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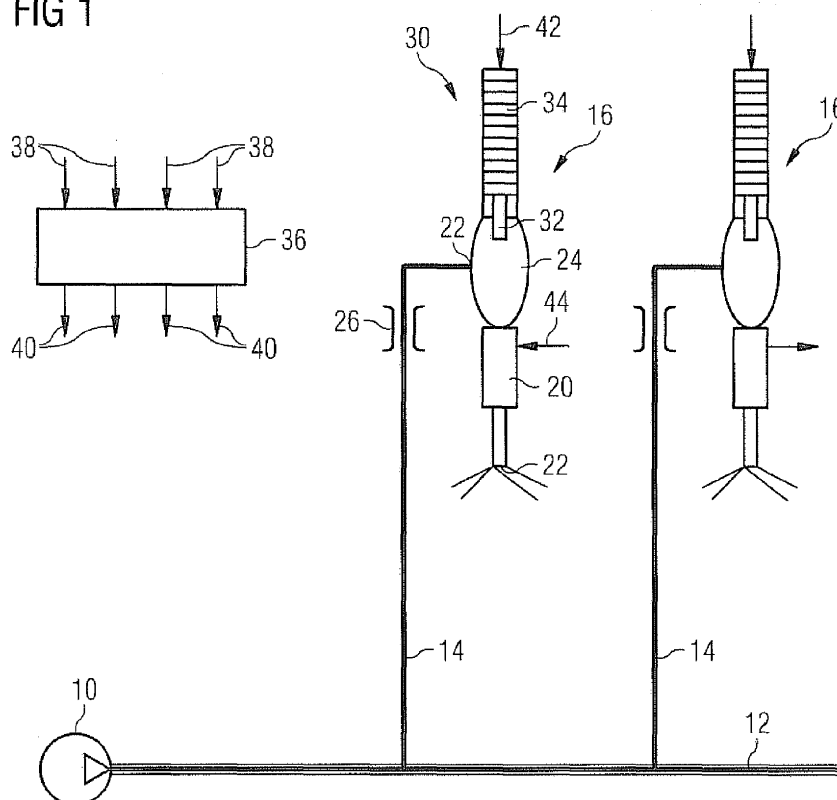
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(54) **A method for controlling an injection rate of a common rail fuel injector, a common rail fuel injection system and a fuel injector**

(57) A common rail fuel injection system may include a common rail (12) adapted to be supplied with a fuel under high pressure, at least one fuel injector (16) with an injection valve, whose upstream side is connected to the common rail (12) via a fuel supply line (14) that passes through a throttle (26) and a storage chamber provided

between the throttle and the injection valve, a valve actuating device (44) for opening and closing the injection valve, a pressure modulating device (30) for modulating the pressure within the storage chamber and a control device (36) for controlling the valve actuating device and the pressure modulating device.

FIG 1



Description

Technical Field

[0001] The present disclosure refers to a method for controlling an injection rate of a common rail fuel injector, and further refers to a common rail fuel injection system and a fuel injector adapted to be used in a common rail fuel injection system.

Background

[0002] US 4,728,074 discloses a piezoelectric flow control valve comprising a slidable closure member for controlling a flow of fluid through a fluid passage between a fluid inlet and a fluid outlet. The closure member is biased towards a normally closed position by a plunger responsive to a hydraulic pressure in a pressure chamber, which pressure chamber is in fluid communication with a fluid inlet through a restriction, and with a pumping chamber of a piezoelectric pump. In order to prevent fluid leakage under conditions where the fluid pressure in the fluid inlet is not high enough to ensure that the closure member is in the closed position, a spring bias pressure mechanism for biasing the closure member towards the normally closed position, and override means for overriding the spring bias pressure mechanism in response to a predetermined pressure at the fluid inlet are provided.

[0003] US 7,588,012 B2 discloses a fuel injector with a nozzle member having at least one orifice, and a needle valve element having a tip end. The needle valve element is axially moveable to selectively allow and block a fuel flow through the at least one orifice with its tip end. The fuel injector also has a fuel supply line in communication with the tip end of a needle valve and a variable restrictive device disposed within the fuel supply line.

[0004] US 2007/0215716 A1 discloses a fuel injector comprising a valve needle and damping means for damping opening movement of the valve needle, the damping means comprising a damper chamber, and the damping means being arranged such that fuel pressure variations within the damper chamber damp opening movement of the valve needle.

[0005] Conventional common rail injectors exhibit a spontaneous opening process of an injector needle. The large volume of fuel that is injected thereby results in high temperatures at the beginning of the combustion and, therefore, in undesirably high emissions of NO_x.

[0006] As a remedial measure, common rail injectors can generate arbitrary individual injection events by directed feed of electric current, thereby enabling a certain injection rate formation for generating a smoothly initiated combustion. These individual injection events are known as comparatively early "pre-injections" which are relatively close to a main injection.

[0007] Another possibility to form the injection volume characteristics at the beginning of the objection is provided by means of a "controlled" injection needle, where-

in, by virtue of hydraulic effects, the injection needle does not open abruptly, but a subtle needle stroke is generated. This can be implemented either by variation of the needle closing force or by dampening devices at the injection needle itself.

[0008] Injectors as used in common rail injection systems usually differ from each other at the beginning of the injection, or their performance changes after a longer period of operation.

[0009] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of prior systems.

Summary of the Disclosure

[0010] According to one aspect of the present disclosure, a method for controlling an injection rate of a common rail fuel injector comprising an injection valve, wherein an upstream side of the injection valve is connected to a common rail via a fuel supply line passing through a throttle, comprises a step of modulating the fuel pressure upstream of the injection valve by changing a volume of the fuel supply line between the throttle and the injection valve.

[0011] According to a further aspect of the present disclosure, a common rail fuel injection system may include a common rail adapted to be supplied with a fuel under high pressure, at least one fuel injector with an injection valve, whose upstream side is connected to the common rail via a fuel supply line that passes through a throttle and a storage chamber provided between the throttle and the injection valve, a valve actuating device for opening and closing the injection valve, a pressure modulating device for modulating the pressure within the storage chamber, and a control device for controlling the valve actuating device and the pressure modulating device.

[0012] According to a still further aspect of the present disclosure, a fuel injector adapted to be used in a common rail injection system may include an injection valve, a fuel supply passage that is provided with a storage chamber and connects an upstream side of the injection valve to an inlet, which is adapted for being connected to the common rail, and a pressure modulating device for modulating the pressure within the storage chamber.

[0013] Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

Brief Description of the Drawings

[0014] The accompanying drawings, which are incorporated herein and constitute part of the specification, illustrate an exemplary embodiment of the disclosure and, together with the description, serve to explain the principles of the disclosure.

[0015] Fig. 1 shows a principle layout of a common rail fuel injection system.

[0016] Fig. 2 shows graphs which illustrate aspects of

the present disclosure.

Detailed Description

[0017] An exemplary embodiment of a common rail fuel injector system will be described with reference to Fig. 1.

[0018] A common rail fuel injection system may comprise a highpressure pumping device 10, which supplies fuel, preferably diesel fuel under a high pressure, e.g. in the range of 1500 bar, to a common rail 12.

[0019] The common rail 12 may be connected to fuel injectors 16, which are assigned to individual cylinders of a multi-cylinder combustion engine, via individual fuel supply lines 14.

[0020] The individual fuel supply lines 14 and the fuel injectors 16 are basically similar or identical to each other; therefore only one of them is described in the following.

[0021] A fuel injector 16 may include an injection valve, accommodated within a housing, which injection valve may comprise a valve actuating device for actuating a valve member, e.g. a valve needle that may be moveable by the valve actuating device 20 to close or open an injection valve. An upstream side of the injection valve may be connected to the fuel supply line 14 via a fuel supply passage. At a downstream side of the injection valve, at least one fuel nozzle 22 may be provided for injecting fuel into a cylinder when the injection valve is open. The fuel injection valve is not described in detail, because it may be designed as commonly known.

[0022] The fuel supply line 14 may be connected to an inlet 22 of the fuel injector, which inlet 22 may be connected to the upstream side of the injection valve via the fuel supply passage. The fuel supply passage may pass through, or include, a storage chamber, which increases the volume of the fuel supply passage between the inlet 22 and the upstream side of the injection valve.

[0023] A throttle 26 with a restricted flow through opening may be provided upstream of the storage chamber 24 near the inlet 22, or within the fuel injector downstream of the inlet 22, but upstream of the storage chamber 24.

[0024] A pressure modulating device 30 for modulating the pressure within the storage chamber 24 may be provided. The pressure modulating device 30 may include a plunger 32 protruding through a fixed wall of the storage chamber 24 in a fluid tight manner. The plunger 32 may be linearly moved with its free end portion such that the portion of the plunger 32, which protrudes into the storage chamber 24, increases or decreases. The portion of the plunger 32 protruding into the storage chamber 24 constitutes a moveable wall, so that the effective volume of the storage chamber 24 may be changed according to the position of the plunger 32. The pressure modulating device 30 may further include a plunger actuating device 34, which may include a piezo stack. An effective length of the piezo stack changes in accordance with a voltage applied to the piezo stack. This dimensional change is transferred to a linear movement of the plunger 32.

[0025] An electronic control device 36 may be provided. Inlet connectors 38 of the electronic control device are connected to sensors providing signals, which are relevant for the fuel injection, e.g. load and speed of an engine.

[0026] Exit connectors 40 of the electronic control device 36 are connected to a connector 42 of the plunger actuating device and connector 44 of the valve actuating device 20. The position of the plunger 32 changes according to the voltage applied to connector 42. The injection valve opens depending on the voltage applied to connector 44.

Industrial Applicability

[0027] As will be explained below, the common rail fuel injection system as described above with reference of Fig. 1 allows for a smoothly increasing injection rate even in a case where a valve member, e.g. a valve needle, of the fuel injector opens the injection valve within a short time. Due to this smoothly increasing rate of the fuel injected into a burning chamber of a cylinder, the engine runs more smoothly, pollutant emission, especially with respect to NOx generation, can be decreased and the lifetime of the engine may be improved due to a decrease of mechanical loads.

[0028] In Fig. 2 the solid lines in graphs b) to e) show functional parameters of a conventional common rail fuel injection system that does not include the storage chamber 24 according to Fig. 1. The abscissa of each graph gives the time with the same time elapse.

[0029] Graph b) shows a storage pressure, which is the fuel pressure immediately upstream the injection valve. The horizontal line means a storage pressure of 1500 bar in the shown example.

[0030] Graph c) shows the injection rate, i.e. the volume of fuel injected by the injection orifice(s) of the fuel injector per time.

[0031] Graph d) shows a stroke of the valve member of the fuel injector, e.g. a valve needle.

[0032] Graph e) shows the current flowing through the valve actuating device 22, e.g. a coil of an electromagnet, which directly or indirectly actuates the valve needle. The injector current is caused by the voltage applied to connector 44 by electronic control device 36.

[0033] Let us assume that the injection valve is closed, i.e. no voltage is applied to connector 44, and that there is a storage pressure of 1500 bar upstream the injection valve. At time t_1 a first voltage is applied to connector 44, which leads to a steep increase of the injector current raising up to a current i_1 . At time t_2 the voltage applied to connector 44 is decreased to a second value, which leads to a decrease of the injector current to i_2 . At time t_3 , voltage on connector 44 is decreased to 0, so that the current also decreases to 0 with a decrease rate determined by the design of the electromagnet.

[0034] The course of the current as described above leads to a course of the needle stroke as shown by graph

d). Due to the high injector current i_1 the valve needle moves to its maximal stroke within short, said maximal stroke being maintained when the injector current decreases to i_2 . The valve needle closes within a short period after the injector current has decreased to 0.

[0035] During the opening movement of the needle stroke between t_1 and t_2 , the storage pressure is constant at 1500 bar. As soon as the valve needle begins its opening movement, injection starts at a steeply increasing injection rate. The injection rate is determined by the entire cross-section of the nozzle orifice(s) and the pressure drop across the nozzle orifice(s) as soon as the flow through cross section of the injection valve is bigger than an oval cross-section of the nozzle orifice(s). Due to the volume of fuel injected through the nozzle orifice(s) and flow resistances upstream of the injection valve, especially the flow resistance caused by the throttle 26, the storage pressure slightly decreases while the injection valve is open and fuel is injected. The gradient of the pressure decrease upstream of the injection valve, e.g. within the storage chamber 24, is marked by α in Fig. 2. As soon as the injection valve closes, the storage pressure begins to increase to its original value of 1500 bar.

[0036] In the following, the effect of the pressure modulating device 30 will be explained by means of the dotted graphs of Fig. 2. Graph a) shows the voltage applied to the piezo stack of the plunger actuating device 34.

[0037] The position of the plunger 32 is determined by a constant voltage V_1 applied to the connector 42 by the electronic control device 36. Simultaneously with or shortly before start of the injection, the piezo stack of the plunger actuating device 34 is de-energized, which causes the plunger 32 to move out of the storage chamber 26 by a given distance, whereby the volume of the storage chamber 24 is increased. This results in a pressure decrease gradient β in the storage chamber 24, which is higher than the pressure decrease gradient α without activating the pressure modulating device 30. The higher gradient of the storage pressure decrease leads to a lower gradient of the increasing injection rate according to the dotted graph c).

[0038] The smooth increase of the injection rate despite the sudden movement of the needle results in a smooth initiation of combustion of the injected fuel, and a smooth increase of the working pressure that acts on a piston of the combustion engine.

[0039] During the injection (between time t_2 and t_3), voltage is again applied to the piezo stack of the pressure modulating device 30. The voltage V_2 applied to connector 42 during an injection is preferably higher than voltage V_1 for a given period that ends after the injection valve has been closed. Due to this higher voltage V_2 , piston 32 moves further into the storage chamber 24 than during voltage V_1 , and thus the storage pressure may even exceed the value of 1500 bar. Therefore, the injection rate may increase to a value higher than the value when the pressure modulating device 33 is not activated.

[0040] After the given period, V_2 is decreased to V_1 so

that the plunger 32 moves to its original position to be ready for a new injection cycle.

[0041] As has been discussed above, the fuel pressure upstream of the injection valve is advantageously reduced before and/or during opening of the injection valve. By reducing the fuel pressure in this way the injection rate can be controlled so as to rise smoothly.

[0042] Furthermore, it is advantageous to increase the fuel pressure before and/or during closing of the injection valve. By doing so, it can be ensured that the injection rate increases until the end of injection.

[0043] The pressure modulating device of the common rail injection system may include a moveable plunger and a plunger actuating device for moving the plunger, wherein a volume of the storage chamber changes according to a position of the plunger. This allows changing the pressure upstream of the injection valve so as to form the injection rate in order to achieve a smooth operation of the engine, with low pollutant emission.

[0044] As has been explained above, the valve actuating device and the plunger actuating device are preferably controlled by the control device such that the volume of the storage chamber is increased before and/or during an opening of the injection valve.

[0045] Furthermore, the valve actuating device and the plunger actuating device are preferably controlled by the control device such that the volume of the storage chamber is decreased before and/or during closing of the injection valve.

[0046] When the plunger actuating device includes a piezo stack that is connected to the plunger, the position of the plunger can be precisely controlled by a voltage applied to the piezo stack.

[0047] The fuel injector may include the pressure modulating device with a moveable plunger that forms a part of a wall of the storage chamber, and a plunger actuating device for moving the plunger, as an integrated unit.

[0048] The plunger actuating device of the fuel injector preferably includes a piezo stack.

[0049] The common rail fuel injection system as described above with reference to Figs. 1 and 2 may be modified in many ways.

[0050] The storage chamber may, for example, be formed within a member separate from a body including the injection valve and the valve actuating device. The moveable wall of the storage chamber 24, which allows for changing the volume of the storage chamber 24, may be actuated by a device other than a piezo stack, e.g. by a hydraulic device, electromagnetic device and so on.

The position of the moveable wall, in the illustrated example the position of the plunger 32, may be controlled such that the volume of the storage chamber is decreased only during the beginning phase of the opening of the injection valve, and returns to its normal volume during injection.

[0051] Although the preferred embodiments of this invention have been described herein, improvements and modifications may be incorporated without departing

from the scope of the following claims.

Claims

1. A method for controlling an injection rate of a common rail fuel injector (16) with an injection valve, whose upstream side is connected to a common rail (12) via a fuel supply line (14) that passes through a throttle (26), the method comprising:

modulating the fuel pressure upstream of the injection valve by changing a volume of the fuel supply line between the throttle and the injection valve.

2. The method according to claim 1, wherein the fuel pressure is reduced before opening of the injection valve.
3. The method according to claim 1 or 2, wherein the fuel pressure is reduced during opening of the injection valve.
4. The method according to any one of claims 1 to 3, wherein the fuel pressure is increased before closing of the injection valve.
5. The method according to any one of claims 1 to 4, wherein the fuel pressure is increased during closing of the injection valve.
6. The method according to any one of claims 1 to 5, wherein the step of modulating the fuel pressure is adapted to generate a desired injection rate profile, which in particular is defined as the volume of fuel injected through the injection orifice(s) of the fuel injector per time.
7. The method according to any one of claims 1 to 6, wherein the step of modulating the fuel pressure is adapted to generate a soft initial increase of combustion pressure and/or an excess combustion pressure, in particular at the end of the injection, with respect to the combustion pressure supplyable without throttle activation.
8. A fuel injector (16) for a common rail injection system, the fuel injector (16) comprising:

an injection valve;
a fuel supply passage provided with a storage chamber (24) and connecting an upstream side of the injection valve to an inlet, which is configured for being connected to the common rail (12); and
a pressure modulating device (30) configured to modulate pressure within the storage chamber

(24).

9. The fuel injector according to claim 8, wherein the pressure modulating device comprises a movable plunger (32) that forms a part of a wall of the storage chamber (24), and a plunger actuating device (34) configured to move the plunger.
10. The fuel injector according to claim 8 or 9, wherein the plunger actuating device (34) comprises a piezo stack, which in particular is connected to the plunger (32).
11. The fuel injector according to any one of claims 8 to 10, wherein a volume of the storage chamber (24) is configured to change according to a position of the plunger.
12. A common rail fuel injection system comprising a common rail (12) adapted to be supplied with a fuel under high pressure;
at least one fuel injector (16) according to any one of claims 8 to 11, whose upstream side of the injection valve is connected to the common rail (12) via a fuel supply line (14) that passes through a throttle (26), and the storage chamber (24) provided between the throttle and the injection valve; and
a valve actuating device (44) configured to open and close the injection valve of the fuel injector (16).
13. The common rail system according to claim 12, further comprising at least one control device (36) configured to control the valve actuating device and/or the pressure modulating device, and
wherein the valve actuating device (20) and the plunger actuating device (34) are controlled by the control device (36) such that the volume of the storage chamber (24) is increased before and/or during opening of the injection valve.
14. The common rail system according to claim 12 or 13, further comprising at least one control device (36) configured to control the valve actuating device and/or the pressure modulating device, and
wherein the valve actuating device (20) and the plunger actuating device (34) are controlled by the control device (36) such that the volume of the storage chamber (24) is decreased before and/or during closing of the injection valve.
15. The common rail system according to any one of claims 12 to 14, further comprising at least one control device (36) configured to control the valve actuating device and/or the pressure modulating device such that a desired injection rate profile is generated, wherein the injection rate profile in particular is defined as the volume of fuel injected through the injection orifice(s) of the fuel injector per time, and

wherein the desired injection rate profile defines, for example, to a soft initial increase of combustion pressure and/or an excess combustion pressure with respect to the combustion pressure suppliable without throttle activation, and wherein the excess pressure is provided in particular at the end of the injection.

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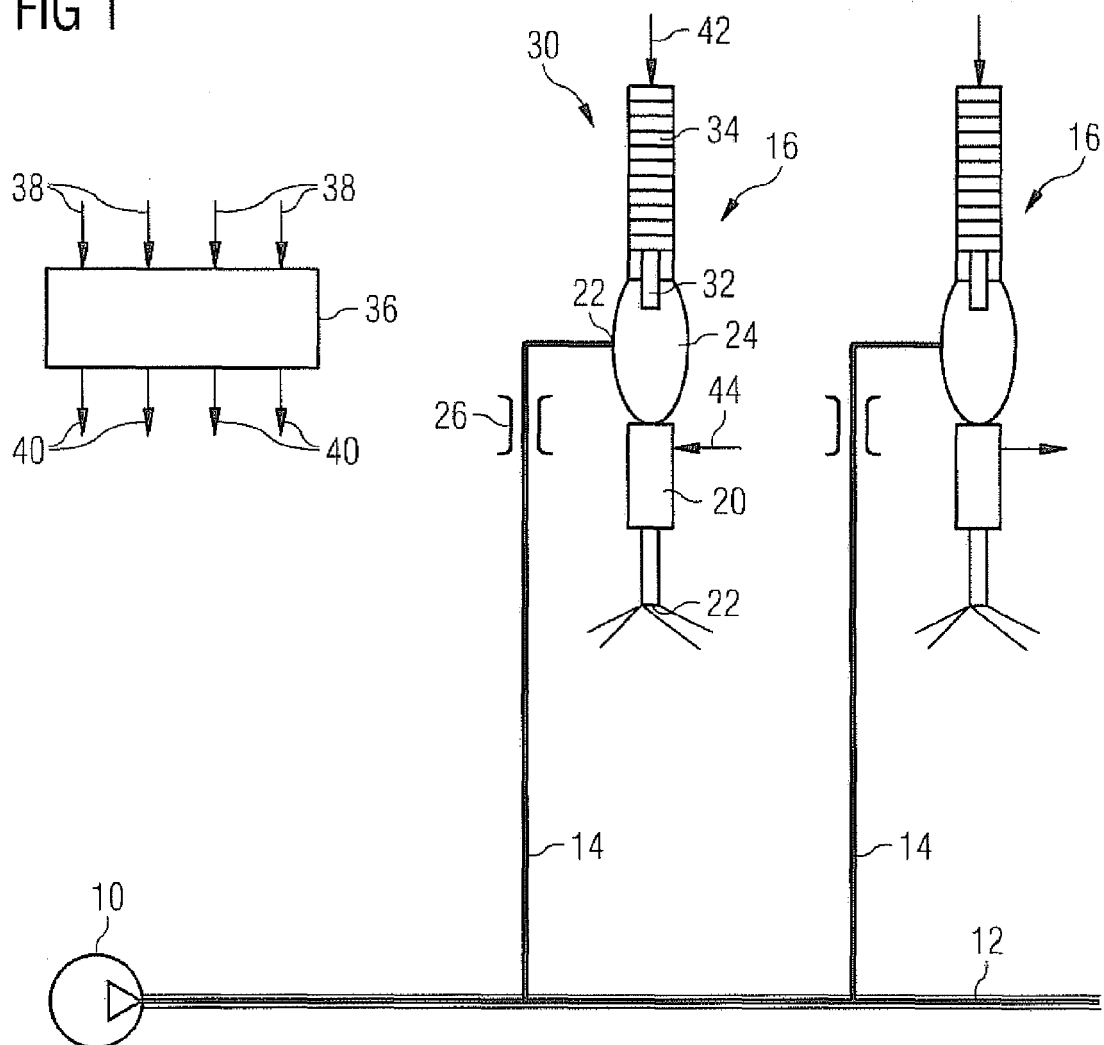
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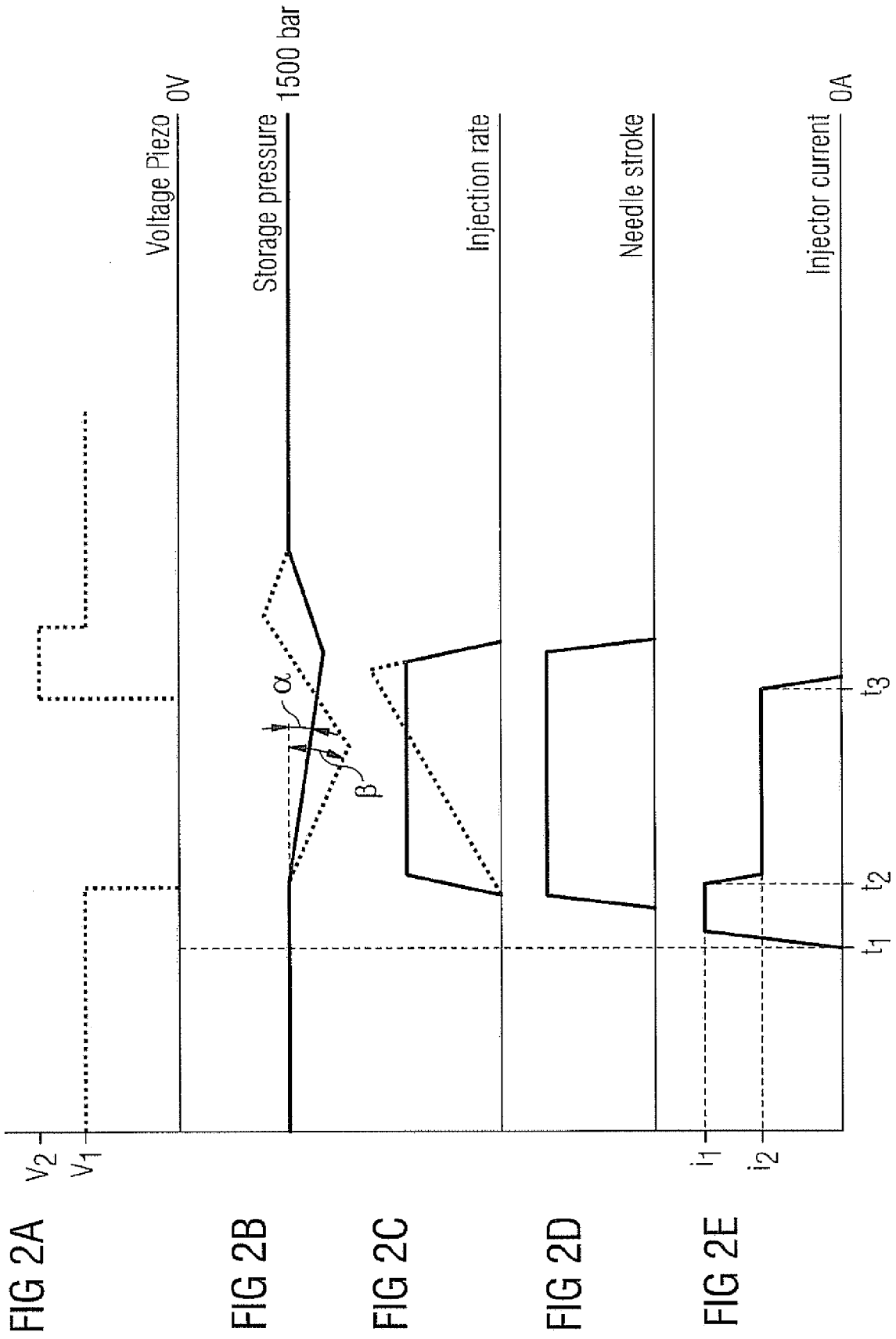
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FIG 1







EUROPEAN SEARCH REPORT

Application Number
EP 11 16 1063

DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 3 August 2011	Examiner Godrie, Pierre
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 11 16 1063

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