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(54) **Fuel injector with piezoelectric actuator**

Brennstoffeinspritzventil mit piezoelektrischem Aktor

Injecteur de combustible à actionneur piézoélectrique

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Description

Field of the invention

[0001] The present invention relates to a fuel injector with a piezoelectric actuator.

Background of the invention

[0002] In fuel injectors, in particular diesel injectors, piezoelectric actuators can be used to obtain very fast injector opening and closing responses. However, the operating stroke of such a piezoelectric actuator is only about 1/1000 of the height of the piezo stack. To obtain an operating stroke that is large enough to open an injector control valve, a stroke amplification function has to be implemented in the injector.

[0003] US patent 5,779,149 shows a fuel injector for an internal combustion engine using a hydraulic amplifier to increase the stroke of a piezoelectric actuator for opening a normally closed drain valve associated with a hydraulic control chamber. This stroke amplifier comprises a first piston and a second piston defining a hydraulic stroke amplifier chamber therebetween. A group of cup-shaped springs acts on the first piston to maintain a direct contact between the latter and the piezoelectric actuator. An actuation of the piezoelectric actuator causes a pressure rise in the fuel contained in the hydraulic stroke amplifier chamber. The fuel pressure in this chamber acts on the second piston, which has a smaller cross section than the first piston. It follows that the small piezoelectric actuator imposed to the first piston results in an amplified stroke of the second piston, which acts on the normally closed drain valve to open it. When the piezoelectric actuator is deactivated again, the pressure in the hydraulic stroke amplifier chamber drops. The force exerted by the second piston on the drain valve diminishes and the latter is closed by a closing spring. It will be noted that a refill valve is mounted in the injector body laterally of the hydraulic stroke amplifier to connect the hydraulic stroke amplifier chamber to a fuel recovery line. This refill valve enables to feed back fuel into the hydraulic chamber when the piezoelectric actuator is deactivated in order to compensate for fuel that has leaked out of the hydraulic stroke amplifier chamber during the compression stroke. However, when the first piston pressurises the fuel of the hydraulic stroke amplifier chamber, the refill valve closes off the connection between the hydraulic stroke amplifier chamber and the fuel recovery line to avoid fuel leakage through this connection. It will be appreciated that the refill valve disclosed in US patent 5,779,149 results in a rather unwieldy fuel injector body. As an alternative solution to the refill valve, US patent 5,779,149 discloses a continuously open small diameter refill duct which is connected between the fuel recovery line and a small diametrical clearance existing between one of the two pistons and the body of the injector. However, such a continuously open small diameter refill duct has negative consequences on the opening and closing responses of the injector.

Object of the invention

[0004] A technical problem underlying the present invention is to provide a very simple solution for refilling a hydraulic stroke amplifier chamber of a piezoelectric fuel injector with fuel, wherein this solution should result in a compact fuel injector design and should not have negative consequences on the opening and closing responses of the fuel injector. This problem is solved by a fuel injector as claimed in claim 1.

Summary of the invention

[0005] A fuel injector for an internal combustion engine in accordance with the present invention comprises a housing with an actuator chamber, a piezoelectric actuator arranged in the actuator chamber, an injector control valve and a hydraulic stroke amplifier module. The hydraulic stroke amplifier module is located axially inbetween the injector control valve and the piezoelectric actuator. It comprises a first piston and a second piston defining a hydraulic stroke amplifier chamber therebetween. In this stroke amplifier chamber, the second piston has a smaller pressure effective cross-section than the first piston and is therefore capable of actuating the injector control valve with an amplified stroke. In accordance with an important aspect of the present invention, the fuel injector further includes a push-rod, a spring means associated with this push-rod and a fuel supply means for supplying fuel to the actuator chamber. The push-rod, which has a first end and an opposite second end, is arranged in the actuator chamber axially between the first piston and the piezoelectric actuator. The first end of the push-rod is in contact with the piezoelectric actuator and the push-rod spring means is associated with the push-rod so as to press this first end of the push-rod against the piezoelectric actuator. In other words, the push-rod pre-loads the piezoelectric actuator and warrants that it operates always in a compressed mode. The second end of the push-rod is capable of entering into mechanical contact with the first piston for communicating to the latter a small compression stroke in the direction of the second piston when the piezoelectric actuator is activated. The first piston includes a through channel for hydraulically connecting the stroke amplifier chamber to the actuator chamber. When the piezoelectric actuator is activated, this through channel is hydraulically closed off by the second end of the push-rod, which is in mechanical contact with the first piston to communicate the compression stroke to the latter. When the piezoelectric actuator is deactivated, the push-rod spring causes the push-rod to move back very rapidly. The first piston follows the movement of the push-rod but at a lower speed. In other words, the slower

first piston looses contact with the second end of the faster push-rod. The result is that the through channel in the first piston is no longer closed and can fulfil the function of a refill channel, allowing fuel contained in the actuator chamber to flow through the through channel of the first piston into the hydraulic stroke amplifier chamber to compensate for fuel leakage during the compression stroke. It will be appreciated that the above arrangement for refilling the hydraulic stroke amplifier chamber with fuel, provides the same function as the refill valve disclosed in US patent 5,779,149. It has however the advantage not to necessitate a lateral refill valve in the injector body. It follows that a fuel injector in accordance with the present invention can be much slender than the fuel injector with refill valve disclosed in US patent 5,779,149.

[0006] In a preferred embodiment the fuel injector further comprises a hydraulic control chamber associated with the injector control valve, wherein the injector control valve establishes a hydraulic communication between the hydraulic control chamber and the actuator chamber when the piezoelectric actuator is activated. In other words, the injector control valve and its associated control chamber are used as fuel supply means for supplying fuel to the actuator chamber.

[0007] It will be noted that there are numerous solutions for hydraulically closing off the through channel with the push-rod. A simple but very effective solution is to provide the second end of the push-rod and the first piston with a flat sealing surfaces co-operating to close off the through channel when the second end of the push-rod is in contact with the first piston for communicating to the latter the compression stroke.

[0008] A very simple design of the injector is obtained, when the piezoelectric actuator is e.g. provided with a fuel-resistant coating and simply immersed an actuator chamber completely filled with fuel. Alternatively, the piezoelectric actuator may e.g. be separated from the push-rod by a fuel-resistant, easily deformable diaphragm. This diaphragm would divide the actuator chamber in a first section that contains the push-rod and is filled with fuel and a second section that contains the piezoelectric actuator and does not contain fuel.

[0009] The stroke amplifier advantageously includes a spring for pushing its two pistons axially apart. This spring ensures direct mechanical contact between the first piston and the push-rod and the second piston and the control valve, before the piezoelectric actuator is activated. The aforementioned spring for pushing the two pistons apart is advantageously received in a spring chamber arranged in the second piston. To still further minimise fuel volume inside the hydraulic stroke amplifier chamber, this spring chamber has advantageously a central insert therein. A reduction of fuel volume in the hydraulic stroke amplifier chamber has indeed a positive influence on the opening and closing responses of the fuel injector.

[0010] It will be appreciated that the hydraulic stroke amplifier module of a fuel injector of the present invention can be easily conceived as a pre-assembled and pre-tested module, which is simply inserted in a bore of the injector housing.

[0011] It will further be appreciated that the present invention provides a fuel injector characterised by a general design concept that favours an easy an cost-effective manufacturing, assembly and testing. In this fuel injector, the control valve is part of a pre-assembled control valve module, the hydraulic stroke amplifier module is a pre-assembled module, and the fuel injector further includes a pre-assembled needle valve module. The housing of this injector includes at least one tube, wherein the pre-assembled needle valve module, the pre-assembled control valve module, the pre-assembled hydraulic stroke amplifier module, the push-rod and the piezoelectric actuator are axially stacked within the at least one tube. In a preferred embodiment of this injector with stacked, pre-assembled modules, the housing includes advantageously a first tube and a second tube, which are assembled by screwing an end of the second tube into an end of the first tube. The pre-assembled needle valve module and the pre-assembled control valve module are then stacked in the first tube and axially pressed together by the second tube, when the latter is screwed into the first tube. In this embodiment, the pre-assembled needle valve module includes advantageously a module body having therein a first channel, the pre-assembled control valve module includes a module body having therein a second channel, and the second tube has therein a third channel. This first, second and third channel co-operate to form a feeding line for pressurised fuel. The spring means, which is associated with the push-rod, bears advantageously on the module body of the pre-assembled hydraulic stroke amplifier module in the second tube, to push this body axially against the body of the pre-assembled control valve module in the first tube.

Brief description of the drawings

[0012] The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. 1: is a schematic longitudinal section through a fuel injector in accordance with the present invention.

FIG. 2, 3 & 4 are enlarged details of FIG. 1.

Detailed description of a preferred embodiment

[0013] FIG. 1 shows a preferred embodiment of a fuel injector 10 for an internal combustion engine in accordance with the invention. This fuel injector 10 includes a tubular housing 12 consisting of a first tube 12a and a second tube 12b. Reference number 14 identifies a

feeding line in the housing 12 connected to a so-called common rail (not shown) for feeding high pressure fuel to an injector needle valve, which is globally identified by reference number 15. This needle valve 15 comprises a closing needle 16 slidingly mounted in a needle valve body 17. The closing needle 16 is actuated by means of a control piston 18 defining a first pressure surface in a first control chamber 20 and a second pressure surface in a second control chamber 22. A closing spring 24 is associated with the control piston 18 in the second control chamber 22, so as to bias the closing needle 16 in the direction of arrow 26 in a closed position, in which the tip of the closing needle 16 closes outlet nozzles 27 in the tip of the needle valve body 17.

[0014] The first control chamber 20 is filled with high pressure fuel through the feeding line 14. Small quantities of high pressure fuel may enter from the feeding line 14 through a flow restrictor channel 28 into the second control chamber 22. If the pressure in the second control chamber 22 equals the pressure in the first control chamber 20, then hydraulic forces acting on the closing needle 16 are substantially in equilibrium, and the closing spring 24 is therefore capable of maintaining the needle valve 15 closed. However, if the pressure in the second control chamber 22 falls below a certain value, a hydrostatic force acts on the closing needle in the opposite direction of arrow 26. The needle valve 15 opens as soon as this hydrostatic force exceeds the closing force of the closing spring 24.

[0015] The fuel pressure inside the second control chamber 22 is controlled by means of a control valve 30. As long as the control valve 30 is closed, the pressure in the second control chamber 22 equals the pressure in the feed line 14. If the control valve 30 opens, pressurised fuel is drained through a drain channel 32 out of the second control chamber 22 and the pressure in the second control chamber 22 drops.

[0016] The control valve 30 is actuated by a piezoelectric actuator 34 which is arranged in an actuator chamber 36 of the tubular housing 12. The piezoelectric actuator 34 has a convex spherical head 40 which engages a concave spherical or conical seat 41 formed in a first end of a push-rod 38 arranged in the lower part of the actuator chamber 36. A spring 42 bears indirectly on the housing 12 to press the push-rod 38 with its seat 41 against the head 40 of the piezoelectric actuator 34. It follows that the push-rod 38 pre-loads the piezoelectric actuator 34 with a compressive force.

[0017] It will be noted that the actuator chamber 36 is entirely filled with fuel. Indeed, during the injection period, the control valve 30 is open, so that pressurised fuel contained in the second control chamber 22 discharges through the drain channel 32 into the lower part of the actuator chamber 36 around the push-rod 38 and the spring 42. This fuel can also flow along the push-rod 38 (see e.g. fuel passage 39) and fill the upper part of the actuator chamber 36, which contains the piezoelectric actuator 34 that is provided with a fuel resistant coating. Arrow 43 is a schematic representation of a fuel recovery line discharging the fuel from the actuator chamber 36 into low pressure fuel return circuit (not shown).

[0018] Reference number 44 globally identifies a compact, pre-assembled hydraulic stroke amplifier module, which will be described in detail referring simultaneously to FIG. 1 & 4. This hydraulic stroke amplifier module 44 includes a cylindrical sleeve 46 which is closed at one end by a first piston 48 and at the other end by a second piston 50. Both pistons 48 and 50 are slideably guided within the sleeve 46 and define a small volume hydraulic stroke amplifier chamber 52 therebetween. It will be noted that the second piston 50 has in the hydraulic stroke amplifier chamber 52 an effective pressure surface smaller than that of the first piston 48. The first piston 48 has a flat front face 54 that is exposed at one end of the sleeve 46. The second piston 50 has a tip 56 that projects from the opposite end of the sleeve 46. A through-bore 58 extends axially through the first piston 48 into the hydraulic stroke amplifier chamber 52 and has an inlet 60 in the front face 54 of the first piston 48. A spacing spring 62 is mounted in a spring chamber 64 inside the second piston 50 so as to push both pistons axially apart. The volume of this spring chamber 64, and consequently of the hydraulic stroke amplifier chamber 52, is reduced by means of a central core 65, which is axially inserted in the spring chamber 64, so as to delimit therein an annular space for the spacing spring 62. Fuel is indeed compressible and the bigger the fuel volume between the two pistons is, the bigger will be the loss of output stroke of the stroke amplifier due to due to compression of the fuel. A first lock washer 66 forms an axial end-stop for the first piston 48 and a second lock washer 67 forms an axial end-stop for the second piston 50. The only function of these lock washers 66, 67 is to maintain the pistons 48, 50 within the sleeve 46 when the hydraulic stroke amplifier module 44 is pre-assembled outside the fuel injector 10. Reference number 68 in FIG. 4 identifies a groove in the sleeve 46, which forms part of the drain channel 32 in the assembled fuel injector 10.

[0019] The operation of the hydraulic stroke amplifier 44 in the fuel injector 10 is as follows. Before the activation of the piezoelectric actuator 34, the hydraulic stroke amplifier module 44 must be in following operative state: (a) the hydraulic stroke amplifier chamber 52 is completely filled with fuel; (b) the second end of the push-rod 38 is in mechanical contact with the flat front face 54 of the first piston 48; and (c) the tip 56 of the second piston 50 is in mechanical contact with the closing element of the control valve 30. An activation of the piezoelectric actuator 34 causes a small stroke of the plunger 38 in the direction of arrow 26. The plunger 38 communicates this small stroke to the first piston 48; i. e. it pushes the first piston 48 in the direction of the second piston 50. This small stroke of the first piston 48 causes a rise of pressure in the hydraulic stroke amplifier chamber 52. As the second piston 50 has in the hy-

draulic stroke amplifier chamber 52 an effective pressure surface smaller than that of the first piston 48, the second piston 50 will follow the first piston 48 with an amplified stroke. This amplified stroke allows to open the control valve 30, whereby the injector needle valve 15 opens as explained above. It will be noted that during the compression stroke, the plunger 38 bears with a flat end-face of its second end against the first front face 54 of the first piston 48, so that it hydraulically closes off the inlet 60 of the through-channel 58. In other words, the first front face 54 of the first piston 48 and the end face of the second end of the plunger 38 form flat annular sealing surfaces around the inlet 60 that are co-operating to seal off the inlet of the through channel 58 during the compression stroke. It remains to be pointed out that the sealing pressure, i.e. the contact pressure between this sealing surfaces, increases proportionally with the pressure increase inside hydraulic stroke amplifier chamber 52 during the compression stroke of the first piston 48.

[0020] As there must be a small diametrical clearance between the piston 48, 50 and the cylindrical bore in the sleeve 46, there will always be a small fluid leakage out of the hydraulic stroke amplifier chamber 52 during the compression stroke of the first piston 48. It follows that fresh fuel must be capable of refilling hydraulic stroke amplifier chamber 52 when the latter is depressurised.

[0021] This refilling of the hydraulic stroke amplifier chamber 52 takes place as follows. When the piezoelectric actuator 34 is deactivated, the spring 42 causes the push-rod 38 to move very rapidly in the opposite direction of arrow 26. Due to the residual pressure in the hydraulic stroke amplifier chamber 52 and, additionally, to the action of the spring 62 mounted between the two pistons 48, 50, the first piston 48 will follow the movement of the push-rod 38 but at a lower speed. It follows that the first front face 54 of the slower first piston 48 looses contact with the end face of the faster push-rod 38. The result is that the inlet 60 of the through channel 58 in the first front face 54 of the first piston 48 is now open, and that fuel contained in the actuator chamber 36 can now penetrate into the hydraulic stroke amplifier chamber 52 through the through channel 58, as the first piston 48 follows the movement of the push-rod 38.

[0022] In summary, when the piezoelectric actuator 34 is deactivated, the hydraulic stroke amplifier chamber 52 is automatically refilled with fuel from the actuator chamber 36 through the through channel 58, and when the piezoelectric actuator 34 is activated, the through channel 58 is hydraulically closed by the push-rod 38.

[0023] It will further be appreciated that the fuel injector shown in FIG. 1 has as a whole a design favouring an easy and cost-effective manufacturing, assembly and testing. This design will now be described in detail.

[0024] As best shown in FIG. 2, the first tube 12a has an axial bore 74 in which a pre-assembled needle valve module 76 and a pre-assembled control valve module 78 are axially inserted one after the other. The pre-assembled needle valve module 76 includes the needle valve 15, i.e. the valve needle 16 and the needle valve body 17. The valve body 17 has a shoulder surface 80 that bears against a corresponding shoulder surface 82 of the first tube 12a. It forms at one end a tubular end portion 84 protruding out of the first tube 12a and at its axially opposite end a module interface surface 86 of the needle valve module 76. Reference number 88 identifies in the module interface surface 86 an inlet of a channel 14a. This channel 14a forms the feeding line 14 in the needle valve body 17 and discharges into the first control chamber 20, which is machined into the needle valve body 17 in axial alignment with a cylindrical bore 92 in which the control piston 18 is axially fitted. A projection 94 of the control piston 18 projects out of this cylindrical bore 92.

[0025] The pre-assembled control valve module 78 includes a module body 96 with a first module interface surface 98 and a second module interface surface 100. The first module interface surface 98 abuts against the module interface surface 86 of the needle valve module 76. The second control chamber 22 is formed by a blind bore 102 extending from the first module interface surface 98 axially into the module body 96. The bottom surface 104 of this blind bore 102 forms a stop face cooperating with the projection 94 of the control piston 18 for defining an end-stop for the valve needle 16 in the opening direction, i.e. the opposite direction of the direction indicated by arrow 26. The closing spring 24 is mounted between the bottom surface 104 of the blind bore 102 and a shoulder surface 105 of the control piston 18. The control valve 30 is a spring closed check-valve that is mounted in a bore 106 extending between the bottom surface 104 of the blind bore 102 and the second module interface surface 100. It includes a closing ball 107, which is pushed by a spring 108 against a seat 109 to close off the bore 106 near the second module interface surface 100. Reference number 14b identifies a channel that extends through the module body 96 from first module interface surface 98 to the second module interface surface 100 to form the feeding line 14 therein. This channel 14b discharges through the inlet 88 in the needle valve module interface surface 86 into the channel 14a. The flow restrictor channel 28 is formed by a stepped, small diameter bore, which is obliquely drilled from the blind bore 102 into the channel 14b.

[0026] As shown on FIG. 1, the needle valve module 76 and the control valve module 78 are axially maintained in place by means of the second tube 12b. The latter is screwed with one end into the first tube 12a, so as to abut with an end face 111 (see FIG. 3) against the second module interface surface 100 (see FIG. 2) of the control valve module 78 and to be capable of firmly pressing the control valve module 78 against the needle valve module 76, which bears on the shoulder surface 82. It remains to be noted that both modules 76, 78 are blocked against rotation in the axial bore 74 of the tube

12a.

[0027] Referring now to FIG. 3, it will be noted that the second tube 12b has an eccentric bore 112 in which the piezoelectric actuator 34, the pushing rod 38 with its spring 42 and the pre-assembled hydraulic stroke amplifier module 44 are axially inserted one after the other. The piezoelectric actuator 34 axially abuts against an axial stop face of the second tube 12b (schematically indicated by reference number 114). When both tubes 12a and 12b are screwed together, the spring 42 bears via the push-rod 38 on the piezoelectric actuator 34 and via a washer 116 on the sleeve 46 of the pre-assembled hydraulic stroke amplifier module 44, to push this sleeve 46 against the second module interface surface 100 (see FIG. 1 & 2). The spring 62 between the two pistons 48, 50 warrants that the first piston 48 is in mechanical contact with the push-rod 38 and that the tip 56 of the second piston 50 is in mechanical contact with the closing ball 107 of the control valve 30. Reference number 14c identifies a channel that extends through the second tube 12b to form the feeding line 14 therein. This channel 14c discharges into the channel 14b in the module body 96 of the control valve module 78.

[0028] In conclusion, the functional modules 76, 78 and 44 can be manufactured, assembled and tested separately and then easily assembled with the injector housing 12a, 12b, the piezoelectric actuator, the push-rod 38 and its spring 42 to form the finished fuel injector 10 shown in FIG. 1. This means lower production costs and better quality.

Claims

1. A fuel injector (10) for an internal combustion engine comprising:

a housing (12) having therein an actuator chamber (36);

a piezoelectric actuator (34) arranged in said actuator chamber (36);

an injector control valve (30) located in said housing (12); and

a hydraulic stroke amplifier module (44) located axially in-between said injector control valve (30) and said piezoelectric actuator (34), said hydraulic stroke amplifier module comprising a first piston (48) and a second piston (50) defining a hydraulic stroke amplifier chamber (52) therebetween, wherein said second piston (50) has a smaller pressure effective cross-section than said first piston (48) and co-operates with said injector control valve (30) to actuate the latter;

characterised
in that said fuel injector (10) further includes:

a push-rod (38) that is arranged in said actuator chamber (36) axially between said first piston (48) and said piezoelectric actuator (34), said push-rod (38) having a first end and a second end, said first end being in contact with said piezoelectric actuator (34) and said second end being capable of entering into contact with said first piston (48) for communicating to the latter a compression stroke in the direction of said second piston (50);

a spring means (42) that is associated with said push-rod (38) so as to press said first end of said push-rod (38) against said piezoelectric actuator (34); and

a fuel supply means (32, 39) for supplying fuel to said actuator chamber (36);

in that said first piston (48) includes a through channel (58) for hydraulically connecting said hydraulic stroke amplifier chamber (52) and said actuator chamber (36); and
in that said push-rod (38) hydraulically closes off said through channel (58) when it is in contact with said first piston (48) for communicating to the latter said compression stroke.

2. The fuel injector as claimed in claim 1, further comprising a hydraulic control chamber (20) associated with said injector control valve (30); wherein said injector control valve (30) establishes a hydraulic communication between said hydraulic control chamber (20) and said actuator chamber (36) when said piezoelectric actuator (34) is activated.

3. The fuel injector as claimed in claim 1 or 2, **characterised in that** said second end of said push-rod (38) and said first piston (48) have flat sealing surfaces co-operating to close off said through channel (58) when said second end of said push-rod (38) is in contact with said first piston (48) for communicating to the latter said compression stroke.

4. The fuel injector as claimed in any one of claims 1 to 3, **characterised in that** said piezoelectric actuator (34) is immersed in the fuel in said actuator chamber (36) and provided with a fuel-resistant coating.

5. The fuel injector as claimed in any one of claims 1 to 4, **characterised in that** said hydraulic stroke amplifier module (44) further includes a spring (62) for pushing said two pistons (48, 50) apart.

6. The fuel injector as claimed in claim 5, **characterised in that**:

said second piston has a spring chamber (64) in which said spring (62) for pushing said two pistons (48, 50) apart is received; and
said spring chamber (64) has a central insert therein to minimise fuel volume inside said hydraulic stroke amplifier chamber (52).

7. The fuel injector as claimed in any one of claims 1 to 6, **characterised in that** said first piston (48) and said second piston (50) are mounted in a sleeve (46) so as to form a pre-assembled hydraulic stroke amplifier module (44) to be inserted in a bore (112) of said housing (12b).

8. The fuel injector as claimed in any one of claims 1 to 7, **characterised:**

in that said control valve (30) is part of a pre-assembled control valve module (78) including a module body (96);

in that said hydraulic stroke amplifier module (44) is a pre-assembled module, including a module body (46);

in that said fuel injector further includes pre-assembled needle valve module (76), including a module body (17);

in that said housing (12) includes at least one tube (12a, 12b); and

in that said pre-assembled needle valve module (76), said pre-assembled control valve module (78), said pre-assembled hydraulic stroke amplifier module (44), said push-rod (38) and said piezoelectric actuator (34) are axially stacked within said at least one tube (12a, 12b).

9. The fuel injector as claimed in claim 8, **characterised:**

in that said housing (12) includes a first tube (12a) and a second tube (12b), which are assembled by screwing an end of said second tube (12b) into an end of said first tube (12a);

in that said pre-assembled needle valve module (76) and said pre-assembled control valve module (78) are stacked in said first tube (12a) and axially pressed together by said second tube (12b); and

in that said pre-assembled hydraulic stroke amplifier module (44), said push-rod (38) and said piezoelectric actuator (34) are axially stacked within said second tube (12b).

10. The fuel injector as claimed in claim 9, **characterised:**

in that said pre-assembled needle valve module (76) includes a first channel (14a) in its module body (17);

in that said pre-assembled control valve module (78) includes a second channel (14b) in its module body (96); and

in that said second tube (12b) has therein a third channel (14c);

wherein said first (14a), second (14b) and third channel (14c) co-operate to form a feeding line (14) for pressurised fuel.

11. The fuel injector as claimed in claim 9 or 10, **characterised in that** said spring means (42) associated with said push-rod (38) bears on said module body (46) of said pre-assembled hydraulic stroke amplifier module (44) in said second tube (12b), to push this body (46) axially against the body (96) of said pre-assembled control valve module (78) in said first tube (12a).

12. A compact hydraulic stroke amplifier module comprising:

a sleeve;

a first piston (48) and a second piston (50) mounted in said sleeve so that they define a hydraulic stroke amplifier chamber (52) therebetween, wherein said first and second piston (48, 50) have different pressure effective cross-sections in said hydraulic stroke amplifier chamber (52), said first piston (48) having an exposed end face (54) against which a push-rod (38) can bear for pushing said first piston (48) towards said second piston (50); and

spring means associated with said first piston (48) and said second piston (50) for biasing the two pistons (48, 50) axially apart;

characterised in that
said first piston (48) includes a through channel (58) for hydraulically connecting said hydraulic stroke amplifier chamber (52) to an inlet (60) that is located in said exposed end face (54) of said first piston (48), so that said inlet (60) can be closed off by said push-rod (38) when the latter bears against said exposed end face (54).

Patentansprüche

1. Brennstoffeinspritzventil (10) für eine Brennkraftmaschine, umfassend:

ein Gehäuse (12) mit einer Aktorkammer (36) darin;

einen piezoelektrischen Aktor (34), der in der Aktorkammer (36) angeordnet ist;

ein Einspritzsteuerventil (30), das im Gehäuse (12) angeordnet ist; und

ein hydraulisches Hubverstärkermodul (44), das axial zwischen dem Einspritzsteuerventil (30) und dem piezoelektrischen Aktor (34) angeordnet ist, wobei das hydraulische Hubverstärkermodul einen ersten Kolben (48) und einen zweiten Kolben (50) umfasst, die dazwischen eine hydraulische Hubverstärkerkammer (52) definieren, wobei der zweite Kolben (50) einen kleineren druckwirksamen Querschnitt als der erste Kolben (48) aufweist und mit dem Einspritzsteuerventil (30) zusammenwirkt, um Letzteres zu betätigen;

dadurch gekennzeichnet, dass
das Brennstoffeinspritzventil (10) ferner umfasst:

eine Schubstange (38), die in der Aktorkammer (36) axial zwischen dem ersten Kolben (48) und dem piezoelektrischen Aktor (34) angeordnet ist, wobei die Schubstange (38) ein erstes und ein zweites Ende aufweist, wobei das erste Ende in Kontakt mit dem piezoelektrischen Aktor (34) steht und das zweite Ende in Kontakt mit dem ersten Kolben (48) treten kann, um Letzterem einen Verdichtungshub in Richtung des zweiten Kolbens (50) zu übertragen;

ein Federmittel (42), das der Schubstange (38) zugeordnet ist, um so das erste Ende der Schubstange (38) gegen den piezoelektrischen Aktor (34) zu drücken; und

ein Brennstoffzuführmittel (32, 39), um der Aktorkammer (36) Brennstoff zuzuführen;

der erste Kolben (48) einen Durchlasskanal (58) umfasst, um die hydraulische Hubverstärkerkammer (52) und die Aktorkammer (36) hydraulisch zu verbinden; und
die Schubstange (38) den Durchlasskanal (58) hydraulisch verschließt, wenn sie in Kontakt mit dem ersten Kolben (48) steht, um Letzterem den Verdichtungshub zu übertragen.

2. Brennstoffeinspritzventil nach Anspruch 1, ferner umfassend eine hydraulische Steuerkammer (20), die dem Einspritzsteuerventil (30) zugeordnet ist; wobei das Einspritzsteuerventil (30) eine hydraulische Verbindung zwischen der hydraulischen Steuerkammer (20) und der Aktorkammer (36) herstellt, wenn der piezoelektrische Aktor (34) betätigt wird.

3. Brennstoffeinspritzventil nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** das zweite Ende der Schubstange (38) und der erste Kolben (48) ebene Dichtflächen aufweisen, die zusammenwirken, um den Durchlasskanal (58) zu verschließen, wenn das zweite Ende der Schubstange (38) in Kontakt mit dem ersten Kolben (48) steht, um Letzterem den Verdichtungshub zu übertragen.

4. Brennstoffeinspritzventil nach irgendeinem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** der piezoelektrische Aktor (34) in den Brennstoff in der Aktorkammer (36) eingetaucht ist und mit einer brennstoffbeständigen Beschichtung versehen ist.

5. Brennstoffeinspritzventil nach irgendeinem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** das hydraulische Hubverstärkermodul (44) ferner eine Feder (62) zum Auseinanderdrücken der zwei Kolben (48, 50) umfasst.

6. Brennstoffeinspritzventil nach Anspruch 5, **dadurch gekennzeichnet, dass**:

der zweite Kolben einen Federraum (64) aufweist, in dem die Feder (62) zum Auseinanderdrücken der zwei Kolben (48, 50) untergebracht ist; und

der Federraum (64) darin einen mittigen Einsatz aufweist, um das Brennstoffvolumen in der hydraulischen Hubverstärkerkammer (52) zu minimieren.

7. Brennstoffeinspritzventil nach irgendeinem der Ansprüche 1 bis 6, **dadurch gekennzeichnet, dass** der erste Kolben (48) und der zweite Kolben (50) in einer Buchse (46) eingebaut sind, um so ein vorgefertigtes hydraulisches Hubverstärkermodul (44) auszubilden, das in eine Bohrung (112) des Gehäuses (12b) einzuführen ist.

8. Brennstoffeinspritzventil nach irgendeinem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass**:

das Steuerventil (30) Teil eines vorgefertigten Steuerventilmoduls (78) ist, das einen Modulkörper (96) umfasst;

das hydraulische Hubverstärkermodul (44) ein

vorgefertigtes Modul ist, das einen Modulkörper (46) umfasst;

das Brennstoffeinspritzventil ferner ein vorgefertigtes Nadelventilmodul (76) umfasst, das einen Modulkörper (17) umfasst;

das Gehäuse (12) mindestens ein Rohr (12a, 12b) umfasst; und

das vorgefertigte Nadelventilmodul (76), das vorgefertigte Steuerventilmodul (78), das vorgefertigte hydraulische Hubverstärkermodul (44), die Schubstange (38) und der piezoelektrische Aktor (34) axial in dem mindestens einen Rohr (12a, 12b) gestapelt sind.

9. Brennstoffeinspritzventil nach Anspruch 8, **dadurch gekennzeichnet, dass**:

das Gehäuse (12) ein erstes Rohr (12a) und ein zweites Rohr (12b) umfasst, die zusammengebaut werden, indem ein Ende des zweiten Rohrs (12b) in ein Ende des ersten Rohrs (12a) eingeschraubt wird;

das vorgefertigte Nadelventilmodul (76) und das vorgefertigte Steuerventilmodul (78) im ersten Rohr (12a) gestapelt sind und axial durch das zweite Rohr (12b) zusammengedrückt werden; und

das vorgefertigte hydraulische Hubverstärkermodul (44), die Schubstange (38) und der piezoelektrische Aktor (34) axial im zweiten Rohr (12b) gestapelt sind.

10. Brennstoffeinspritzventil nach Anspruch 9, **dadurch gekennzeichnet, dass**:

das vorgefertigte Nadelventilmodul (76) einen ersten Kanal (14a) in seinem Modulkörper (17) umfasst;

das vorgefertigte Steuerventilmodul (78) einen zweiten Kanal (14b) in seinem Modulkörper (96) umfasst; und

das zweite Rohr (12b) darin einen dritten Kanal (14c) aufweist;

wobei der erste (14a), zweite (14b) und dritte Kanal (14c) zusammenwirken, um eine Zulaufleitung (14) für unter Druck stehenden Brennstoff auszubilden.

11. Brennstoffeinspritzventil nach Anspruch 9 oder 10, **dadurch gekennzeichnet, dass** das der Schubstange (38) zugeordnete Federmittel (42) auf dem Modulkörper (46) des vorgefertigten hydraulischen Hubverstärkermoduls (44) im zweiten Rohr (12b) lagert, um diesen Körper (46) axial gegen den Körper (96) des vorgefertigten Steuerventilmoduls (78) im ersten Rohr (12a) zu drücken.

12. Kompaktes hydraulisches Hubverstärkermodul, umfassend:

eine Buchse;

einen ersten Kolben (48) und einen zweiten Kolben (50), die so in der Buchse eingebaut sind, dass sie eine hydraulische Hubverstärkerkammer (52) dazwischen definieren, wobei der erste und der zweite Kolben (48, 50) unterschiedliche druckwirksame Querschnitte in der hydraulischen Hubverstärkerkammer (52) aufweisen, wobei der erste Kolben (48) eine freie Endfläche (54) aufweist, an der eine Schubstange (38) anliegen kann, um den ersten Kolben (48) zum zweiten Kolben (50) zu drücken; und

ein Federmittel, das dem ersten Kolben (48) und dem zweiten Kolben (50) zugeordnet ist, um die zwei Kolben (48, 50) axial auseinander vorzuspannen;

dadurch gekennzeichnet, dass
der erste Kolben (48) einen Durchlasskanal (58) umfasst, um die hydraulische Hubverstärkerkammer (52) hydraulisch mit einem Einlass (60) zu verbinden, der so in der freien Endfläche (54) des ersten Kolbens (48) angeordnet ist, dass der Einlass (60) durch die Schubstange (38) verschlossen werden kann, wenn Letztere an der freien Endfläche (54) anliegt.

Revendications

1. Injecteur de combustible (10) pour un moteur à combustion interne, comprenant :

un logement (12) pourvu d'une chambre d'actionneur (36) ;

un actionneur piézoélectrique (34) disposé dans ladite chambre d'actionneur (36) ;

une soupape de commande d'injecteur (30) située dans ledit logement (12) ; et

un module d'amplification de course hydraulique (44) situé axialement entre ladite soupape de commande d'injecteur (30) et ledit actionneur piézoélectrique (34), ledit module d'ampli-

fication de course hydraulique comprenant un premier piston (48) et un second piston (50) définissant entre eux une chambre d'amplification de course hydraulique (52), ledit second piston (50) ayant une section effective de pression plus petite que ledit premier piston (48) et coopère avec ladite soupape de commande d'injecteur (30) pour actionner ce dernier ;

caractérisé
en ce que ledit injecteur de combustible (10) comprend, en outre :

une tige poussoir (38) qui est disposée axialement dans ladite chambre d'actionneur (36) entre ledit premier piston (48) et ledit actionneur piézoélectrique (34), ladite tige poussoir (38) ayant une première extrémité et une seconde extrémité, ladite première extrémité étant en contact avec ledit actionneur piézoélectrique (34) et ladite seconde extrémité étant capable d'entrer en contact avec ledit premier piston (48) pour communiquer à ce dernier une course de compression dans la direction dudit second piston (50) ;

un moyen de ressort (42) qui est associé à ladite tige poussoir (38) de manière à presser ladite première extrémité de ladite tige poussoir (38) contre ledit actionneur piézoélectrique (34) ; et

un moyen d'alimentation en combustible (32, 39) pour alimenter du combustible vers ladite chambre d'actionneur (36) ;

en ce que ledit premier piston (48) est pourvu d'un canal de passage (58) pour connecter hydrauliquement ladite chambre d'amplification de course hydraulique (52) et ladite chambre d'actionneur (36) ; et
en ce que ladite tige poussoir (38) ferme hydrauliquement ledit canal de passage (58) lorsqu'elle est en contact avec ledit premier piston (48) pour communiquer ladite course de compression à ce dernier.

2. Injecteur de combustible selon la revendication 1, comprenant, en outre, une chambre de commande hydraulique (20) associée à ladite soupape de commande d'injecteur (30) ; dans lequel ladite soupape de commande d'injecteur (30) établit une communication hydraulique entre ladite chambre de commande hydraulique (20) et ladite chambre d'actionneur (36) lorsque ledit actionneur piézoélectrique (34) est activé.

3. Injecteur de combustible selon la revendication 1 ou 2, **caractérisé en ce que** ladite seconde extrémité de ladite tige poussoir (38) et ledit premier piston (48) ont des surfaces d'étanchéité plates coopérant pour fermer ledit canal de passage (58) lorsque ladite seconde extrémité de ladite tige poussoir (38) est en contact avec ledit premier piston (48) pour communiquer ladite course de compression à ce dernier.

4. Injecteur de combustible selon l'une quelconque des revendications 1 à 3, **caractérisé en ce que** ledit actionneur piézoélectrique (34) est immergé dans le combustible dans ladite chambre d'actionneur (36) et est pourvu d'un revêtement résistant au combustible.

5. Injecteur de combustible selon l'une quelconque des revendications 1 à 4, **caractérisé en ce que** ledit module d'amplification de course hydraulique (44) comprend, en outre, un ressort (62) pour écarter l'un de l'autre les deux pistons (48, 50) en les poussant.

6. Injecteur de combustible selon la revendication 5, **caractérisé en ce que** :

ledit second piston comporte une chambre de ressort (64) dans laquelle ledit ressort (62), pour écarter lesdits deux pistons (48, 50) en les poussant, est reçu ; et

ladite chambre de ressort (64) contient un insert rapporté central pour minimiser le volume de combustible à l'intérieur de ladite chambre d'amplification de course hydraulique (52).

7. Injecteur de combustible selon l'une quelconque des revendications 1 à 6, **caractérisé en ce que** ledit premier piston (48) et ledit second piston (50) sont montés dans un manchon (46) de manière à former un module d'amplification de course hydraulique préassemblé (44) destiné à être inséré dans un alésage (112) dudit logement (12b).

8. Injecteur de combustible selon l'une quelconque des revendications 1 à 7, **caractérisé :**

en ce que ladite soupape de commande (30) fait partie d'un module de soupape de commande préassemblé (78) comprenant un corps de module (96) ;

en ce que ledit module d'amplification de course hydraulique (44) est un module préassemblé comprenant un corps de module (46) ;

en ce que ledit injecteur de combustible comprend, en outre, un module de soupape à poin-

teau préassemblé (76) comprenant un corps de module (17) ;

en ce que ledit logement (12) comprend au moins un tube (12a, 12b) ; et

en ce que ledit module de soupape à pointeau préassemblé (76), ledit module de soupape de commande préassemblé (78), ledit module d'amplification de course hydraulique préassemblé (44), ladite tige poussoir (38) et ledit actionneur piézoélectrique (34) sont empilés axialement à l'intérieur dudit au moins un tube (12a, 12b).

9. Injecteur de combustible selon la revendication 8, **caractérisé :**

en ce que ledit logement (12) comprend un premier tube (12a) et un second tube (12b) que l'on assemble en vissant une extrémité dudit second tube (12b) dans une extrémité dudit premier tube (12a) ;

en ce que ledit module de soupape à pointeau préassemblé (76) et ledit module de soupape de commande préassemblé (78) sont empilés dans ledit premier tube (12a) et pressés ensemble axialement par ledit second tube (12b) ; et

en ce que ledit module d'amplification de course hydraulique préassemblé (44), ladite tige poussoir (38) et ledit actionneur piézoélectrique (34) sont empilés axialement à l'intérieur dudit second tube (12b).

10. Injecteur de combustible selon la revendication 9, **caractérisé :**

en ce que le corps de module (17) dudit module de soupape à pointeau préassemblé (76) est pourvu d'un premier canal (14a) ;

en ce que le corps de module (96) dudit module de soupape de commande préassemblé (78) est pourvu d'un deuxième canal (14b) ; et

en ce que ledit second tube (12b) est pourvu d'un troisième canal (14c) ;

dans lequel lesdits premier (14a), deuxième (14b) et troisième (14c) canaux coopèrent pour former une conduite d'alimentation (14) pour le combustible sous pression.

11. Injecteur de combustible selon la revendication 9 ou 10, **caractérisé en ce que** ledit moyen de ressort (42) associé à ladite tige poussoir (38) appuie sur ledit corps de module (46) dudit module d'amplification de course hydraulique préassemblé (44) dans ledit second tube (12b) pour pousser ce corps (46) axialement contre le corps (96) dudit module de soupape de commande préassemblé (78) dans ledit premier tube (12a).

12. Module amplificateur de course hydraulique compact comprenant :

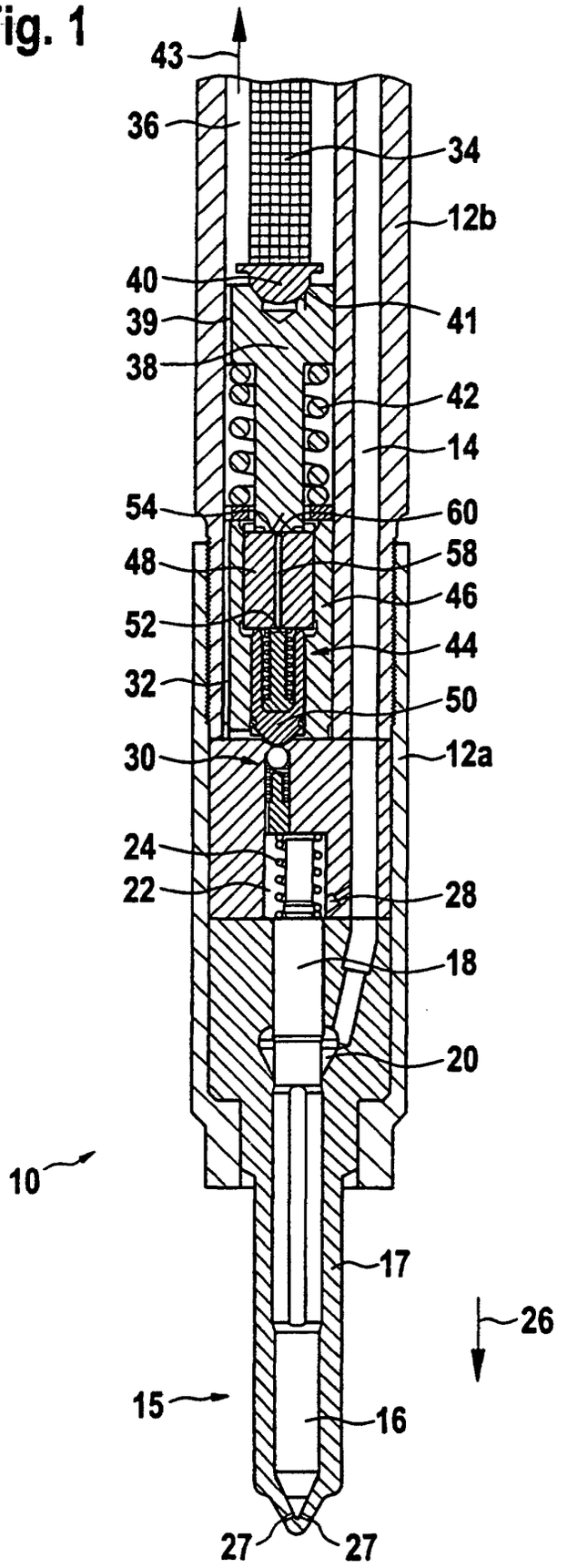
un manchon ;

un premier piston (48) et un second piston (50) montés dans ledit manchon de manière à définir entre eux une chambre d'amplification de course hydraulique (52), lesdits premier et second pistons (48, 50) ayant des sections effectives de pression différentes dans ladite chambre d'amplification de course hydraulique (52), ledit premier piston (48) ayant une face d'extrémité exposée (54) contre laquelle une tige poussoir (38) peut appuyer pour pousser ledit premier piston (48) vers ledit second piston (50) ; et

un moyen de ressort associé audit premier piston (48) et audit second piston (50) pour contraindre les deux pistons (48, 50) à s'écarter axialement ;

caractérisé en ce que
ledit premier piston (48) est pourvu d'un canal de passage (58) pour connecter hydrauliquement ladite chambre d'amplification de course hydraulique (52) à une entrée (60) située dans ladite face d'extrémité exposée (54) dudit premier piston (48) de manière à ce que ladite entrée (60) puisse être fermée par ladite tige poussoir (38) lorsque cette dernière appuie contre ladite face d'extrémité exposée (54).

Fig. 1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36
34
12b
40
41
39
38
42
14
54
60
48
58
46
52
44
32
50
30
12a
24
22
28
18
20
10
17
26
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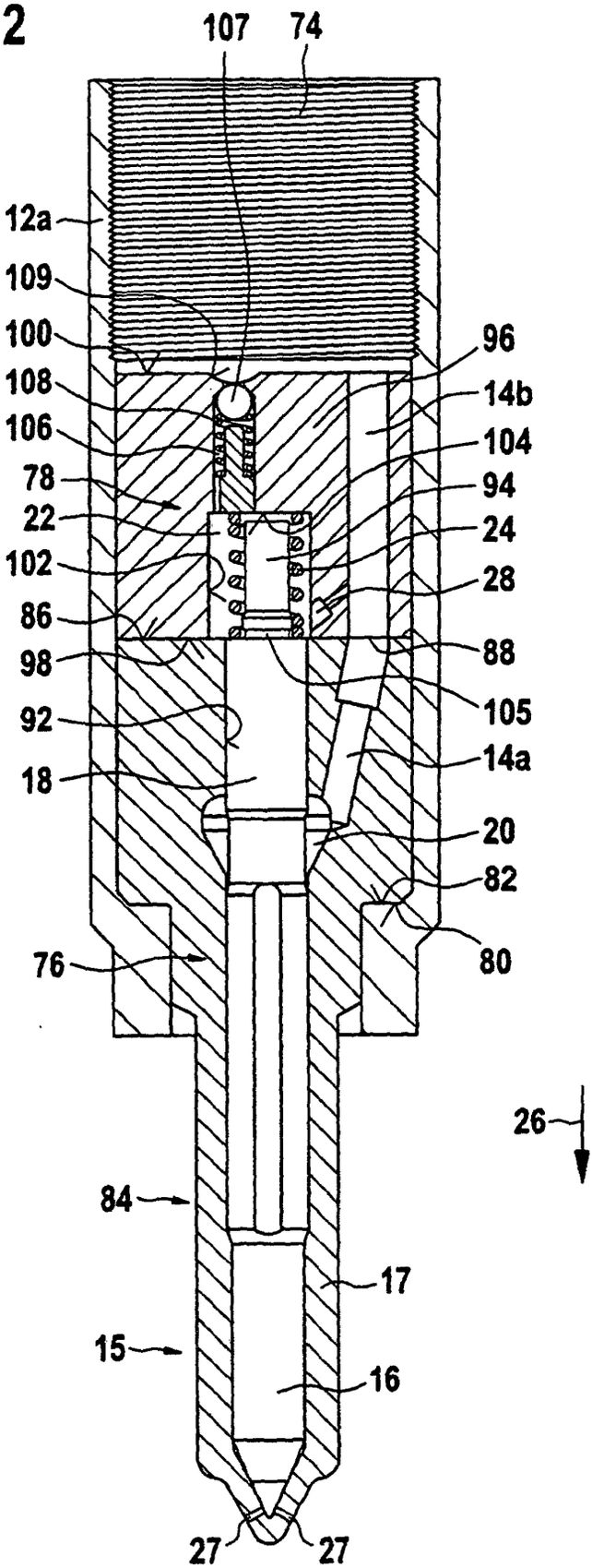
27
27

Fig. 2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12a
109
100
108
106
78
22
102
86
98
92
18
96
14b
104
94
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88
105
14a
20
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76
26
84
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27
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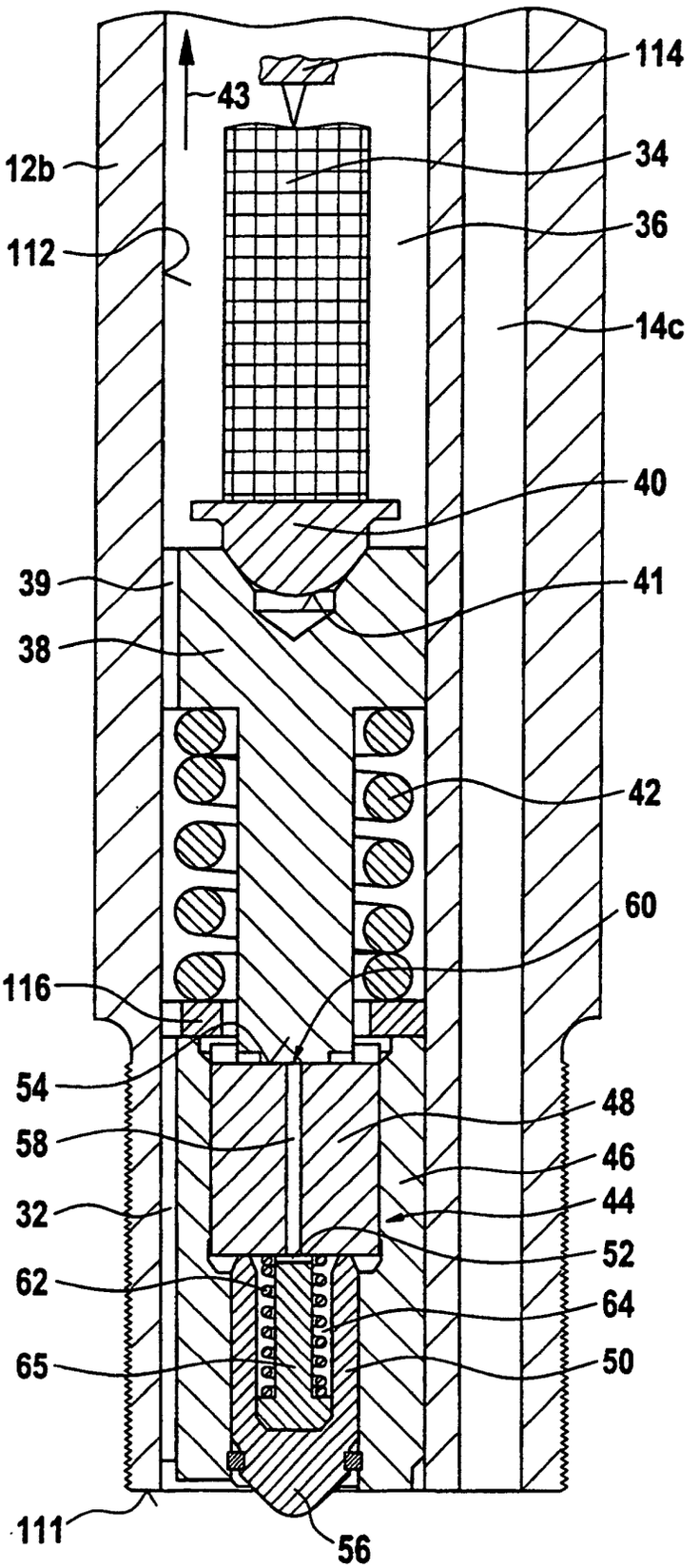
Fig. 3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14c
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41
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42
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62
64
65
50
111
56

Fig. 4