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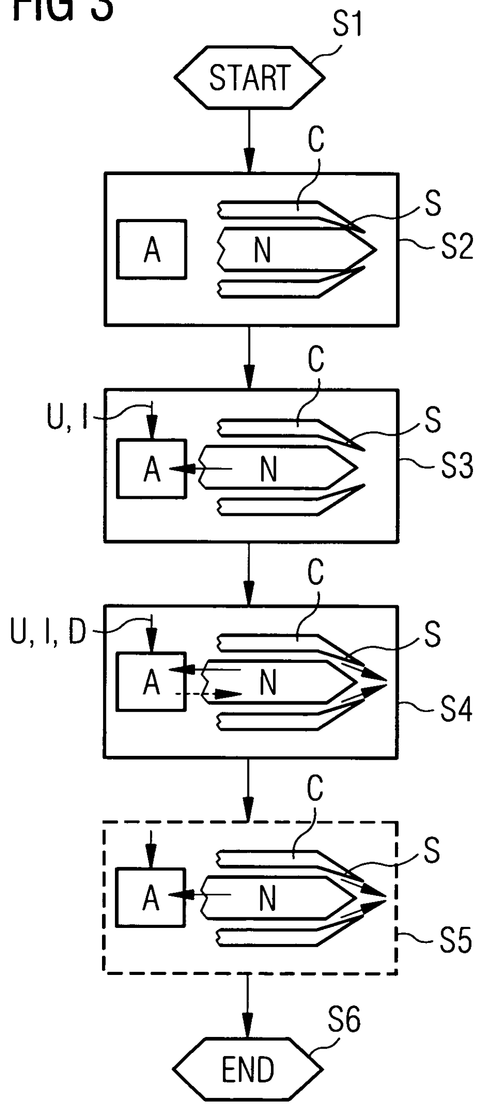
(54) **Method for producing an injector**

(57) In a method for producing an injector the injector is assembled at least to an extent, that a valve needle (N) of the injector can be lifted from its valve seat (S) by applying a drive signal to an actuator (A) of the injector. The drive signal is generated and applied to the actuator (A) of the injector such that the valve needle (N) is lifted from its valve seat (S) for a duration (D) of at least a predetermined minimum static opening duration that is longer than an opening duration during dynamic operation of the injector. A fuel path of the injector is flushed within this duration (D).

FIG 3



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Description

[0001] The invention relates to a method for producing an injector and particularly to a method for producing a fuel injector for injecting fuel into an internal combustion engine.

[0002] During the production of an injector a fuel path of the injector may be contaminated, e.g. with small particles. These particles can get stuck between the valve needle and the valve seat of the injector when dynamically opening and closing the injector valve. By this, the valve needle and/or the valve seat, i.e. a sealing band of the injector valve, can get damaged and the injector may leak afterwards. As a consequence, the injector is rejected after testing and becomes scrap.

[0003] The object of the invention is to provide a method for producing injectors with a low reject rate.

[0004] The invention is characterized by a method for producing an injector. The injector is assembled at least to an extent, that a valve needle of the injector can be lifted from its valve seat by applying a drive signal to an actuator of the injector. The drive signal is generated and applied to the actuator of the injector such that the valve needle is lifted from its valve seat for a duration of at least a predetermined minimum static opening duration. The predetermined minimum static opening duration is longer than an opening duration during dynamic operation of the injector. A fuel path of the injector is flushed within this duration.

[0005] The predetermined minimum static opening duration is long in comparison to a maximum opening duration of the injector valve during the dynamic operation, e.g. when injecting fuel into a cylinder of an internal combustion engine. As a consequence, the valve is statically opened for a comparatively long time instead of dynamically opened and closed in rapid succession as during the dynamic operation. Preferably, the injector is assembled completely before its fuel path is flushed with its valve statically opened. Further, the method is preferably performed before a calibration and/or testing of the injector and is particularly performed directly before the calibration and/or testing of the injector.

[0006] The invention is based on the finding that during production of the injector a fuel path of the injector may be contaminated, e.g. with small particles and particularly with metal particles. These particles can get stuck between the valve needle and the valve seat of the injector when dynamically opening and closing the injector valve. By this, the valve needle and/or the valve seat, i.e. a sealing band of the injector valve, can get damaged and the injector may leak afterwards. As a consequence, the injector is rejected after testing and becomes scrap. By statically opening the injector valve for a time long enough to clean the fuel path from the contamination and particularly from the metal particles, the risk of damage and thus also the risk of rejection of the injector after testing can be reduced significantly. With the injector valve statically opened the fuel path of the injector can be flushed easily and the fuel path can be cleaned from the contamination. Because the injector valve is opened for the duration of at least the predetermined minimum static opening duration that is longer than an opening duration during dynamic operation the risk is reduced that the contaminating particles get caught between the valve needle and the valve seat. By this, the risk is reduced that the valve needle and/or the valve seat are damaged when closing the injector valve due to the particles caught between the valve needle and the valve seat. Another advantage is that the method is compatible with serial production.

[0007] According to a preferred embodiment, the drive signal is generated within the duration comprising a sequence of at least two pulses modulating a degree of opening of the injector valve. The injector valve keeps open during the sequence, i.e. the valve needle does not touch the valve seat. Due to the modulation of the degree of opening of the injector valve a pressure of a fluid used for flushing is also modulated and pulsates accordingly. By this, a better cleaning effect is achieved without the risk of damage.

[0008] According to a further preferred embodiment, each pulse has a pulse duration of at least the predetermined minimum static opening duration. The advantage is that the fuel path of the injector and particularly a region of the injector valve between the valve needle and the valve seat can be cleaned particularly well and reliably. Preferably, the sequence comprises at least 15 pulses.

[0009] According to a further preferred embodiment, the predetermined minimum static opening duration amounts to at least 0.2 seconds. By this, the duration is more than one magnitude longer than the maximum opening duration during the dynamic operation in the engine and the injector valve is open long enough to flush most particles and thus to reduce the risk of damage. For example, the predetermined minimum static opening duration is roughly one thousand times longer than the maximum opening duration during the dynamic operation in the engine. Preferably, the predetermined minimum static opening duration amounts to at least 0.4 seconds and further preferably amounts to at least 0.5 seconds. Preferably, the whole flushing procedure, including more than one pulse if applicable, has a duration of several seconds, for example more than five seconds and preferably about seven seconds. By this, the fuel path of the injector and particularly a region of the injector valve between the valve needle and the valve seat can be cleaned particularly well and reliably.

[0010] According to a further preferred embodiment, the drive signal is generated such that the valve needle is lifted at least 20 micrometers from the valve seat. By this, for example, the valve needle is lifted more than 25 percent and preferably at least 30 percent with respect to a predetermined maximum lift of the valve needle from the valve seat. The opening of the injector valve is then wide enough to let particles pass. Preferably, the drive signal is generated such that the valve needle is lifted at least 30 micrometers from the valve seat and is further preferably lifted about 35 micrometers from the valve seat. By this, for example, the valve needle is lifted about 50 percent with respect to the predetermined maximum lift of the valve needle from the valve seat. The opening is then big enough to let even comparatively big particles pass. The fuel path of the injector and particularly a region of the injector valve between the valve needle and the valve seat can be cleaned particularly well and reliably.

[0011] According to a further preferred embodiment, the drive signal is generated comprising a voltage step of at least 80 percent of a predetermined maximum voltage of the actuator. When the actuator of the injector is a piezo actuator the degree of opening of the injector valve may be dependent on a voltage of the drive signal. By applying the voltage step to the actuator of the injector the injector valve can be opened wide enough to let particles pass. Preferably, the drive signal is generated comprising a voltage step of at least 160 volt. The opening is then big enough to let even comparatively big particles pass. By this, the fuel path of the injector and particularly a region of the injector valve between the valve needle and the valve seat can be cleaned particularly well and reliably.

[0012] According to a further preferred embodiment, the drive signal is generated such that a current of the drive signal is limited to a predetermined maximum current that is predetermined for a static activation of the actuator. When the actuator of the injector is a piezo actuator the piezo ceramics may not be able to tolerate a high current for a long time while a static load is applied. By limiting the current the piezo actuator can be secured from damage. Preferably, the predetermined maximum current amounts to about 50 milliampere. By this, the actuator can reliably be secured from damage.

[0013] In the following, embodiments of the invention are illustrated with reference to the schematic drawings.

[0014] The figures are illustrating:

FIG. 1, a first diagram with a voltage and a current of a drive signal,

FIG 2, a second diagram with the voltage of the drive signal and

FIG. 3, a flow chart of a method for producing an injector.

[0015] Elements of same construction or function are provided with the same reference signs throughout all figures.

[0016] An injector and in particular a fuel injector for injecting fuel into an internal combustion engine comprises a cartridge C with a valve seat S. A valve needle N is arranged axially movable within the cartridge C such that the valve needle N is seated on the valve seat S in a closed position of the injector valve and is lifted of the valve seat S in an opened position of the injector valve. The injector further comprises an actuator A coupled with the valve needle N to move the valve needle N in the opened position or the closed position of the injector valve dependent on a drive signal applied to the actuator A. The actuator A preferably is designed as a piezo actuator comprising a stack of piezo ceramics. The actuator A can alternatively be designed differently.

[0017] During production and after assembly of the injector a fuel path of the injector often is contaminated with small metal particles. During a calibration phase and/or testing phase of the injector or, even worse, later during operation of the injector for example in the internal combustion engine, i.e. when the injector valve is dynamically opened and closed in rapid succession, such particles may get caught between the valve needle N and the valve seat S. Due to the forces acting between the valve needle N and the valve seat S when closing the injector valve the valve needle N and/or the valve seat S may get damaged because of the particle caught between them, i.e. a sealing band of the injector valve may get damaged. As a consequence, the injector may leak, is rejected after testing and becomes scrap.

[0018] To avoid such damage of the injector the fuel path of the injector is flushed while the injector valve is statically opened, i.e. does not open and close in rapid succession, for example within a few ten or hundred microseconds, as may be the case during normal dynamic operation in the internal combustion engine. Preferably, a suitable fluid and in particular a suitable liquid is used for flushing. Preferably, the fluid is applied to the fuel path of the injector under high pressure such that the fluid is pressed through the fuel path and out of the opening of the statically opened injector valve. By this, contamination of the fuel path and particularly the metal particles in the fuel path can be flushed out of the injector. Because the injector valve keeps open during the complete flushing procedure, i.e. the valve needle N does not touch the valve seat S, no particles can get caught between the valve needle N and valve seat S and pressed with high forces into the material of the valve needle N and/or the valve seat S. Thus, the risk of damage of the injector is reduced.

[0019] Figure 1 shows a first diagram with a voltage U and a current I of the drive signal applied to the actuator A for statically opening the injector valve. The injector valve is opened, i.e. the valve needle N is lifted from its valve seat S, for a duration D. The duration D is at least a predetermined minimum static opening duration long. The predetermined minimum static opening duration is longer than an opening duration during dynamic operation of the injector, i.e. when the injector valve is opened and closed in rapid succession during normal dynamic operation in the internal combustion engine. Generally, the opening duration during dynamic operation of the injector may be a few ten or hundred microseconds long but is less than 200 milliseconds long. The predetermined minimum static opening duration preferably amounts to at least 200 milliseconds and further preferably amounts to at least 400 milliseconds or even longer. For example, the whole flushing procedure, i.e. the duration D, is five seconds long or longer and is preferably about seven seconds long. The duration D can also be selected differently and particularly depends on the conditions, e.g. a degree of contamination, a degree of cleanliness required, the fluid used for flushing, the pressure used for pressing the fluid through the fuel pass, etc.

[0020] Further, the drive signal for the actuator A is applied with the voltage U comprising a voltage step VS and with the current I being limited to a predetermined maximum current IMAX. The limitation of the current I to the predetermined maximum current IMAX is important to avoid damage of the actuator A. Application of too high a current I could damage the piezo ceramics of the actuator A. The predetermined maximum current IMAX depends on the design of the actuator A and may be different for different designs of the actuator A. For example, the predetermined maximum current IMAX amounts to 50 milliampere. The predetermined maximum current IMAX can alternatively be predetermined differently.

[0021] The voltage step VS is selected such that an opening of the statically opened injector valve is wide enough to let the contamination and in particular the particles pass. The voltage step VS required for this thus depends on the design of the injector. To allow for comparatively big particles to pass through the opening of the statically opened injector valve the voltage step VS preferably amounts to at least eighty percent of a predetermined maximum voltage of the actuator A. Preferably, the valve needle is then lifted at least 20 micrometers from the valve seat S and is further preferably lifted at least 30 micrometers, for example about 35 micrometers, from the valve seat S. The predetermined maximum voltage depends on the design of the actuator A and may be different for different designs of the actuator A. For example, the predetermined maximum voltage amounts to 200 volt and the voltage step VS amounts to about 160 volt. The predetermined maximum voltage and the voltage step VS and the opening degree of the injector valve can alternatively be predetermined differently.

[0022] The drive signal preferably is generated by a switching unit designed to switch on so slowly that a peak of current I does not exceed the predetermined maximum current IMAX. Voltage U and current I then each set according to the electronic conditions of the electronic circuit comprising the actuator A. For example, the piezo actuator electronically behaves similar to a capacitance. After switching on, the voltage U of the capacitance rises to the voltage predetermined by the voltage step VS and the current I falls after its initial peak. The duration D is preferably long enough so that the voltage U of the actuator A reaches the voltage predetermined by the voltage step VS. A different design of actuator A may result in a different drive signal.

[0023] Figure 2 shows a second diagram with the voltage U of the drive signal. Preferably, the drive signal is generated comprising a sequence SEQ of at least two pulses, for example a first pulse P1 and a second pulse P2. Preferably, each pulse reaches the voltage predetermined by the voltage step VS, but it is alternatively also possible to have pulses with different amplitudes and/or maximum voltages. The sequence SEQ of pulses is applied to the actuator A within the duration D. Each pulse has a pulse duration PD. Preferably, the pulse duration PD is at least as long as the predetermined minimum static opening duration, but it is alternatively also possible that the pulse duration PD of one or more than one or all pulses is shorter than the predetermined minimum static opening duration. Further, the pulse duration PD may be equal for all pulses or may alternatively be different. Because of the pulses of the drive signal a degree of opening of the injector valve is modulated.

[0024] During the duration D, and thus also during the sequence SEQ, the injector valve keeps open, i.e. the valve needle N does not touch the valve seat S. This is for example achieved by not letting the voltage U of the actuator A fall back to zero voltage between two consecutive pulses, i.e. after switching on the drive signal the voltage U of the actuator A is kept above zero voltage such that the injector valve keeps statically opened during the duration D. Again, the drive signal may have to be generated differently when using a differently designed actuator A, particularly when not using the piezo actuator as actuator A. For example, the pulse duration PD amounts to about 0.4 to 0.5 seconds and a pulse interval amounts to about 0.8 to 1 seconds. The pulse duration PD and/or the pulse interval may alternatively be selected differently. Preferably, more than two pulses are generated within the duration D, and further preferably, at least fifteen pulses are generated within the duration D.

[0025] Figure 3 shows a flow diagram of a method for producing an injector. The method begins in a step S1. In a step S2, the injector is assembled at least to an extent, that the valve needle N can be lifted from its valve seat S at the cartridge C by applying the drive signal to the actuator A. Preferably, the injector is completely, i.e. finally, assembled in step S2. In a step S3, the drive signal is generated and is applied to the actuator A of the injector as explained with reference to figures 1 and 2. By this, the valve needle N is lifted from its valve seat S and the injector valve is thus opened. The injector valve is kept statically opened for the duration D of at least the predetermined minimum static opening duration. Within the duration D, the fuel path of the injector is flushed in a step S4, for example by pressing the fluid through the fuel path. One pulse or preferably two or more than two pulses may be generated in the drive signal as explained above with reference to figures 1 and 2. After the flushing and preferably directly after the flushing, i.e. after an end of duration D, a step S5 may be performed in which the injector is calibrated and/or tested. During calibration and/or testing a different drive signal may be generated to dynamically open and close the injector valve in rapid succession. Due to the flushing with statically opened injector valve the risk of damage and rejection of the injector is reduced. The method ends in a step S6.

Claims

1. Method for producing an injector, wherein

   - the injector is assembled at least to an extent, that a valve needle (N) of the injector can be lifted from its valve seat (S) by applying a drive signal to an actuator (A) of the injector,
   - the drive signal is generated and applied to the actuator (A) of the injector such that the valve needle (N) is lifted from its valve seat (S) for a duration (D) of at least a predetermined minimum static opening duration that is longer than an opening duration during dynamic operation of the injector and
   - a fuel path of the injector is flushed within this duration (D).

2. Method according to claim 1, wherein the drive signal is generated within the duration (D) comprising a sequence (SEQ) of at least two pulses modulating a degree of opening of the injector valve.

3. Method according to claim 2, wherein each pulse has a pulse duration (PD) of at least the predetermined minimum static opening duration.

4. Method according to any one of claims 2 or 3, wherein the sequence (SEQ) comprises at least 15 pulses.

5. Method according to any one of the previous claims, wherein the predetermined minimum static opening duration amounts to at least 0.2 seconds.

6. Method according to any one of claims 1 to 4, wherein the predetermined minimum static opening duration amounts to at least 0.4 seconds.

7. Method according to any one of the previous claims, wherein the drive signal is generated such that the valve needle (N) is lifted at least 20 micrometers from the valve seat (S).

8. Method according to any one of claims 1 to 6, wherein the drive signal is generated such that the valve needle (N) is lifted at least 30 micrometer from the valve seat (S).

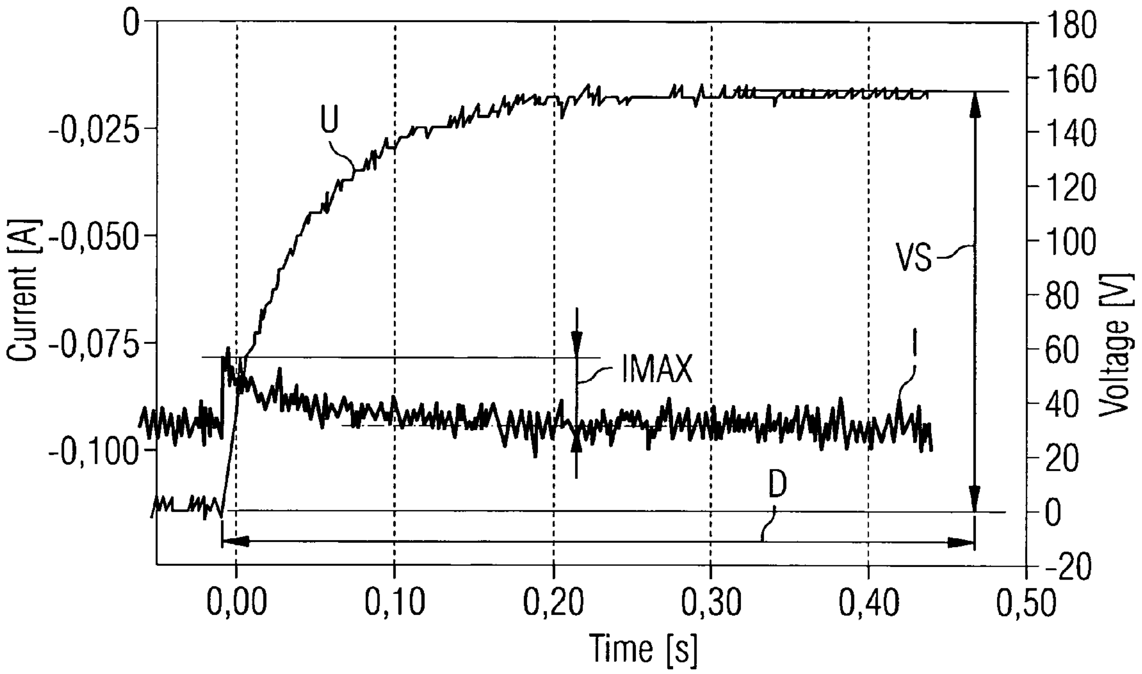
9. Method according to any one of the previous claims, wherein the drive signal is generated comprising a voltage step (VS) of at least 80 percent of a predetermined maximum voltage of the actuator.

10. Method according to any one of the previous claims, wherein the drive signal is generated comprising a voltage step (VS) of at least 160 volt.

11. Method according to any one of the previous claims, wherein the drive signal is generated such that a current (I) of the drive signal is limited to a predetermined maximum current (IMAX) that is predetermined for a static activation of the actuator.

12. Method according to claim 11, wherein the predetermined maximum current amounts to about 50 milliampere.

FIG 1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20
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-20
Voltage [V]
U
VS
IMAX
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D
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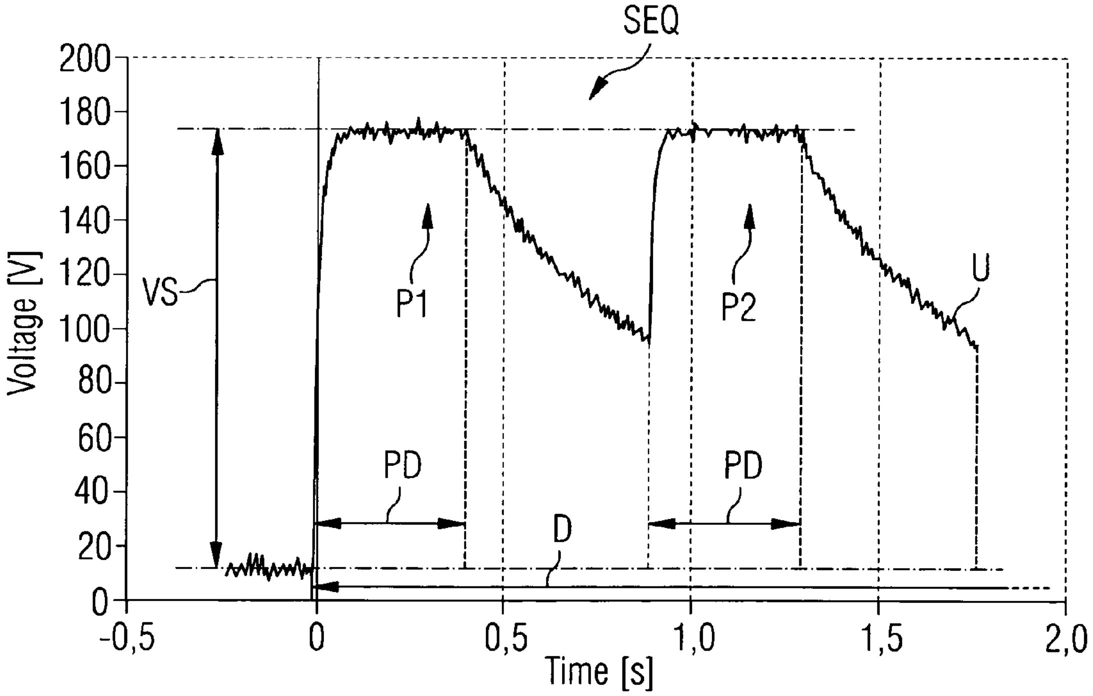
Time [s]

FIG 2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180
160
140
120
100
80
60
40
20
0
Voltage [V]
VS
P1
P2
U
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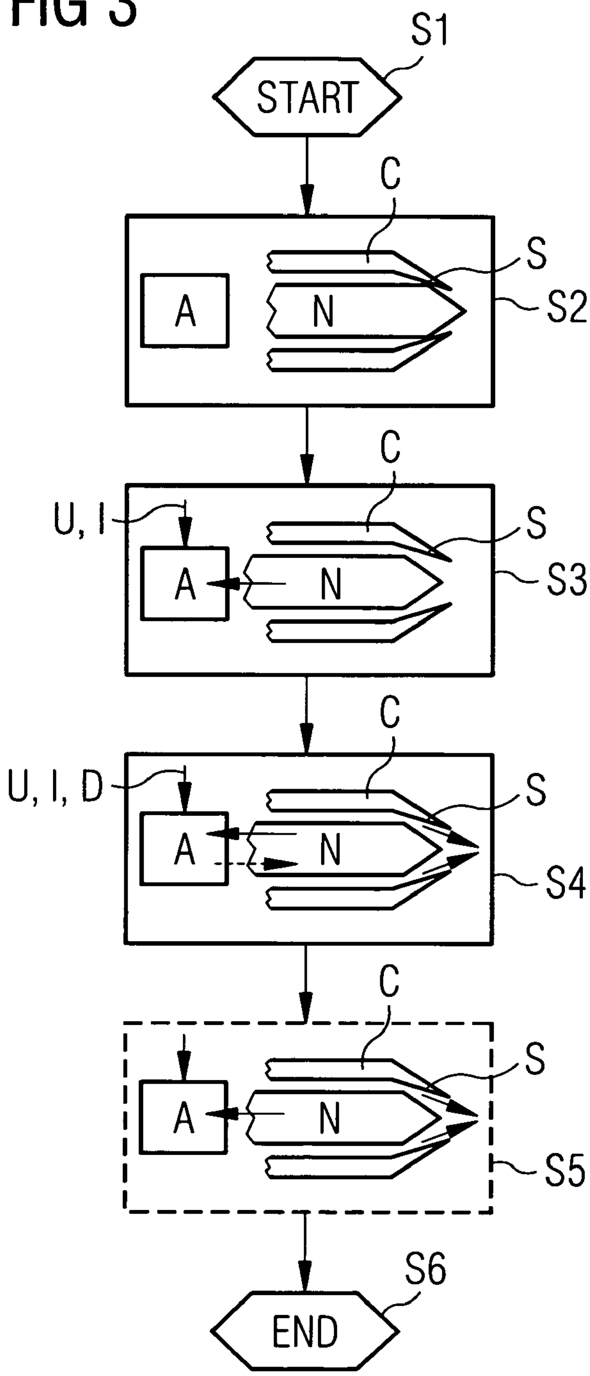
Time [s]

FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 08 00 8611

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 295 627 A (WAHBA BRENT J [US]) 22 March 1994 (1994-03-22) * column 1, line 57 - column 2, line 4; figures *	1-12	INV. F02M65/00 F02M61/16
A	WO 96/33344 A (NEW AGE AUTOMOTIVE PTY LTD [AU]; SCHOENFELD PETER FREDERICK [AU]) 24 October 1996 (1996-10-24) * page 2, line 12 - page 6, line 11; figure 4 *	1-12	
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A	DE 103 26 914 A1 (BOSCH GMBH ROBERT [DE]) 5 January 2005 (2005-01-05) * paragraph [0007]; figure 5 *	1-12	

TECHNICAL FIELDS SEARCHED (IPC)

F02M
F02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 November 2008	Torle, Erik

CATEGORY OF CITED DOCUMENTS

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EP 08 00 8611

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