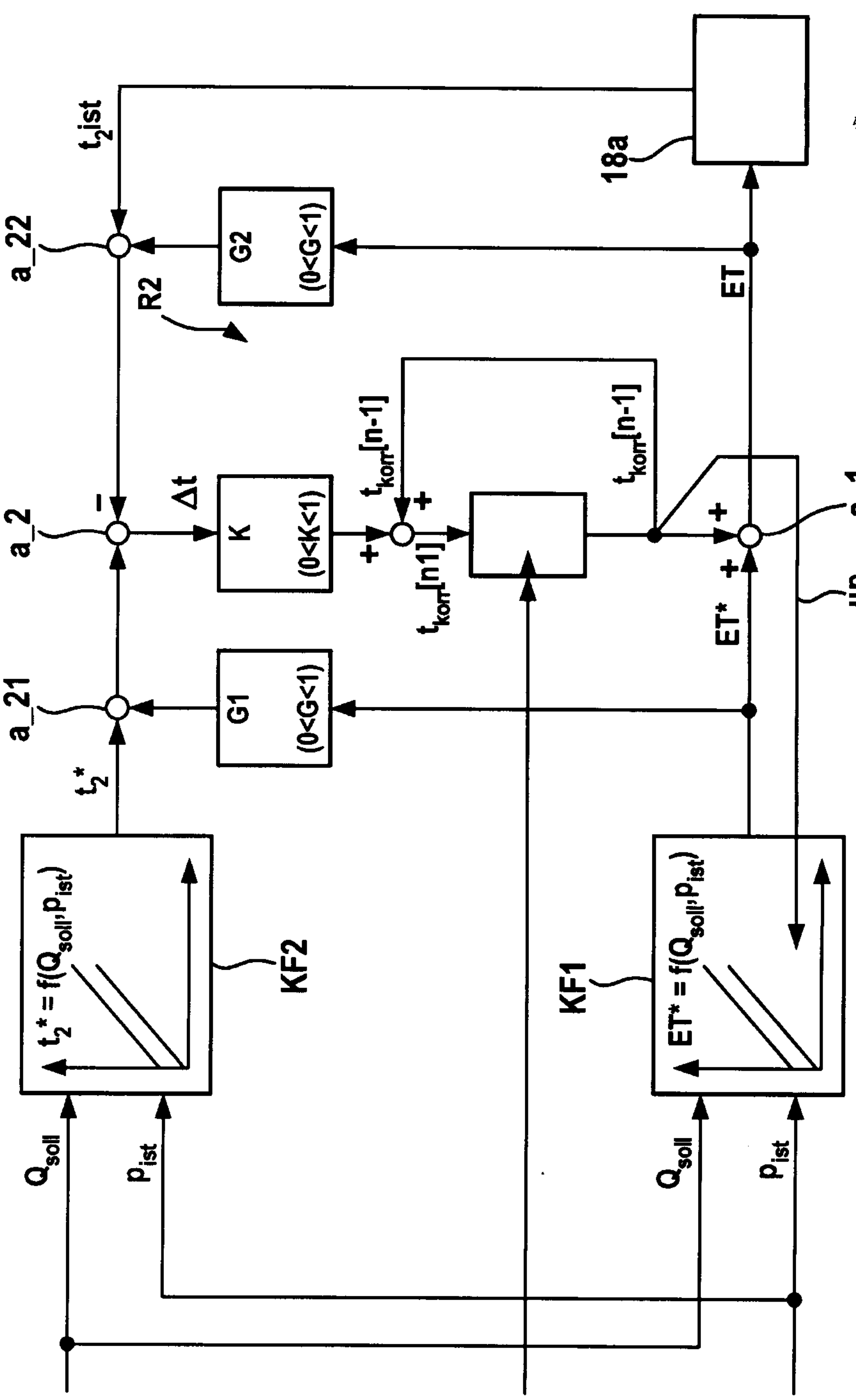
Fig. 4b



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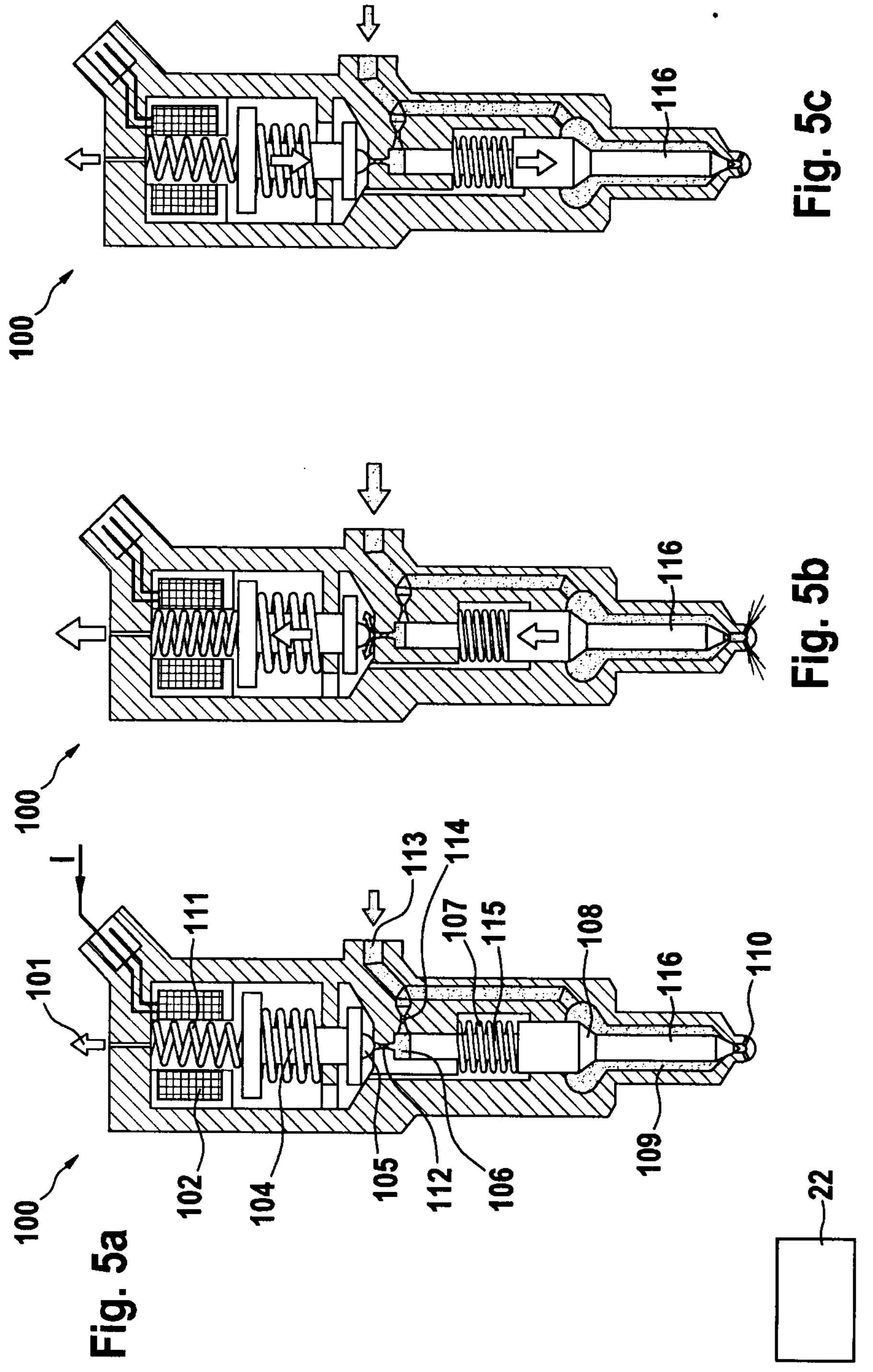

Fig. 5a

Fig. 5b

Fig. 5c

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Technical Field

The present subject matter relates to a method for operating a valve actuated by means of an actuator, particularly a fuel injection valve of an internal combustion engine of a motor vehicle.

Background

Method and control devices of the type mentioned above are, for example, used in high-pressure fuel injectors for gasoline direct injection, where a movement of a valve needle is controlled, for example, by energizing a magnetic circuit. The magnetic circuit is a component of an electromagnetic actuator, which exerts a magnetic force on the valve needle during energization. Common types of high-pressure injection valves are designed so that the energization of the magnetic coil of the electromagnetic actuator causes an opening of the injection valve, that is, a lifting of the needle valve from its closing position and a subsequent holding of the valve needle on a stroke stop corresponding to one of its open position. A quick removal of the magnetic force takes place initially in a known manner at the end of energization, so that a closing spring applies a spring force on the needle valve in a closing direction, to accelerate the needle valve towards the closing position. The closing process ends, when the valve needle valve reaches its seat. Starting from this time point, the closing spring force not only acts on the valve needle, but also acts as a sealing force that transmits the valve needle to its valve seat.

In addition to a flight path of the valve needle and a stroke throttle curve of the valve, a fuel quantity injected during the above described actuation process can be determined mainly by an opening duration of the valve, and thus, by the time interval between the lifting off of the valve needle towards its closing position and the re-reaching of its closing position.

Usually, however, the hydraulic opening duration of the valve is not known directly in context of a control device controlling the valve, but merely an actuation duration of the actuator driving the valve needle is known. An opening delay time lies between the start of the actuation duration and an actual hydraulic opening of the injection valve, and a closing delay time lies between an end of the actuation duration and the actual hydraulic closing time point of the injection valve.

These delay times of the valve are not known, but rather depend on operating and adjustment parameters of the valve and other edge limiting conditions. Especially for very short desired opening durations of the valve, in which the valve needle does not reach the stroke stop corresponding to its completely open position, but rather performs a ballistic trajectory, the metering accuracy of the conventional systems are inadequate.

SUMMARY

This summary is provided to introduce concepts related to a method and a control device for operating a valve and the concepts are further described below in the detailed description. This summary is neither intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

In one embodiment, the present subject matter relates to a method for operating a valve actuated by means of an actuator, in particular a fuel injection valve of an internal combustion engine of a motor vehicle. The actuator is actuated by means of an actuating parameter having an actuating duration. According to the present subject matter, the actuating duration is formed as a function of a target value for a closing delay time of the valve, characterizing a time differential between an end of the actuating duration and a closing time point of the valve. An actual value of the closing delay time is determined, particularly determined in a measurement technological manner. Further, an actuation variable is formed between the target value and the actual value for the closing delay time. The target value for the actuation duration is modified as a function of the actuation variable. The actuation variable is multiplied with a feedback factor K having a value range of $K = 0$ to $K = 2$, particularly $K = 1$.

In another embodiment, the present subject matter further relates to a control device for operating a valve actuated by means of an actuator, in particular a fuel injection valve of an internal combustion engine of a motor vehicle. The control device is configured for execution of the method as claimed in one of the preceding claims.

Brief Description Of The Figures

The present subject matter is explained in more details with the help of the following exemplary embodiments represented in the drawings, without limiting the scope of the present subject matter. There are:

Fig. 1 shows a schematic representation of an internal combustion engine having a plurality of inventive operating injection valves.

Fig. 2a to 2c show a detailed schematic view of an injection valve of Fig. 1 in three different operating conditions.

Fig. 3a shows a function diagram for configuration of an actuation duration according to a conventional method.

Fig. 3b shows a time curve of operating parameters of conventional operating injection valves.

Fig. 4a shows a function diagram of an embodiment of an operating method.

Fig. 4b shows a function diagram of another embodiment of the operating method.

Fig. 5a, 5b, 5c show different operating conditions of an injection valve having a control valve for execution of the operating method.

Detailed Description

The present subject matter provides an improved method and a control device such that a more precise injection of the fuel is possible.

The present subject matter relates to a method for operating a valve actuated by means of an actuator, particularly a fuel injection valve of an internal combustion engine of a motor vehicle. The actuator is actuated by means of a actuating parameter having an actuating duration. According to an embodiment, the actuation duration is formed as a function of a target value for a closing delay time of the valve, which characterizes a time differential between an end of the actuation duration and a closing time point of the valve.

The inclusion of the target value for the closing delay time allows a more precise metering of a fluid to be injected, especially in an operational region of the injection valve, in which the valve needle executes an essentially ballistic trajectory.

In an embodiment, it is provided that an actual value of the closing delay time is determined. In particular, it is detected by a measurement technique that an actuation variable is formed between the target value and the actual value for the closing delay time, and that the target value for the actuation duration is modified as a function of the actuation variable.

Further, in other embodiment, a correction parameter for modification of the target value for the actuation duration is configured by means of an actuation/control structure of the actuation variable, wherein the control/actuation structure in particular has an actuator/controller as an integral part.

In other embodiment, during the configuration of the actuation variable, the target value for the actuation duration, in particular weighted about a preset weight factor, is considered, in particular by addition of a target value weighted about the weight factor to the target value for the closing delay time.

In yet another embodiment, by usage of aforementioned technique, a precision can be increased during the injection of the fluid, especially in the ballistic range/region of the injection valve and/or its valve needle. Through the consideration of the actuation variable, in which the actual value of the closing delay time is also received, a possibility is achieved that the actuation current, in particular the actuation duration, modifies the operation of the valve so that the time-varying closing delay times can be met, such as, by a change in the actual (target) actuation duration of the valve.

The method of operation can be advantageously used for the operation of valves, in which a component driven by the actuator, particularly the valve needle, at least partially carries out a ballistic trajectory as a result of actuation with the actuation current.

In other embodiment, the method proposed in the present subject matter is used in so-called direct-driven fuel injection valves, in which an actuator, for example, an electromagnetic actuator, acts directly on the valve needle, as it is preferably the case in a gasoline direct injection system

The method proposed in the present subject matter is further used for such injection valve, in which an actuator, for example an electromagnetic actuator, does not act directly on the valve needle, but a drive of the valve needle is carried out, for example, using a control valve arranged between the electromagnetic actuator and the valve needle and a corresponding hydraulic effect chain. Such injection valves are now often used in common rail diesel injection systems.

The present subject matter further relates to a control device disclosed in accordance with claim 9. Further, the realization of the method in the form of a computer program is of particular importance.

Further embodiments and/or implementations of the present subject matter are set forth in the dependent claims. Further advantages, features and details are resulted from the below mentioned description, in which the various embodiments of the present subject matter are shown with reference to the drawing. The features mentioned in the claims and in the description can be used essentially individually for the present subject matter or in any combination.

An internal combustion engine shown in Fig. 1 is represented by a reference numeral 10. It includes a tank 12 from which a conveyor system 14 delivers fuel into a distribution system 16, wherein the distribution system 16 is preferably a common rail system. Several electro-magnetically actuated injection valves 18a to 18d are connected to this distribution system 16 and inject the fuel directly in its associated combustion chambers 20a to 20d. The operation of the internal combustion engine 10 is controlled preferably by a control and regulating device 22 that among other things controls/actuates the injection valves 18a to 18d.

Fig. 2a to 2c show a schematic view of the injection valve 18a according to Fig. 1 in three different operating conditions. Further, the injection valves 18b, 18c, 18d illustrated in Fig. 1 have a corresponding structure and functionality.

The injection valve 18a has an electromagnetic actuator, which has a magnetic coil 26 and a magnetic armature 30 interacting with the magnetic coil 26. The magnetic armature 30 is connected to a valve needle 28 of the injection valve 18a, such that the magnetic armature 30 is movable in relation to a vertical moving direction of the valve needle 28, as represented in Fig. 2a, with a non-zero mechanical clearance relative to the valve needle 28.

Thus, a two-part mass system 28, 30 is resulted, which effects the drive of the valve needle 28 by the electromagnetic actuator 26, 30. Through this two-part configuration, the mounting of the injection valve 18a is improved and an unwanted bounce back of the valve needle 28 at the impact in its valve seat 38 is reduced.

In the present configuration illustrated in Fig. 2a, an axial clearance of the magnetic armature 30 is limited to the valve needle 28 by two stops 32 and 34. The lower stop 34 in

Fig. 2a at least can be implemented through a region of a housing 40 of the injection valve 18a. The valve needle 28 is subjected to a corresponding spring force, against the valve seat 38 in region of the housing 40, configured by a valve spring 36 as shown in Fig. 2a. In the current figure, the injection valve 18a is shown in a closed state, in which no fuel injection takes place.

To effect a fuel injection system, the actuator 26, 30 is applied an actuation current over a predetermined actuation duration. Through this energization, the magnetic coil 26 of the magnetic armature 30 is moved upwards in Fig. 2b, so that the valve needle 28 moves out against the spring force from its valve seat 38 and intervenes in the stop 32. Thus, fuel 42 can be injected into a combustion chamber 20a (Fig. 1) by the injection valve 18a, see Fig. 2c.

Once the energization of the magnetic coil 26 is terminated by the control device 22 (Fig. 1) at the end of the predetermined actuation duration, the valve needle 28 moves under the influence of the spring force exerted by the valve spring 36 again towards its valve seat 38. A force transfer from the valve needle 28 to the magnetic armature 30 is here again carried out by the upper stop 32.

When the valve needle 28 terminates its closing movement with the occurrence of the valve seat 38, the magnetic armature 30 can move downwards further due to the axial clearance in Fig. 2c, until it rests against the second stop 34. This again corresponds to the closed condition of the injection valve 18a shown in Fig. 2a.

In order to achieve particularly low injection volumes, the actuation duration for energizing the actuator 26, 30 is preferably selected to such a small extent, that the valve needle 28 and/or the magnetic armature 30 do not reach an upper stroke stop 26a limiting the opening movement, which is formed by a lower front side, in Fig. 2c, of an iron core 26a arranged essentially co-axially with the magnetic coil 26. The valve needle 28 and the magnetic armature 30 therefore execute a ballistic trajectory during the opening of the injection valve 18a. In the present case, the magnetic armature 30, as shown in Fig 2c, in its upper dead center includes a non-disappearing stroke distance Δh from the upper stroke stop 26a.

In comparison to a complete stroke actuation, the valve needle 28 and/or the magnetic armature 30 initially securely reach the upper stroke stop 26a (that is, stroke distance $\Delta h = 0$), thereby resulting in major fluctuations particularly for a late closing time during smaller actuation duration in the ballistic range (reversal point at $\Delta h > 0$), which characterizes a period between one end of the actuation duration and an actual closing time point of the valve 18a. Further, the method described with reference to Fig. 4a, 4b allows a significant increase in precision during the injection of the small amounts of fuel, which - in contrast to the complete stroke range – requires a ballistic operation of the injection valve 18a.

Fig. 3b shows a schematic view of a time curve of the operating parameters, actuation current I, stroke h of the valve needle 28 (Fig. 2a), as it is resulted during an actuation cycle in scope of working of a fuel injection system.

Initially, at the time point t_{ET0}, the electromagnetic actuator 26, 30 of the injection valve 18a is energized, to ensure a lifting of the magnetic armature 30 and hence also the valve needle 28 from its valve seat 38. The time point t_{ET0} thus defines a start of an actuation duration ET defined by an actuation current I of the electromagnetic actuator 26, 30 and thus also of the injection valve 18a.

Fig. 3a shows an example of a simplified functional diagram for determining the actuation duration ET of the actuation current I (Fig. 3b). In a first function block 201 realized, for example, by means of a characteristic diagram, the actuation duration ET for the actuation of the electromagnetic actuator 26, 30 with a corresponding actuation current I is determined as a function of a fuel quantity Q_{soll} to be injected during a conventional operating method, and a fuel pressure p_{ist}. (Fig. 3b).

As interference variables occur during the actuation of the actuator 26, 30 (Fig. 2a) of the injection valve 18a, the actuation current I representing the actuation duration ET is determined in a conventional manner. The actuation delay times, t11, t2, which are subsequently closely described in detail hereinafter, are added to the conventionally determined actuation duration ET, so that an actual opening time $T_{op} = ET - t11 + t2$ results for the injection valve 18a. Possible tolerances occurring in the high-pressure hydraulic system of the injection valve 18a are symbolized in Fig. 3a by the function block 18a'. Due to the above-described actuation with the real control signal T_{op} and at the given fuel pressure p_{ist}, the actual injected fuel quantity Q_{ist} is obtained, in the conventional system at the output of the function block 18a', which is generally different from the fuel quantity Q_{soll} to be injected.

Fig. 3b shows a time curve of the needle stroke h of the valve needle 28 (Figure 2a) as it is resulted with the actuation current I during the actuation. Because of inertia, friction effects and other interference effects, the valve needle 28 (Fig. 2a) initially begins after the electrical actuation beginning t_{ET0}, namely at the time point $t_{öff}$ with its opening sequence, wherein the needle 28 moves from downwards to upwards as shown in Fig. 2b, 2c, that is, move out of its closing position. Initially at the time point t_{ET0} + t1, the valve needle 28, as shown in Fig. 3b, has clearly achieved a target needle stroke h_{soll}, which corresponds to the actuation current I.

A non-disappearing closing delay time t2 corresponds to a period between the end t_{ET1} of the actuation duration ET and the actual hydraulic closing at the time pointy t_s, if the fuel is injected by the injection valve 18a after the end t_{ET1} of the actuation duration ET. The closing delay time t2 - as already described above - is not constant especially for very short actuation durations ET. Especially at the pure ballistic operation, in which the valve needle 28 does not reach the stroke stop 26a, representing a maximum opening during its opening process in region of the iron core, the closing delay time t2 can assume to have different values, which again depends on the movement parameters of the valve needle 28 prior to the time point t_{ET1}, that is, at the end of the actuation duration ET, and depends on a closing spring force, a magnetic force, a rail pressure, an actuation duration, temperature, a feedback pressure and / or other parameters.

According to the present subject matter it is therefore suggested to form the actuation duration ET as a function of a target value t2* for the closing delay time t2 of the valve 18a, wherein the closing delay time t2 characterizes a time differential between the end t_{ET1} of the actuation duration ET and an actual hydraulic closing time point ts of valve 18a.

Fig. 4a shows a functional diagram of a first embodiment of the present subject matter. A target value ET* for the actuation duration is determined by means of a first characteristic field KF1 as a function of the target injection quantity Q_{soll} and the fuel pressure p_{ist}.

According to the present subject matter, the target value ET* for the actuation duration is corrected by means of a correction value t_{korr} [n-1], which takes place by an addition of the parameter t_{korr} [n-1] to the target value ET* by means of the adder a_1. The proposed actuation duration ET is provided at the output of the adder a_1. The signal corresponding to the actuation duration ET, according to Fig. 4a, acts on the function block 18a representing the injection valve 18a.

A target value t2* for the closing delay time t2 is received from the input parameter Q_{soll}, P_{ist} by means of a second characteristic field KF2. At the same time, the actual value t2ist of the closing delay time t2 is determined, for example by a measurement technique that analyzes the time curve of the actuation current I (Fig. 3b).

An actuating variable $\Delta t2 = t2^* - t2$ is formed with the help of the adder a_2. The actuating variable Δt2 is then multiplied with a predetermined correction factor K in a functional block R1, wherein a preferred range of values for the correction factor K is provided between 0 and 2, in particular between 0 and 1. A function block R11 within the block R1 , as well as its subordinate adder a_3 and the other function block, subsequent to the adder a_3 and not specified in Fig. 4a, is part of a first controller structure R1, which forms the correction factor t_{korr} [n- 1] as a function of the actuating variable Δt2.

Therefore, a correction value for a subsequent injection cycle of the injection valve 18a is provided at the output of the adder a_3, which is calculated as follows:

$$t_{korr}[n] = t_{korr}[n-1] + K^* \Delta t2$$

This means that the presently regarded controller structure R1 has a simple digital controller as an integral characteristic, which allows a little complex implementation of the principle proposed in the present subject matter. Alternatively or additionally, other controller structures can also be used, to form the inventive correction parameter t_{korr} [n] as a function of the actuating variable Δt2.

In particular, controller structures are used with proportional-integral characteristic, proportional characteristic, or even a non-linear controller. Essentially for the operation of the principle proposed by the present subject matter, the formation of a correction value depends on the actuating variable Δt2. The function block downstream to the adder a_3 and presently unspecified has a particularly preferred embodiment, according to a clock input, to which a synchronous speed clock signal CLK is supplied, so that the resulting correction value according to the present subject matter can be passed to the synchronous speed adder a_1.

The controller structure illustrated in Fig. 4a ensures an advantageous controlling of the closing delay time t2 of the injection valve 18a and thus ensures a very precise and smaller amounts of fuel injection in a ballistic operation mode of the injection valve 18a.

Fig. 4b shows a functional diagram of another embodiment of the method proposed in the present subject matter. In addition to the basic structure already described with reference to Fig. 4a, the embodiment according to Fig. 4b, has a second controller structure R2, which provides a consideration of the target value ET^* for the actuation duration ET and the actuation duration ET. For this purpose, the parameters ET^*, ET are weighted by unspecified functional block with a first weighting factor G1 and a second weighting factor G2, before they are added to the target value of $t2^*$ for the closing delay time t2 and/or the actual value t2ist for the closing delay time t2 via the adder a_21, a_22.

The adder a_2 subsequently determines the actuation parameter Δt comparable to an actuating variable $\Delta t2$ already described in the context of Figure 4a, which is used as input parameter for the controller structure R2.

For the actuation current Δt, it is given as:

$$\Delta t = (t2^* + G1^* ET^*) - (t2_{ist} + G2^* ET)$$

For the weighting factors G1, G2, again a range of values from 0 to 1 is provided. Once the controller structures R1, R2 provided in Figures 4a, 4b have reached a steady state, which is characterized by the small actuation variables $\Delta t2$, Δt, the characteristic diagram KF1 can be adjusted as a function of the correction parameter t_{korr} via an update path up. In this case, at the same time the correction value for supplying to the adder a_1, is set to null, because a corresponding consideration of the correction value already takes place by the adaptation of the characteristic diagram KF1.

Particularly preferably, the value of the correction factor K is selected between 0 and 1. In exceptional cases, an expansion of the value ranging from $0 < K < 2$ is also possible, wherein the factor K determines the adjustment speed of the controller circuit R1, R2. For a fast adjusting characteristic, a value for K is beneficial if it is approximately in a range between 0 and 1. If needed, robustness of the controller circuit can be increased compared to interfering signals by lowering the factor K. Thus, for example, with a value $K = 0.5$, an increased robustness against interference signals can be achieved, without making any significant reductions in the controller dynamics of the controller R1, R2. In case of a controller deviation, the inventive controller R1, R2 is settled for more than about 90% during investigations of the applicant performed after only about 4 work cycles of the injection valve 18a (Fig. 2a).

The controller structures R1, R2 are characterized by a particularly small complexity, which has small application cost and contributes to the robustness of the system. Above mentioned type of valve injections are described with reference to Fig. 2a, 2b, 2c, in which they are used as a direct actuated injection valve 18a, thereby describing the method of the proposed subject matter.

In an embodiment, the method described in the present subject matter can be used with injection values, which are not directly driven, preferably with such injection valves, in which the electromagnetic actuator 26, 30 actuates a component of a control valve, and in which an essential hydraulic and/or mechanical working chain can be provided between the control valve and the valve needle 28.

Fig. 5a-5c shows an embodiment of an injection valve 100 provided for the fuel injection of a diesel common-rail fuel injection system of an internal combustion engine in various operating conditions of an injection cycle.

Fig. 5a shows the injection valve 100 in its rest condition, in which it is not actuated by its associated control device 22. A magnetic valve spring 111 here presses a valve ball 105 in a provided seat of an outlet throttle 112, so that a fuel pressure corresponding to the rail pressure can be built up in a valve control chamber 106, as it is also prevailed in the region of a high pressure connection 113.

The rail pressure is also available in a chamber volume 109, which surrounds a valve needle 116 of the injection valve 100. The force applied by the rail pressure on the front side of a control piston 115 and the force of a nozzle spring 107 keeps the valve needle 116 closed against an opening force that acts upon a pressure shoulder 108 of the valve needle 116.

Fig. 5b shows the injection valve 100 in its open state. The injection valve 100 is actuated by the control device 22 in the following manner as a function of an idle condition configured as shown in Fig. 5a: In the present case, an electromagnetic actuator 102, 104 is configured by a magnetic coil 102 shown in Fig. 5a and by a magnetic armature 104 interacting with the magnetic coil 102. The magnetic coil 102 is supplied with an actuation current I by the control device 22, to open the present magnetic valve 104, 105, 112 working as the control valve. The magnetic force of the electromagnetic actuator 102, 104 in this case exceeds the spring force of the valve spring 111 (Fig. 5a), so that the magnetic armature 104 lifts the valve ball 105 from its valve seat and hereby opens an outlet throttle 112.

With the opening of the outlet throttle 112, now fuel from the valve control chamber 106 flows in a hollow chamber shown in Fig. 5a, see the arrows, and flows back into a non configured fuel tank via a fuel return line 101. An inlet throttle 114 prevents a complete pressure equalization between the rail pressure applied in the region of the high pressure connection 113 and the pressure in the valve control chamber 106, so that the pressure in the valve control chamber 106 reduces. This means that the pressure in the valve control chamber 106 is less than the pressure in the chamber volume 109, which still corresponds to the rail pressure. The reduced pressure in the valve control chamber 106 causes a correspondingly reduced force on the control piston 115 and thus leads to the opening of the injection valve 100, that is, the valve needle 116 lifts from its valve seat in region of the injection holes 110. This operating condition is illustrated in Figure 5b.

Subsequently, that is, after lifting off from the valve needle seat, the valve needle 116 implements an essentially ballistic trajectory primarily under the influence of hydraulic forces in the chamber volume 119 and the valve control chamber 106. Once the electromagnetic actuator 102, 104 (Fig. 5a) is no longer actuated at an end of the actuation duration by the control device 22, the valve spring 111 pushes the magnetic armature 104 downwards as shown in Fig 5c, so that the valve ball 105 then closes the outlet throttle 112. This reverses the direction of movement of the valve needle 116, so that it is brought back into its closed position.

The fuel injection is terminated, once the needle valve needle 116 reaches its valve seat in region of the injection holes 110 and seals these, as shown in Fig. 5c. Also for the injection valve 100 described and shown in Fig. 5a to 5c, which is actuated by a control valve 104, 105, 112, the method of the correction of the actuation duration can be executed as a function of a target value for the closing delay time.

The electromagnetic actuator 102, 104 of the injection valve 100 can, for example, be actuated by the actuation current I, which has a time curve comparable to the time curve shown in Fig. 3b. Accordingly, the closing delay time is resulted in the injection valve 100. In contrast to the closing delay time of the injection valve 18a described with reference to the

Fig. 2a to 2c, the closing delay time with the injection valve 100 under a condition according to Fig. 5a, however, does not clearly illustrate time components, which are characterized by several conditions changes and/or other processes of the electromechanical and/or hydraulic effect chain located between the electromagnetic actuator 102, 104 and the valve needle 116.

In each case, the closing delay time can also be defined for the injection valve 100 as shown in Fig. 5a, as the time between the end of the actuation duration ET (Fig. 3b) and an actual hydraulic closing time point, at which the valve needle 116 receives its closing position in the region of the injection holes 110. For the application of the principle of the present subject matter with the injection valve 100 according to Fig. 5a, it is possible to determine the actual hydraulic closing time point, which, for example, can take place by acceleration and/or knock sensor or alike, thereby allowing a detection of impact of the valve needle 116 in its closing position in the region of the injection holes 110.

The principle of the present subject matter can also be separately applied to the control valve 104, 105, 112 of injection valve 100 as shown in Fig. 5a, which is then preferably useful, when a strong correlation exists between the condition changes of the control valve 104, 105, 112 and the valve needle 116, and therefore it can be assumed that a regulation of the closing delay time of the control valve 104, 105, 112 already provides a sufficiently accurate injection.

Generally, the principle to increase the precision is suitable with the fluid measurement means particularly ballistically operated injection valves and not limited to fuel injectors. Distribution of pieces can be advantageously compensated through the application of the proposed operating method.

The proposed control principle is also advantageously applicable when an injection valve is ballistically operated only temporarily, that is, only in some operating cycles. The determination of the actual closing delay time t2ist (Fig. 4a), can be carried out depending on the configuration of the respective injection valve, for example, from the time curve of the actuation current I (Fig. 3b) detected by measurement techniques and/or a voltage applied to the electromagnetic actuator.

Sensor data separate sensor devices such as acoustic sensors or acceleration sensors can also be evaluated to obtain information about an actual operating condition of the components 28, 105, 116 of the injection valve.

Further, a computer program with program code means, executes a method proposed in accordance with the present subject matter, when the computer program is executed in a computer or a corresponding computing unit, in particular in the control device 22.

A computer program product with a program code means, is stored on a computer readable medium data carrier, to execute a method proposed in accordance with the present subject matter, when the computer program is executed on a computer or a corresponding computing unit, in particular in the control device 22.