ORIGINAL

ABSTRACT

METHOD AND CONTROL APPLIANCE FOR OPERATING A VALVE

The present subject matter relates to a method for operating a valve (18a), particularly a fuel injection valve of an internal combustion engine (10) of a motor vehicle. An auxiliary variable (m) is obtained according to at least one electrical operating variable (u) of an electromagnetic actuator (26, 30) driving a component of the valve (18a), particularly a valve needle (28), and is examined for the appearance of a pre-determined characteristic. Further, the method includes determining a reference variable (m_{ref}) characterizing an operational mode of the electromagnetic actuator (26, 30), modifying the auxiliary variable (m) according to the reference variable (m_{ref}) in order to obtain a modified auxiliary variable (m_{mod}), and examining the modified auxiliary variable (m_{mod}) for the appearance of the pre-determined characteristic.

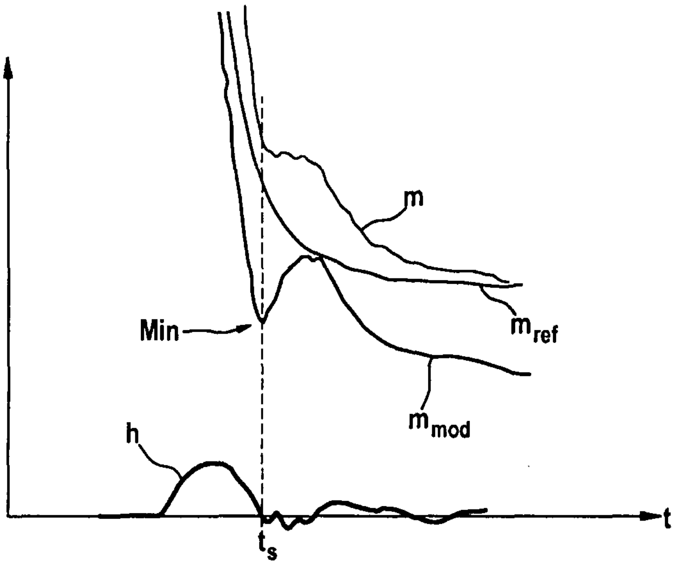

Fig. 5

I/We claim:

1. A method for operating a valve (18a), particularly a fuel injection valve of an internal combustion engine (10) of a motor vehicle, the method comprising:

obtaining an auxiliary variable (m) according to least one electrical operating variable (u) of an electromagnetic actuator (26, 30) driving a component, particularly a needle valve (28), of the valve (18a); and

examining the auxiliary variable (m) for the appearance of a predetermined characteristic;

characterized in that, the method further comprises:

determining a reference variable (m_{ref}) characterizing an operational mode of the electromagnetic actuator (26, 30);

modifying the auxiliary variable (m) as a function of the reference variable (m_{ref}), in order to obtain a modified auxiliary variable (m_{mod}); and

examining the modified auxiliary variable (m_{mod}) for the appearance of the predetermined characteristic (Min).

2. The method as claimed in claim 1, wherein the at least one electrical operating variable for forming the auxiliary variable (m) is a time curve of an actuator voltage (u) or an actuation current (I).

3. The method as claimed in one of the preceding claims, wherein the obtaining the reference variable (m_{ref}) is carried out by means of a model (200) that simulates a dynamic behavior of the electromagnetic actuator (26, 30), particularly dynamic behavior of magnetic circuit of the electromagnetic actuator (26, 30).

4. The method as claimed in claim 3, wherein the model (200) simulates a time curve of the at least one electrical operating variable (u) and/or of the auxiliary variable (m), particularly obtained without a movement of a movable component (26) of the electromagnetic actuator (26, 30).

5. The method as claimed in one of the preceding claims, wherein the obtaining the reference variable (mref) according to the at least one electrical operating variable (u).

6. The method as claimed in claim 5, wherein the obtaining the reference variable (mref) is carried out from values of the at least one electrical operating variable (u), as the values resulted in an operational mode of the electromagnetic actuator (26, 30) in which no movement of the movable component (26) of the electromagnetic actuator (26, 30) takes place.

7. The method as claimed in claim 6, wherein the values of the at least one electrical operating variable (u) are detected by measurement carried out during an actuation of the electromagnetic actuator (26, 30).

8. The method as claimed in one of the preceding claims, wherein the method further comprises subtracting the reference value (m_{ref}) from the auxiliary variable (m) in order to obtain the modified auxiliary variable (m_{mod}).

9. The method as claimed in claim 8, the method further comprises dividing a difference between the auxiliary variable (m) and the reference value (m_{ref}) by the auxiliary variable (m) and/or the reference variable (m_{ref}), in order to obtain the modified auxiliary variable (m_{mod}).

10. The method as claimed in one of the preceding claims, wherein the method further comprises storing the reference variable (mref) after its determination.

11. The method as claimed in claim 10, wherein the stored reference variable (mref) is used for modifying the auxiliary variable (m).

12. A computer program that is programmed for the application in a method as claimed in one of the preceding claims.

13. An electronic or optical storage medium for a control and/or regulating appliance (22) for operating a valve (18a), wherein the electronic or optical storage medium stores a computer program for executing a method as claimed in one of the claims 1 to 11.

14. A control and/or regulating appliance (22) for operating a valve (18a), particularly a fuel injection valve of an internal combustion engine (10) of a motor vehicle, wherein the control and/or regulating appliance (22) is configured for the application in a method as claimed in one of the claims 1 to 11.

Dated this 09th day of April 2012

S. JAYARAM
IN/PA-1347
AGENT FOR THE APPLICANT

To
The Controller of Patents
The Patent Office at New Delhi

Applicant(s) Name: **ROBERT BOSCH GmbH**

Application No.:

Sheet No.: 1

Total No. of Sheets: 4

ORIGINAL

2972 DELNP 12

09 APR 2012

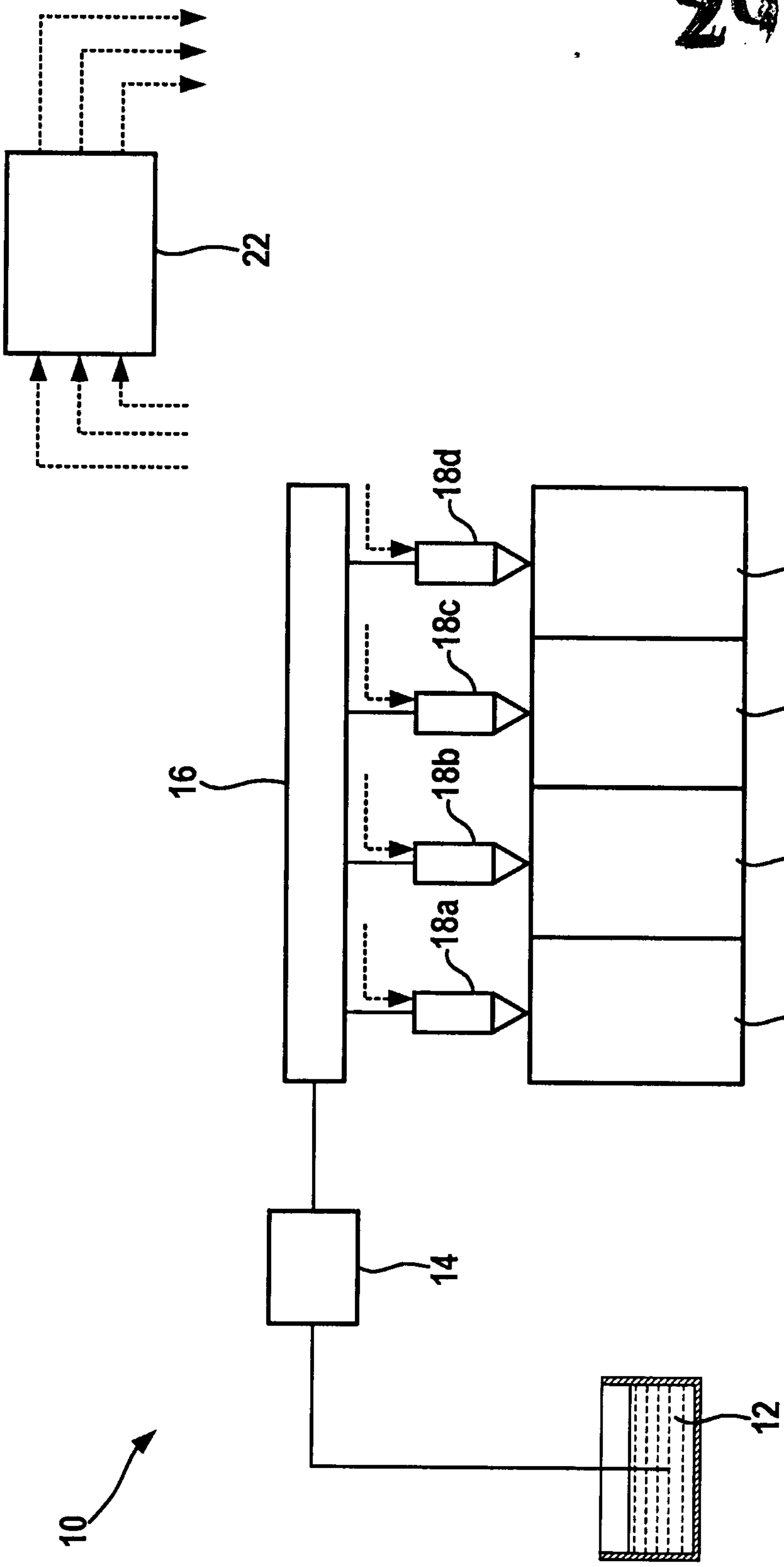

Fig. 1

S. Jayaram

S. JAYARAM
IN/PA-1347
Agent for the Applicant

Applicant(s) Name: **ROBERT BOSCH GmbH** Sheet No.: 2

Application No.: Total No. of Sheets: 4

ORIGINAL

2972DELNP12

09 APR 2012

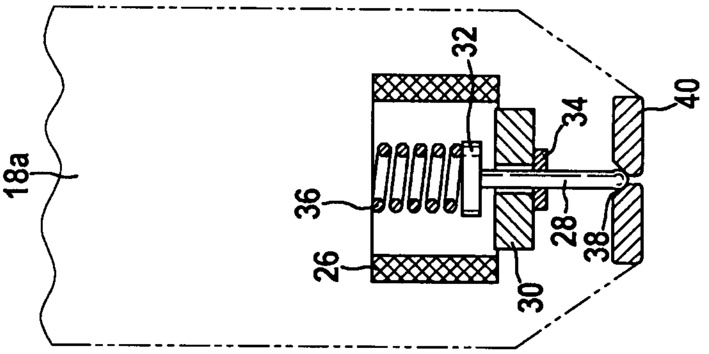

Fig. 2C

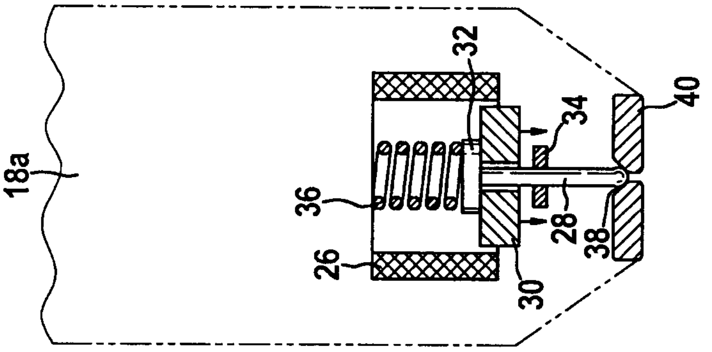

Fig. 2B

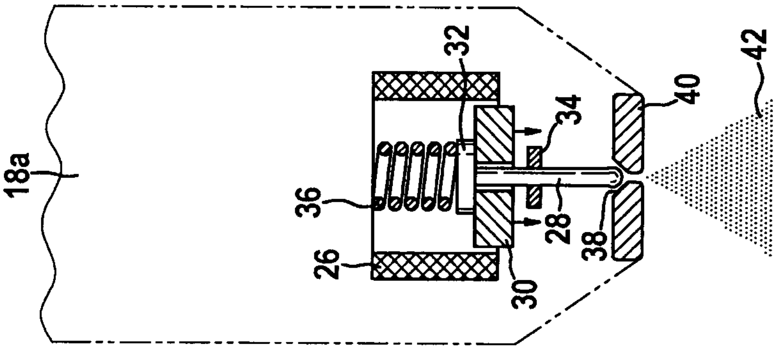

Fig. 2A

S. JAYARAM
IN/PA-1347
Agent for the Applicant

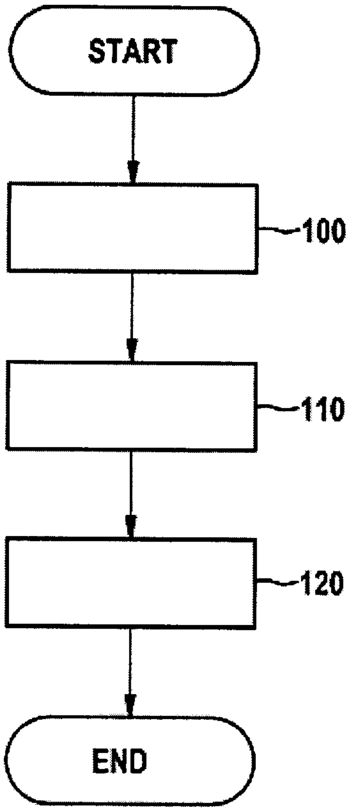

Fig. 3

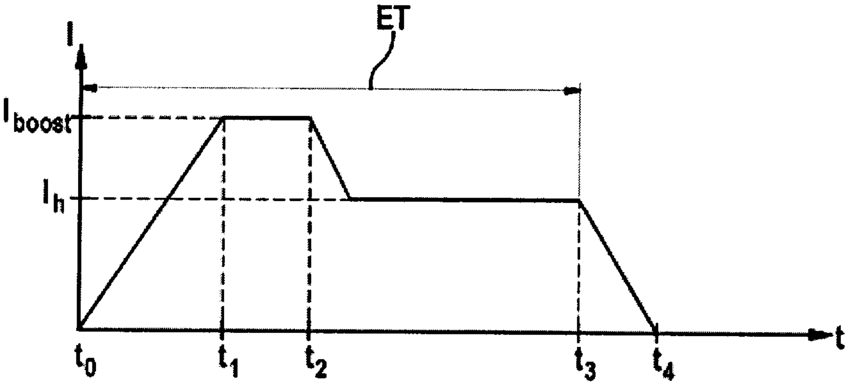

Fig. 4

S. Jayaram
S. JAYARAM
IN/PA-1347
Agent for the Applicant

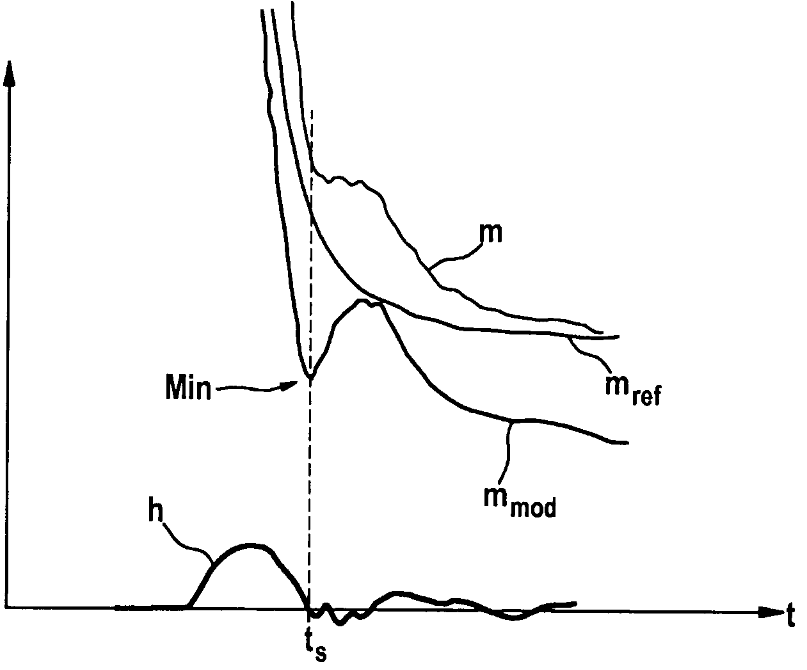

Fig. 5

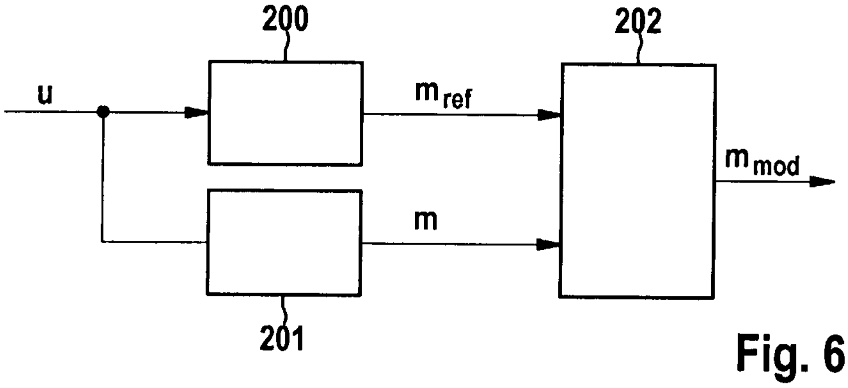

Fig. 6

S. Jayaram
S. JAYARAM
IN/PA-1347
Agent for the Applicant

TECHNICAL FIELD

The present subject matter relates to a method for operating a valve, particularly a fuel injection valve of an internal combustion engine of a motor vehicle, and further relates to a control appliance for operating the valve.

BACKGROUND

Method and devices for operating a valve are generally used for obtaining information about an operating condition of the valve. Particularly, important changes in the operating conditions, as for example a transition from an opening position into a closing position can be derived at least in some operational modes or points of conventional injection valves from the extremes of a time curve of the auxiliary variable.

However, in lower control durations and/or lower valve strokes of the valve, the accuracy of evaluation of the conventional method is often insufficient.

SUMMARY

This summary is provided to introduce concepts related to a method and a control appliance 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 describes a method for operating a valve, particularly a fuel injection valve of an internal combustion engine of a motor vehicle, in which an auxiliary variable is obtained according to at least one electrical operating variable of an electromagnetic actuator driving a component, particularly a needle valve, of the valve, and is examined for the appearance of a predetermined characteristic. Further, the method includes determining a reference variable characterizing an operational mode of the electromagnetic actuator, modifying the auxiliary variable according to the reference variable in order to obtain a modified auxiliary variable, and examining the modified auxiliary variable for the appearance of the pre-determined characteristic.

In another embodiment, the subject matter further describes a computer program that is programmed for carrying out the aforementioned method proposed by the present subject matter.

In yet another embodiment, the subject matter further describes an electronic or optical storage medium for a control and/or regulating appliance for operating a valve. The electronic or optical storage medium stores a computer program for carrying out the aforementioned method proposed by the present subject matter.

In a further embodiment, the subject matter further describes a control and/or regulating appliance for operating a valve, in particular a fuel injection valve of an internal combustion engine of a motor vehicle. The control and/or regulating appliance is configured to for carrying out the aforementioned method proposed by the present subject matter.

BRIEF DESCRIPTION OF THE FIGURES

Further advantages and characteristics result from the following description, in which different embodiments of the present subject matter are described with reference to the figures. Therefore, the features mentioned in the claims and in the description can be essential for technical contribution, individually or in any combination.

Fig. 1 shows a schematic representation of an internal combustion engine with a plurality of injection valves operated in accordance with the present subject matter.

Figs. 2a to 2c show a detailed schematic view of an injection valve from Fig 1 in three different operational modes.

Fig. 3 shows a simplified flow diagram of an embodiment of the method in accordance with the present subject matter.

Fig. 4 shows a schematic time curve of an actuation current for a valve operated in accordance with the present subject matter.

Fig. 5 shows a time curve of an auxiliary variable obtained from an electrical operating variable of the valve from Fig. 2a, and variables derived from it in accordance with the present subject matter, and

Fig. 6 shows a block diagram for implementing an embodiment of the method in accordance with the present subject matter.

DETAILED DESCRIPTION

An object of the present subject matter is to provide a method and a control appliance so that a precise evaluation and the receipt of the information about operational modes or an electromagnetic actuator are possible even at lower valve strokes of the valve. Accordingly, the present subject matter describes a method for operating a valve, particularly a fuel injection valve of an internal combustion engine of a motor vehicle, in which an auxiliary variable is obtained according to at least one electrical operating variable of an electromagnetic actuator driving a component, particularly a needle valve, of the valve, and is examined for the appearance of a predetermined characteristic.

Further, the method includes determining a reference variable characterizing an operational mode of the electromagnetic actuator, modifying the auxiliary variable according to the reference variable in order to obtain a modified auxiliary variable, and examining the modified auxiliary variable for the appearance of the pre-determined characteristic.

In one embodiment, the auxiliary variable enables a particularly precise evaluation, by which even at lower control durations or valve strokes, a higher accuracy of evaluation is provided in view of the detection of change of the operational modes of the valve.

Furthermore, as a result of a time curve of an actuation voltage or an actuator current, at least one electrical operating variable is used for generating the auxiliary variable. The time curve of an electrical potential is present on a magnetic coil of the electromagnetic actuator and also refers to a time curve of the current flowing through the magnetic coil.

In accordance with the present subject matter, it has been recognized that independent of the specific generation of the auxiliary variable, (e.g., about actuation voltage and/or actuator current), a first signal component of the auxiliary variable is constantly available, which is generated because of the magnetic and electrical characteristics of a magnetic circuit of the electromagnetic actuator, and a second signal component, which is generated by a movement of elements of the magnetic circuit, and for this reason is generated by the change in the geometric parameters of the magnetic circuit.

In such operational conditions, in which the magnetic armature moves as a movable component of the magnetic circuit only relatively less further (actual stroke considerably lower than the maximum nominal stroke) or quickly, the component of the generated signal of the auxiliary variable reduces by the armature movement, while the first signal component of the auxiliary variable which is generated because of the magnetic and electrical characteristics of the magnetic circuit of the electromagnetic actuator remains substantially the same.

As a result, the examination of a predetermined characteristic in the auxiliary variable in the conventional method is made difficult. By the application of the reference variable in accordance with the present subject matter, which preferably simulates the first signal component of the reference variable and which is generated because of the magnetic and electrical characteristics of the magnetic circuit of the electromagnetic actuator, the particularly interesting second signal component is advantageously targeted. The second signal component can be evaluated by a movement of elements of the magnetic circuit and for this reason, the second signal component is generated by the change of geometric parameters of the magnetic circuit.

In an embodiment of the present subject matter, a particularly efficient evaluation results, if the reference variable is obtained by means of a model, which simulates a dynamic behavior of the electromagnetic actuator, particularly of its magnetic circuit. Particularly, for this purpose, in an embodiment, the model simulates a time curve of the at least one electrical operating variable and/or the auxiliary variable, particularly as it results without a movement of a movable component (e.g., magnetic armature) of the electromagnetic actuator.

In another embodiment, the reference variable is obtained as a function of the at least one electrical operating variable, particularly preferably from such values of the at least one electrical operating variable, as the values results from an operational mode of the electromagnetic actuator, in which no movement of a movable component (e.g., magnetic armature) of the electromagnetic actuator results. The values of the at least one electrical operating variable are preferably detected for this purpose by measurement, during a particular actuation of the electromagnetic actuator. The particular actuation, for example, is characterized by a relatively lower control duration, which advantageously ensures that despite the actuation, an armature movement does not already occur.

In other embodiment of the present subject matter, the modified auxiliary variable is obtained by subtracting the reference variable from the auxiliary variable. Such obtaining particularly presents lower demands on a control appliance or a computing unit contained therein and carrying out the method in accordance with the present subject matter. As a result, in another embodiment of the present subject matter, a difference between the auxiliary variable and the reference variable is divided by the auxiliary variable and/or the reference variable, in order to obtain the modified auxiliary variable.

In accordance with the present subject matter, in another embodiment, the reference variable can be stored after its determination, so that it is available for a prospective execution of the method in accordance with the present subject matter and need not be determined afresh constantly.

The present subject matte further relates to a control and/or regulating appliance according to claim 14. Further, the method for operating the valve can be carried out by a computer program that is stored on an electronic and/or optical storage medium and that is be executed by the control and/or regulating appliance of an internal combustion engine.

An internal combustion engine 10 is shown in Fig. 1 in accordance with an embodiment of the present subject matter. The internal combustion engine 10 includes a tank 12, from which a supply system 14 forwards fuel in a common rail 16. At the common rail 16, a plurality of electromagnetically actuated fuel injection valves 18a to 18d are connected, which inject the fuel directly into associated combustion chambers 20a to 20d. An operation of the internal combustion engine 10 is controlled by a control and/or regulating appliance 22, which among other things, controls the fuel injection valves 18a to 18d.

Fig. 2a to 2c show schematic views of a fuel injection valve 18a of Fig. 1 in three different operating conditions. Other fuel injection valves 18b, 18c, 18d illustrated in Fig. 1 have a substantially similar structure and function.

The fuel injection valve 18a has an electromagnetic actuator, which has a magnetic coil 26 and an armature 30 interacting with the magnetic coil 26. The armature 30 is connected to a valve needle 28 of the injection valve 18, so that the a two-part system 28, 30 makes a vertical movement direction of the valve needle 28 with a non-zero mechanical play, as shown in Fig. 2a. The two-part system 28, 30 through an electromagnetic actuator 26, 30 can act to drive the valve needle 28. Moreover, through the two-part system 28, 30, the mounting capability of the injection valve 18a is improved and an improved unwanted back bouncing of the valve needle 28 with its placement on the valve seat 38 is reduced. In the embodiment illustrated in Fig. 2a, an axial play of the armature 30 is limited on the valve needle 28 by two stops 32 and 34. At least one lower stop 34 in Fig. 2a can also be realized through an area of a housing 40 of the fuel injection valve 18a.

The valve needle 28 as shown in Fig. 2a is subjected to a corresponding spring force against the valve seat 38, by a valve spring 36, in the area of the housing 40. In Fig. 2a, the fuel injection valve 18a is shown in an open condition. In this open condition, the armature 30 is moved upward by a current of the magnetic coil 26 in Fig. 2a, so that the armature 30 is moved to intervene the valve needle 28 against the spring force from the valve seat 38 in the stop 32. Thus, fuel 42 can be injected from the fuel injection valve 18 into a combustion chamber 20a (Fig. 1). Once the energization of the magnetic coil 26 by the control and/or regulating appliance 22 (Fig. 1) is completed, the valve needle 28 moves under the influence of the spring force exerted by the valve spring 36 on the valve seat 38 and activates the armature 30. A force transfer from the valve needle 28 to the armature 30 is here carried out with an upper stop 32.

Once the valve needle 28 terminates its closing motion with impingement on the valve seat 38, the armature 30, as shown in Fig. 2b, due to the axial clearance in Fig. 2b, is continued to move downward until, as illustrated in Fig. 2c, the valve needle 28 contacts the stop 34.

According to the present subject matter, the method for controlling a fuel injection valve 18a is carried out with reference to the flowchart shown in Fig. 3.

In a first method step 100, an electric operating variable of the electromagnetic actuator 26, 30 (Fig. 2a), in the present example, actuation voltage u applied to the magnetic coil 26 of the actuator 30 is detected. The detection can be done in a known manner by a technical measurement integrated in the control and/or regulating appliance 22 (Fig. 1). Depending on the actuation voltage u, again in method step 100, an auxiliary variable m (Fig. 5) is formed.

In simplest particular case, the auxiliary variable m is identical to the actuation voltage u. The auxiliary variable m can also be obtained, in general, as a function of the actuator 30 and/or the actuation current I through the magnetic coil 26. A more common method of filtering and signal processing can also be used to obtain the auxiliary variable m from the actuation voltage u and/or the actuation current I.

In a subsequent method step 110, a reference variable m_{ref} (Fig. 5) is determined as a function of the auxiliary variable m. Subsequently, in method step 120, the auxiliary variable m is modified as a function of the reference variable m_{ref} to obtain modified auxiliary variable m_{mod} (Fig. 5).

The auxiliary variable m_{mod} modified in the manner described above has a particular strong correlation with major changes in the status of the fuel injection valve 18a and is therefore ideally suited for the detection of such operating condition changes. In particular, by the formation of the modified auxiliary variable m_{mod}, it is possible to determine with great precision, a hydraulic closing time of the valve 18a, at which the valve needle 28 reaches a closed position in the area of injection holes and the valve seat 38.

Fig. 4 shows schematically an example of a time curve of the actuation current I for the electromagnetic actuator 26, 30 (Fig. 2a) of the fuel injection valve 18a during a control for a fuel injection system.

To enable a quick opening of the fuel injection valve 18a, starting from a closed state at $t = t_0$, the actuation current I at the time point t0, corresponding to the beginning of actuation, is increased to the booster current I_{boost} from the value I=0. The booster current I_{boost} is reached at the time point t_1. Until the next time point t_2, the booster current I_{boost} is maintained. At the end of time point t_2, the so-called booster phase, which lies between the time point t_0 and the time point t_2, it can be assumed that the fuel injection valve 18a has reached its opening state. In order to obtain the opening of the fuel injection valve 18a for time point $t > t_2$, the actuation current I is then not reduced to zero but to the so-called holding current I_h.

The holding current I_h, shown in Fig. 4, is maintained up to the time point t_3. The time difference $t_3 - t_0$ defines the entire electrical actuation time ET of the fuel injection valve 18a and the electromagnetic actuator 26, 30.

At the end of the actuation time ET, that is, starting from $t = t_3$, the electromagnetic actuator 26, 30, is more acted on, by the control and/or regulating appliance 22, with the actuation current I and a corresponding actuation voltage u, so that the remaining actuation current I following the induction laws ultimately up to the time point t_4 breaks down to zero.

The time point t_{ist} shown in Fig. 4 represents an observed time point within the actuation period ET, whose time interval Δt_3 of the state change of the actuation current I at t

$= t_3$ (end of current flow) is significant for a later described embodiment of the present method.

Fig. 5 shows a time curve of a needle lift h of the valve needle 28 (Fig. 2a), as it is resulted during a control according to the above-described actuation current curve I, as seen in Fig. 4, with substantially less electrical actuation time ET.

With such actuation processes, in which a relatively small actuation duration ET is given or a relatively low maximum valve lift h is given, the auxiliary variable m usually has features that are not directly very easily assessable to reliably determine an actual hydraulic closing time t_s (Fig. 5). At the actual closing time ts, according to the present subject matter, the auxiliary variable m considered here has a non-vanishing curve, but not a simple extrema that is detected in a simpler manner. The representation of the variables shown in Fig. 5 is not drawn to scale. In particular, the auxiliary variable m at the time t_s actually has a far more significant smaller progress than it corresponds to the present configuration of Fig. 5.

Accordingly, the reference variable m_{ref} is formed as a function of the auxiliary variable m to provide an efficient evaluation of the auxiliary variable m. According to an embodiment of the present subject matter, the reference variable m_{ref}, for example, can be obtained as an average of the auxiliary variable m.

A modification of the auxiliary variable m using the reference variable m_{ref}, which is described, due to their determination from the auxiliary variable m, as an appropriate reference, leads to the modified auxiliary variable m_{mod}, which as shown in Fig 5. m_{mod} has a pronounced local minimum Min at the closing time t_s.

Accordingly, the present subject matter enables formation of the reference variable m_{ref} and the subsequent modification of the auxiliary variable m as a function of the reference variable m_{ref}, whereby the modified auxiliary variable m_{mod} is obtained. A simple analysis of the auxiliary variable m and the modified auxiliary variable m_{mod} is done for the occurrence of a change of an operating state such as, as described above, closing of the valve 18a.

According to one embodiment, relatively short actuation times ET and relatively low maximum needle lift h has proven to be particularly reliable. In general, in an embodiment, smoothing methods are used to obtain the reference variable m_{ref} from the time curve of the auxiliary variable m. In the above-described variables, the auxiliary variable m, the reference variables m_{ref}, and the modified reference m_{mod} are used as an appropriate time curve of the respective variables. In an embodiment of the method of the present subject matter with the aid of a digital signal processing, the sampling rate selected for the respective variable m, m_{ref}, m_{mod} according to the desired accuracy is sufficiently high.

As a result, a particularly low-cost computational generation of the modified auxiliary variable m_{mod} is specified, such that the reference variable m_{ref} is subtracted from the auxiliary variable m. It can be provided further in accordance with the present subject matter, that a difference is obtained from the variables m, m_{ref}, which on its part is divided by the auxiliary variable m and/or the reference variable m_{ref}, in order to obtain the modified auxiliary variable m_{mod}, e.g.:

$$m_{mod} = (m - m_{ref}) / m.$$

Fig. 6 shows, as an example, a block diagram of a computing structure for determining the modified auxiliary variable m_{mod} in accordance with the present subject matter. By means of a first function block 200 in accordance with the present subject matter, the reference variable m_{ref} is generated from the actuation voltage u. The auxiliary variable m is obtained by means of a second function block 201, as a function of the actuation voltage u.

As already described, in the simplest case, the auxiliary variable m can be identical to the actuation voltage u. In this case, the first function block 201 can be provided. However, the auxiliary variable m can also be obtained, in the most general, as a function of the actuation voltage u and/or as a function of the actuator current I passing through the magnetic coil 26. A filtering and a conventional method of the signal processing can be used, in order to obtain the auxiliary variable m from the actuation voltage and/or the actuator current.

The reference variable m_{ref} and the auxiliary variable m themselves are then fed to a difference generator 202, which determines the difference $m - m_{ref}$. Because of the characteristics of the reference variable m_{ref} in accordance with the present subject matter, the difference $m - m_{ref}$ obtained at the output of the function block 202 reproduces a signal component of the auxiliary variable m. This signal component results because of the armature movement of the magnetic armature 30 (Fig. 2A).

In an embodiment of the present subject matter, the difference can be directly used as a characteristic of interest, e.g., a local Minimum Min (Fig. 5), and a modified auxiliary variable m_{mod} to be examined.

In another embodiment of the present subject matter, instead of the model 200 (Fig. 6), the reference variable m_{ref} is obtained directly as a function of at least one electrical operating variable, such as the actuation voltage u or the actuator current I, and in fact, from such value(s) of these variables u, I, as they result in an operational mode of the electromagnetic actuator 26, 30, in which there is no movement of the movable component, i.e. presently of the magnetic armature 30 of the electromagnetic actuator 26, 30.

For this purpose, the electromagnetic actuator 26, 30 can be targeted, and for example, actuated in such a manner that an armature movement does not already result. For example, such state may be obtained by means of a sufficiently short actuation duration ET. During the actuation, the values of at least one electrical operating variable u, I are detected by way of measurement, in order to be used further as a reference variable mref within the meaning of the method in accordance with the present subject matter.

In one embodiment, the reference variable m_{ref} determined in accordance with the present subject matter, can be stored even after its determination 110 (Fig. 3) for a prospective use, so that a new determination is not necessary constantly.

Although, the method in accordance with the present subject matter is used for finding the characteristics Min, which cannot be determined by conventional methods, generally other simpler detectable changes in the operational modes can also be detected by the application of the method in accordance with the present subject matter, which involves a uniform evaluation and a correspondingly lower cost.

The other application of the method in accordance with the present subject matter having other methods of detection for further recognizing characteristics of the auxiliary variable m can be conceived as well.

The principle in accordance with the present subject matter is applicable irrespective of whether the auxiliary variable m having the characteristic of interest Min is obtained by means of an analogue or a digital signal processing or by carrying out the known signal processing methods or by preparations, such as filtering, differentiation, integration. In such cases, it is only to be ensured that the model 200 with the signal processing methods simulates the corresponding processing steps, in order that the model 200 based obtained reference variable m_{ref} matches with the auxiliary variable m to be evaluated.

The same holds true for the embodiments of the present subject matter, in which instead of a model based determination of the reference variable m_{ref}, the reference variable m_{ref} is determined from variables u, I obtained by way of measurement.

In the embodiments of the present subject matter, in which the reference variable m_{ref} is determined from variables u, I obtained by way of measurement, it is particularly important further that during the actuation of the actuator 26, 30 for determining the corresponding measured value of the variables u, I for generating the reference variable mref, the actuator or the injection valve 18a has a definitely closed condition, in order to avoid obtaining the signal components generated by the armature movement, as components of the reference variable m_{ref}.