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(54) DUAL FUEL INJECTOR FOR ENGINE

(57) A dual fuel injector for an engine includes a main housing, an outer valve body coupled to the main housing, an intermediate body and a needle valve. The outer valve body has a first fuel nozzle and a first valve seat. The intermediate body is disposed linearly movable in the inner chamber of the outer valve body. The intermediate body has a second fuel nozzle and a second valve seat. A first pressure chamber and a first control chamber are formed between the intermediate body and the outer valve body. The first fuel nozzle is in communication with the first pressure chamber through the first valve seat. The needle valve is disposed linearly movable in the inner chamber of the intermediate body. A second pressure chamber and a second control chamber are formed between the needle valve and the intermediate body. The second fuel nozzle is in communication with the second pressure chamber through a second valve seat.

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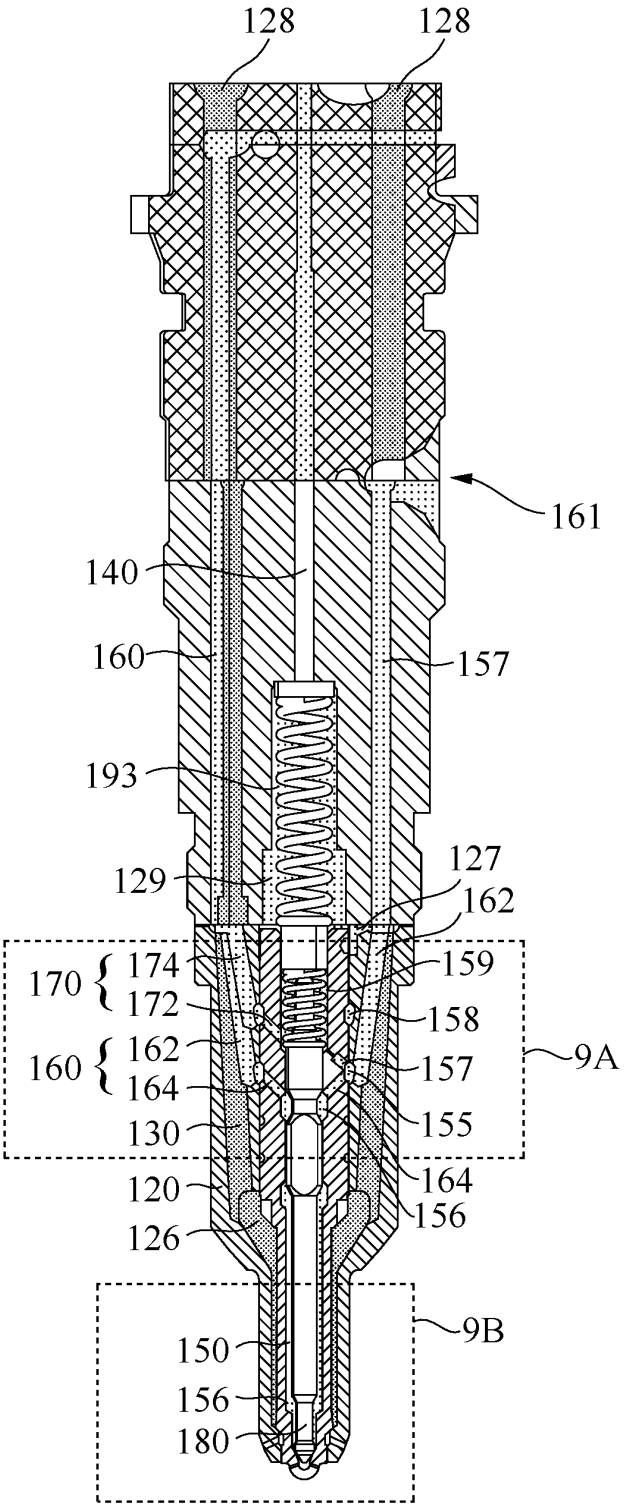
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9B
150
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180

FIG. 8

Description

Technical field

[0001] This application relates to fuel injectors, and in particular to dual fuel injectors for an engine.

Background

[0002] Dual-fuel engines employing a conventional fuel and an alternative fuel play a positive role in optimized use of energy source and environmental control. In a dual fuel engine, such as a diesel-natural gas engine, with gaseous fuel as an alternative fuel, the fuel injector therein cannot be used for a dual fuel engine that uses liquid fuel as an alternative fuel. Therefore, there is a need to provide a dual fuel injector for the engine for use with liquid fuel as both traditional fuel and alternative fuel, and the use of a dual fuel injector without retrofitting an engine and fuel injector mounting interface, such that the liquid replacement fuel may be effectively utilized.

Summary

[0003] In one aspect, the invention provides a fuel injector for an engine. The fuel injector includes a main housing; an outer valve body coupled to the main housing, the outer valve body having a first fuel nozzle and a first valve seat; an intermediate body, the intermediate body being disposed linearly movable in an inner chamber of the outer valve body, the intermediate body having a second fuel nozzle and a second valve seat, the intermediate body and the outer valve body forming therebetween a first pressure chamber and a first control chamber, the first fuel nozzle being in communication with the first pressure chamber through the first valve seat; a first input channel in communication with the first pressure chamber; a first return channel in communication with the first control chamber; a needle valve, the needle valve being disposed linearly movable in an inner chamber of the intermediate body, the needle valve and the intermediate body forming therebetween a second pressure chamber and a second control chamber, the second fuel nozzle being in communication with the second pressure chamber through the second valve seat; a second input channel in communication with the second pressure chamber; a second return channel in communication with the second control chamber; wherein the intermediate body is linearly movable relative to the outer valve body between a first intermediate body position and a second intermediate body position; when in the first intermediate body position, the intermediate body abuts against the first valve seat to block a fluid communication between the first pressure chamber and the first fuel nozzle; when in the second intermediate body position, the intermediate body is spaced from the first valve seat, to allow communication between the first pressure chamber and the first fuel nozzle; the needle valve being linearly movable relative to the intermediate body between a first needle valve position and a second needle valve position; when in the first needle valve position, the needle valve abuts against the second valve seat, to block a fluid communication between the second pressure chamber and the second fuel nozzle; when in the second needle valve position, the needle valve is spaced apart from the second valve seat, to allow communication between the second pressure chamber and the second fuel nozzle.

[0004] Preferably, the first input channel is formed in the outer valve body and arranged along a first radial direction of the outer valve body; the second input channel is formed in the outer valve body and arranged along a second radial direction of the outer valve body, the second radial direction is angularly offset relative to the first radial direction along a second circumferential direction of the outer valve body about a longitudinal axis of the fuel injector.

[0005] Preferably, the fuel injector according to the present invention further comprises an annular feed groove formed between the outer valve body and the intermediate body; an annular return groove axially offset relative to the annular feed groove; and a second control chamber in communication between the annular feed groove and the annular return groove, the second input channel including a primary input section formed in the outer valve body and a secondary input section formed in the intermediate body, an outlet of the primary input section and an inlet of the secondary input section are respectively in communication with the annular feed groove, the outlet of the secondary input section is in communication with the second pressure chamber, wherein the secondary input section is arranged along a first radial direction of the outer valve body.

[0006] Preferably, a radial distance between the inlet of the secondary input section and the longitudinal axis of the fuel injector is greater than a radial distance between the outlet of the secondary input section and the longitudinal axis of the fuel injector, the outlet of the secondary input section being disposed along the longitudinal axis between the inlet of the secondary input section and the secondary fuel nozzle, such that the secondary input section is arranged obliquely relative to the longitudinal axis and is arranged converged in a direction toward the second fuel nozzle.

[0007] Preferably, the annular feed groove comprises a first inner groove formed surround an inner wall of the outer valve body; and a first outer groove surround an outer wall of the intermediate body, the first outer groove being aligned with the first inner groove along the longitudinal axis.

[0008] Preferably, the first inner groove and the first outer groove are in a fitting engagement with each other at a first segment gap between the outer valve body and the intermediate body, to form a liquid communication between the annular feed groove and the first segment gap.

[0009] Preferably, the annular return groove compris-

es a second inner groove formed on and surround an inner wall of the outer valve body; and a second outer groove formed on and surround an outer wall of the intermediate body, the second outer groove being aligned with the first inner groove along the longitudinal axis.

[0010] Preferably, the second inner groove and the second outer groove are in a fitting engagement with each other at a second segment gap between the outer valve body and the intermediate body, to form a liquid communication between the annular return groove and the second segment gap.

[0011] Preferably, the second return channel is formed in the outer valve body and arranged along a third radial direction, the third radial direction is angularly offset relative to the first radial direction and the second radial direction along a third circumferential direction of the outer valve body about the longitudinal axis of the fuel injector.

[0012] Preferably, the second return channel comprises a primary return section formed in the intermediate body and a secondary return section formed in the outer valve body, an inlet of the primary return section being in communication with the second control chamber, an outlet of the primary return section and an inlet of the secondary return section are respectively in communication with the annular return groove, the primary return section and the secondary return section being arranged along the third radial direction.

[0013] Preferably, the fuel injector according to the present invention further includes a first control channel in communication with the second input channel and the first control chamber, the first control channel forming a first damping through-hole between the second input channel and the first control chamber.

[0014] Preferably, the first control channel is arranged along the third radial direction.

[0015] Preferably, the intermediate body includes a second control channel in communication with the second input channel and the second control chamber, the second control channel being arranged along the third radial direction.

[0016] Preferably, the dual fuel injector according to the present invention further includes a second damping through-hole between the second input channel and the second control chamber, wherein the second damping through-hole includes an aperture sized for providing a pressure difference between the second input channel and the second control chamber.

[0017] Preferably, the inner chamber of the intermediate body has a guiding inner surface, the needle valve has a plurality of guiding ridges parallel to a longitudinal axis of the fuel injector, the plurality of guiding ridges being linearly movable relative to the guiding inner surface cooperatively and being distributed circumferentially, a connection portion is formed between respective adjacent guiding ridges, a radial gap is formed between the respective connection portions and the guiding inner surface, the radial gap forming a liquid channel.

[0018] Preferably, the guiding ridges abut against the guiding inner surface of the intermediate body.

[0019] Preferably, a portion of the needle valve corresponding to the guiding inner surface of the intermediate body comprises a prismatic segment, the prismatic segment comprising a plurality of guiding ridges distributed circumferentially and a connection portion between respective adjacent guiding ridges.

[0020] Preferably, an envelope surface of the guiding ridges forms a tight translationally movable fit with a cylindrical inner surface of the inner chamber of the intermediate body, such that the intermediate body provides guiding support to the needle valve.

[0021] Preferably, the fuel injector according to the present invention further includes a secondary housing; a first fuel inlet opening on a top portion of the secondary housing; and a second fuel inlet opening on a side wall of the main housing, the second fuel inlet being disposed between the first fuel inlet and the first fuel nozzle.

[0022] Preferably, the fuel injector according to the present invention further includes a return outlet opening on the main housing, wherein a communication between the return outlet and each of the first return channel and the second return channel is turned on or turned off controllably through a respective solenoid valve.

Brief description of the drawings

[0023]

FIG. 1 is a perspective view of a dual fuel injector for an engine according to one embodiment of the present invention;

FIG. 2 is an exploded view of the fuel injector shown in Fig. 1;

FIG. 3 is a schematic diagram of the corresponding sectional view and other views of the interface between the housing and the valve body of the fuel injector;

FIG. 4 is a partial exploded sectional view of the fuel injector shown in FIG. 1, showing a longitudinal section along the section line A-A as shown in FIG. 3;

FIG. 5 is a partial exploded sectional view of the fuel injector shown in FIG. 1, showing a longitudinal section along the section line B-B as shown in FIG. 3;

FIG. 6 is a partial exploded sectional view of the fuel injector shown in FIG. 1, showing a longitudinal section along the section line C-C as shown in FIG. 3;

FIG. 7 is a partial sectional view of the fuel injector valve body shown in FIG. 1;

FIG. 8 is a combined sectional view of the fuel injector valve body shown in FIG. 1, showing the cross-sections of different flat planes along the first radial direction, the second radial direction and the third radial directions superimposed on the same plane;

FIG. 9A is an enlarged view of part 9A of the fuel injector valve body shown in FIG. 8;

FIG. 9B is an enlarged view of part 9B of the fuel

injector valve body shown in FIG. 8;
FIG. 10A is an enlarged sectional view of the valve body portion of the fuel injector as shown in FIG. 2, showing a longitudinal section along the section line D-D as shown in FIG. 3;
FIG. 10B is a partially exploded view of FIG. 10A;
FIG. 11 is an enlarged front sectional view of the fuel nozzle portion of the fuel injector as shown in FIG. 1, wherein both the intermediate body and the needle valve are in a closed position;
FIG. 12 is an enlarged front sectional view of the fuel nozzle portion of the fuel injector as shown in FIG. 1 with the intermediate body in an opened position;
FIG. 13 is an enlarged front sectional view of the fuel port portion of the fuel injector as shown in FIG. 1 with the needle valve in an opened position.

Reference numerals:

[0024]

90	longitudinal axis
100	fuel injector
102	main housing
104	secondary housing
106	valve body
108	connecting holes
110	valve body cross section
111	first radial direction
112	second radial direction
112a	second circumferential direction
113	third radial direction
113a	third circumferential direction
120	outer valve body
120a	top surface
122	first fuel nozzle
123	first valve seat
126	first pressure chamber
127	first control channel
129	first control chamber
130	first input channel
131	first fuel inlet
140	first return channel
150	intermediate body
152	second fuel nozzle
153	second valve seat
155	annular feed groove
155a	first inner groove
155b	first outer groove
155c	first segment gap
156	second pressure chamber
157	second control channel
158	annular return groove
158a	second inner groove
158b	second outer groove
158c	second segment gap
159	second control chamber
1501	first intermediate body position
1502	second intermediate body position
160	second input channel
161	second fuel inlet
162	primary input section
162a	inlet of the primary input section
162b	outlet of the primary input section
1621a	radial distance between the primary input section inlet and the longitudinal axis
1621b	radial distance between the primary input section outlet and the longitudinal axis
164	secondary input section
164a	inlet of the secondary input section
164b	outlet of the secondary input section
1641a	radial distance between the secondary input section inlet and the longitudinal axis
1641b	radial distance between the outlet of the secondary input section and the longitudinal axis
170	second return channel
172	primary return section
174	secondary return section
176	return outlet
178	return channel
180	needle valve
182	radial gap
184	guiding ridge
185	prismatic segment
186	connecting portion
1801	first needle valve position
1802	second needle valve position
191	first solenoid valve
192	second solenoid valve
193	first elastic member
194	second elastic member

Detailed Description

[0025] It will be appreciated that components of the embodiments as generally described and illustrated in the drawings herein may be arranged and designed in a variety of different arrangements in addition to the described exemplary embodiments. Accordingly, the exemplary embodiments shown in conjunction with the accompanying drawings and the following detailed description are representative of example embodiments only, and do not limit the scope of claims of the embodiments.

[0026] Reference in this specification to "one embodiment," "another embodiment" or "an embodiment" (or similar terms) means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases "in one embodiment" or "in an embodiment," etc. in various places throughout this specification are not necessarily referring to the same embodiment.

[0027] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided to

provide a thorough understanding of the embodiments. One skilled in the relevant art will recognize, however, that the various embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, some or all known structures, materials, or operations may not be shown or described in detail.

[0028] As shown in FIG. 1 and FIG. 2, a dual-fuel injector 100 for an engine according to an embodiment of the present disclosure includes a main housing 102, a secondary housing 104 connected to a side portion of the main housing 102, and a valve body disposed along a longitudinal axis 90 of the fuel injector 100 and connected to the main housing 102. A first fuel inlet 131 is formed on the main housing 102, and a second fuel inlet 161 is formed on the secondary housing 104. The fuel injector 100 also includes a first solenoid valve 191 coupled to the main housing 102 for controlling the first fuel injection, and a second solenoid valve 192 coupled to the secondary housing 104 for controlling the second fuel injection. The secondary housing 104 includes several mounting holes for coupling with the engine, such as bolt holes 108. In the disclosure, the term "couple" refers to two or more independent components in the dual fuel injector 100 of the present invention which are directly or indirectly connected, assembled, combined or installed, including the connection, assembly, combination or installation of parts in a detachable manner between the two or more independent components, such as connection, assembly, combination or installation through threaded structure, mechanical tolerance fit structure, etc., and the two or more independent parts connected, assembled in a non-detachable manner, such as connected, assembled, combined or installed by welding, riveting, etc.

[0029] FIGS. 3 to 10B illustrate an internal structure of the fuel injector 100 in a perspective view, a plan view, a cross-sectional view, and an exploded view, respectively, wherein FIG. 8 is a cross-sectional view of the fuel injector valve body shown in FIG. 1 in an assembled state, and the cross sections of the first, second and third radial directions located in different planes are superimposed in the same plane as shown in FIG. 4, FIG. 5, and FIG. 6. FIG. 10A is a longitudinal cross-sectional view of the valve body 106 as shown in FIG. 2, wherein the outer valve body 120 is sectioned along the B-B direction shown in FIG. 3, and the intermediate body 150 is sectioned along the D-D direction shown in FIG. 3. As shown in FIG. 3 to FIG. 10B, in one embodiment, the valve body 106 includes an outer valve body 120 coupled to the main housing 102, an intermediate body 150 is disposed linearly movable in an inner chamber of the outer valve body 120, and a valve core, for example, a needle valve 180, is disposed linearly movable in an inner chamber of the intermediate body 150. The outer valve body 120 has a first fuel nozzle 122 and a first valve seat 123. The intermediate body 150 has a second fuel nozzle 152 and a second valve seat 153. A first pressure chamber 126 and a first control chamber 129 are formed between the intermediate body 150 and the outer valve body 120. The first fuel nozzle 122 is in communication with the first pressure chamber 126 through the first valve seat 123. A second pressure chamber 156 and a second control chamber 159 are formed between the needle valve 180 and the intermediate body 150. The second fuel nozzle 152 is in communication with the second pressure chamber 156 through the second valve seat 153. The first fuel inlet 131 opening on a top side of the secondary housing 104, and the second fuel inlet 161 opening on a sidewall of the main housing 102. The second fuel inlet 161 is disposed between the first fuel inlet 131 and the first fuel nozzle 122. A first elastic member, such as a first coil spring 193 is disposed in the first control chamber 129, and a second elastic member, such as a second coil spring 194 is disposed in the second control chamber 159.

[0030] The fuel injector 100 includes a pair of first input channel 130 in communication with the first pressure chamber 126, and a first return channel 140 in communication with the first control chamber 129. The first input channel 130 is formed in the main housing 102 and the secondary housing 104, and is in fluid communication with the first fuel inlet 131. The first input channel 130 forms a fluid communication between the first pressure chamber 126 and the first fuel inlet 131. The first return channel 140 is formed in the main housing 102, to form a fluid communication between the first control chamber 129 and the first solenoid valve 191.

[0031] The fuel injector 100 also includes a pair of second input channels 160 in communication with the second pressure chamber 156, and a second return channel 170 in communication with the second control chamber 159. A second input channel 160 is formed in the main housing 102 and in fluid communication with a second fuel inlet 161. The second input channel 160 forms a fluid communication between the second pressure chamber 156 and the second fuel inlet 161. A second return channel 170 is formed in the main housing 102 and the secondary housing 104, to form a fluid communication between the second control chamber 159 and the second solenoid valve 192.

[0032] An annular feed groove 155 and an annular return groove 158 offset relative to the annular feed groove 155 along the longitudinal axis 90 are formed between the outer valve body 120 and the intermediate body 150. The annular feed groove 155 includes a first inner groove 155a formed surround an inner wall of the outer valve body 120, and a first outer groove 155b formed surround the outer wall of the intermediate body 150, the first outer groove 155b is aligned with the first inner groove 155a along the longitudinal axis 90. The annular return groove 158 includes a second inner groove 158a formed on and surround an inner wall of the outer valve body 120, and a second outer groove 158b formed on and surround an outer wall of the intermediate body 150, the second outer groove 158b is aligned with the first inner groove 155a

along the longitudinal axis 90. The second control chamber 159 is in communication between the annular feed groove 155 and the annular return groove 158. The first inner groove 155a in a fitting engagement with the first outer groove 155b to form an annular feed groove 155 for containing and transporting the liquid fuel therein. At the same time, the first inner groove 155a and the first outer groove 155b are in a fitting engagement at a first segment gap 155c disposed between the outer valve body 120 and the intermediate body 150, forming a liquid communication between the annular feed groove 155 and the first segment gap 155c, allowing the liquid fuel in the annular feed groove 155 to penetrate into the gap 155c. Similarly, the second inner groove 158a is in a fitting engagement with the second outer groove 158b to form an annular return groove 158 for containing and transporting the liquid fuel therein. At the same time, the second inner groove 158a and the second outer groove 158b are in a fitting engagement at a second segment gap 158c disposed between the outer valve body 120 and the intermediate body 150, forming a liquid communication between the annular return groove 158 and the second segment gap 158c, allowing the liquid fuel in the annular return groove 158 to penetrate into the gap 155c. The liquid fuel penetrating into the gaps 155c and 158c provides lubrication between the outer valve body 120 and the intermediate body 150, assisting in a smooth linear movement of the intermediate body 150 relative to the outer valve body 120.

[0033] The second input channel 160 includes a pair of primary input sections 162 formed in the outer valve body 120 and a pair of secondary input sections 164 formed in the intermediate body 150. The inlet 162a of each primary input section 162 opens on a top surface 120a of the outer valve body 120. The outlet 162b of each primary input section 162 and the inlet 164a of each secondary input section 164 are respectively in communication with the annular feed groove 155. As illustrated in FIG. 10A and 10B, a radial distance 1621a between the inlet 162a of the primary input section 162 and the longitudinal axis 90 of the fuel injector 100 is greater than a radial distance 1621b between the outlet 162b of the primary input section 162 and the longitudinal axis 90 of the fuel injector 100, that is, the outlet 162b of the primary input section 162 in comparison to the inlet 162a is closer to the longitudinal axis 90, such that the primary input section 162 is arranged obliquely relative to the longitudinal axis 90 and is arranged converged in a direction towards the second fuel nozzle 152.

[0034] Each outlet 164b of the secondary input section 164 is in communication with the second pressure chamber 156. The annular feed groove 155 and the second pressure chamber 156 are arranged at different height positions along the longitudinal axis 90, so that the second pressure chamber 156 is located between the annular feed groove 155 and the second fuel nozzle 152. The radial distance 1641a between the inlet 164a of the secondary input section 164 and the longitudinal axis 90 of the fuel injector 100 is greater than the radial distance 1641b between the outlet 164b of the secondary input section 164 and the longitudinal axis 90 of the fuel injector 100, and the outlet 164b of the secondary input section 164 is disposed between the inlet 164a of the secondary input section 164 and the second fuel nozzle 152 along the direction of the longitudinal axis 90. That is, the outlets 164b of the pair of secondary input sections 164 is closer to the longitudinal axis 90 than the respective inlets 164a, so that the secondary input section 164 is arranged obliquely with respect to the longitudinal axis 90 and is arranged converged in a direction towards the second fuel nozzle 152.

[0035] Referring to FIGS. 3 to 6, as an example, a pair of first input channels 130 are arranged along the first radial direction 111 of the outer valve body 120. A pair of second input channels 160 are arranged along the second radial direction 112 of the outer valve body 120. The second radial direction 112 is angularly offset relative to the first radial direction 111 along the second circumferential direction 112a of the outer valve body 120 about the longitudinal axis 90 of the fuel injector 100. The second return channel 170 is arranged along the third radial direction 113. The third radial direction 113 is angularly offset relative to the first radial direction 111 along the third circumferential direction 113a of the outer valve body 120 about the longitudinal axis 90 of the fuel injector 100. The third circumferential direction 113a and the second circumferential direction 112a are angularly offset in opposite directions relative to the first radial direction 111. A second input channel 160 and a first control channel 127 are also formed in the outer valve body 120. The second input channel 160 and the first control channel 127 are in communication with the first control chamber 129. The first control channel 127 is arranged along the third radial direction 113. The first control channel 127 has an aperture sized for providing a pressure difference between the second input channel 160 and the first control chamber 129, thereby forming a damping throughhole between the second input channel 160 and the first control chamber 129. According to the above arrangement, a pair of first input channels 130, a pair of second input channels 160, and a second return channel 170 are all formed in the outer valve body 120, and the structural space provided by the outer valve body 120 is obtained and reasonably utilized, so that the overall structure of the fuel injector 100 is compact, which can adapt to the external dimensions of the existing engine housing, so that there is no need to substantially modify the existing engine and fuel injector installation interface.

[0036] The second return channel 170 includes a primary return section 172 formed in the intermediate body 150 and a secondary return section 174 formed in the outer valve body 120. The inlet of the primary return section 172 is in communication with the second control chamber 159, and the outlet of the primary return section 172 and the inlet of the secondary return section 174 are respectively in communication with the annular return

groove 158. The secondary return section 174 is arranged along the third radial direction 113 (FIG. 6).

[0037] The intermediate body 150 includes a second control channel 157 in communication with the second input channel 160 and the second control chamber 159. The second control channel 157 is arranged along the third radial direction 113. The second control channel 157 includes a second damping through-hole between the second input channel 160 and the second control chamber 159, and the second damping-through hole has an aperture sized to provide a pressure difference.

[0038] The fuel injector 100 further includes a return outlet 176 opening at a side of the main housing 102, and a return channel 178 in communication between the return outlet 176, the first solenoid valve 191 and the second solenoid valve 192. The return channel 178 is in communication with the first return channel 140 and the second return channel 170 through the first solenoid valve 191 and the second solenoid valve 192 respectively.

[0039] In one embodiment, as shown in FIG. 7, the inner chamber of the intermediate body 150 has a guiding inner surface, such as a cylindrical inner surface. The needle valve 180 comprises a prismatic segment 185 at a portion corresponding to the guiding inner surface of the intermediate body 150, thus forming a plurality of guiding ridges 184 circumferentially distributed and connecting portions 186 between respective adjacent guiding ridges. The guiding ridge 184 abuts against the guiding inner surface of the intermediate body 150, and the envelope surface of the guiding ridge 184 forms a tight translationally movable fit with a cylindrical inner surface of the inner chamber of the intermediate body 150, such that the intermediate body 150 provides guiding support to the needle valve 180. At the same time, a radial gap 182 is formed between the connecting portion 186 and the inner guide surface. The radial gap 182 is form as a liquid channel. The radial gap 182 forms part of the second pressure chamber 156. After the second solenoid valve 192 is switched on, the second fuel can pass through the radial gap 182 during the flow from the annular feed groove 155 to the second pressure chamber 156, and be ejected from the second fuel nozzle 152.

[0040] The intermediate body 150 is linearly moveable relative to the outer valve body 120 between a first intermediate body position 1501 and a second intermediate body position 1502. When in the first intermediate body position 1501, as shown in FIG. 11, the intermediate body 150 abuts against and closely engages the first valve seat 123 to block a fluid communication between the first pressure chamber 126 and the first fuel nozzle 122. When in the second intermediate body position 1502, as shown in FIG. 12, the intermediate body 150 is spaced apart from the first valve seat 123, to form a communication between the first pressure chamber 126 and the first fuel nozzle 122. Independent from the linear movement of the intermediate body 150 relative to the outer valve body 120, the needle valve 180 is linearly moveable relative to the intermediate body 150 between a first needle valve position 1801 and a second needle valve position 1802. When in the first needle valve position 1801, as shown in FIG. 10, the needle valve 180 abuts against and closely engages the second valve seat 153 to block a fluid communication between the second pressure chamber 156 and the second fuel nozzle 152. When in the second needle valve position 1802, as shown in FIG. 12, the needle valve 180 is spaced apart from the second valve seat 153 to form a communication between the second pressure chamber 156 with the second fuel nozzle 152.

[0041] When the fuel injector 100 is in operation, a first fuel, such as liquid methanol, is provided by a first fuel high-pressure pump or a first fuel storage vessel, to enter the first input channel 130 and the first pressure chamber 126 through the first fuel inlet 131. A second fuel, such as liquid diesel, is provided by a second fuel high-pressure pump or a second fuel storage vessel, to enter the second input channel 160, the first return channel 140, the second return channel 170, the first control chamber 129 , the second control chamber 159, the first control channel 127 , the second control channel 157 and the second pressure chamber 156 through the second fuel inlet 161.

[0042] The first solenoid valve 191 is used to control the ejection and to block the ejection of the first fuel. The opening of the first solenoid valve 191 causes the second fuel in the first control chamber 129 to flow to the return outlet 176 through the first return channel 140 and the first solenoid valve 191, thereby causing the liquid pressure in the first control chamber 129 to be lower than the liquid pressure in the first pressure chamber 126, and at the same time, under the damping effect of the first control channel 127, a liquid pressure difference is formed between the first control chamber 129 and the first pressure chamber 126. When the liquid pressure difference between the first control chamber 129 and the first pressure chamber 126 towards the direction away from the first fuel nozzle 122, exerts on the intermediate body 150 a thrusting force larger than the elastic force of the first elastic member 193, the intermediate body 150 is actuated by the first fuel in the first pressure chamber 126, to move linearly from a first intermediate body position 1501 (FIG. 11) to a second intermediate body position 1502 (FIG. 12). The intermediate body 150 at the second intermediate body position 1502 forms a communication between the first pressure chamber 126 and the first fuel nozzle 122, such that the first fuel can be ejected from the fuel injector 100 through the first fuel nozzle 122, to provide the first fuel to the engine of which the fuel injector 100 is installed on. After the first solenoid valve 191 is closed, the second fuel flows to the first control chamber 129 through the first control channel 127, such that the pressure in the first control chamber 129 increases. When the pressure difference between the first control chamber 129 and the first pressure chamber 126 is smaller than the elastic force of the first elastic member 193, the intermediate body 150 returns to the first intermediate

body position 1501 (Fig. 11), closing the communication between the first pressure chamber 126 and the first fuel nozzle 122, thereby blocking the ejection of the first fuel from the first fuel nozzle 122.

[0043] Independent from the control of the first solenoid valve 191, the second solenoid valve 192 is used to control the ejection or to block the ejection of the second fuel. The opening of the second solenoid valve 192 causes the second fuel in the second control chamber 159 to flow to the return outlet 176 through the second return channel 170 and the second solenoid valve 192. This causes a decrease in the liquid pressure of the second control chamber 159, and is lower than the liquid pressure in the second pressure chamber 156, and at the same time, under the damping effect of the second control channel 157, a liquid pressure difference is formed between the second control chamber 159 and the second pressure chamber 156. When the liquid pressure difference between the second control chamber 159 and the second pressure chamber 156 towards the direction away from the second fuel nozzle 152, exerts on the needle valve 180 a thrusting force larger than the elastic force of the second elastic member 194, the needle valve 180 is actuated by the second fuel in the second pressure chamber 156, to move linearly from the first needle valve position 1801 (FIG. 11) to the second needle valve position 1802 (FIG. 13). Needle valve 180 at second needle valve position 1802 forms a communication between the second pressure chamber 156 and the second fuel nozzle 152, such that a second fuel may be ejected from the fuel injector 100 through the second fuel nozzle 152, to provide the second fuel to the engine of which the fuel injector 100 is mounted to. After the second solenoid valve 192 is closed, the second fuel flows to the second control chamber 159 through the second control channel 157, such that the pressure in the second control chamber 159 increases. When the pressure difference between the second control chamber 159 and the second pressure chamber 156 is smaller than the elastic force of the second elastic member 194, the needle valve 180 resets to the first needle valve position 1801, closing the second pressure chamber 156 and the second fuel nozzle 152, thereby blocking the ejection of the second fuel from the second fuel nozzle 152. As mentioned above, through the independent and/or coordinated opening and closing operations of the first solenoid valve 191 and the second solenoid valve 192, the injection of the first fuel and the second fuel can be controlled or blocked, thereby providing the engine with a first fuel and a second fuel.

[0044] As used herein, the singular "a" and "an" may be construed to include the plural "one or more" unless expressly stated otherwise.

[0045] This invention has been presented for purposes of illustration and description, not exhaustion or limitation. Various modifications and changes will be apparent to those of ordinary skill in the art. The exemplary embodiments selected and described herein are for explaining principles and practical applications, so that those skilled in the art can understand various modifications suitable for various embodiments of the present invention, so as to achieve expected specific technical effects.

[0046] Accordingly, while illustrative example embodiments have been described herein with reference to the accompanying drawings, it is to be understood that such description is not limiting and that those skilled in the art may make other modifications without departing from the scope or inventive concepts and embodiments of the invention. It is subject to various other changes and modifications.

Claims

1. A dual fuel injector for an engine, the dual fuel injector comprising:

a main housing;

an outer valve body coupled to the main housing, the outer valve body having a first fuel nozzle and a first valve seat;

an intermediate body, the intermediate body being disposed linearly movable in an inner chamber of the outer valve body, the intermediate body having a second fuel nozzle and a second valve seat, the intermediate body and the outer valve body forming therebetween a first pressure chamber and a first control chamber, the first fuel nozzle being in communication with the first pressure chamber through the first valve seat;

a first input channel in communication with the first pressure chamber;

a first return channel in communication with the first control chamber;

a needle valve, the needle valve being disposed linearly movable in an inner chamber of the intermediate body, the needle valve and the intermediate body forming therebetween a second pressure chamber and a second control chamber, the second fuel nozzle being in communication with the second pressure chamber through the second valve seat;

a second input channel in communication with the second pressure chamber;

a second return channel in communication with the second control chamber;

wherein the intermediate body is linearly movable relative to the outer valve body between a first intermediate body position and a second intermediate body position; when in the first intermediate body position, the intermediate body abuts against the first valve seat to block a fluid communication between the first pressure chamber and the first fuel nozzle; when in the second intermediate body position, the intermediate body is spaced from the first valve seat to

allow communication between the first pressure chamber and the first fuel nozzle;
wherein the needle valve is linearly movable relative to the intermediate body between a first needle valve position and a second needle valve position; when in the first needle valve position, the needle valve abuts against the second valve seat to block a fluid communication between the second pressure chamber and the second fuel nozzle; when in the second needle valve position, the needle valve is spaced apart from the second valve seat to allow communication between the second pressure chamber and the second fuel nozzle.

2. The dual fuel injector according to claim 1, wherein the first input channel is formed in the outer valve body and arranged along a first radial direction of the outer valve body; the second input channel is formed in the outer valve body and arranged along a second radial direction of the outer valve body, the second radial direction is angularly offset relative to the first radial direction along a second circumferential direction of the outer valve body about a longitudinal axis of the fuel injector.

3. The dual fuel injector according to claim 2, further comprising an annular feed groove formed between the outer valve body and the intermediate body; an annular return groove axially offset relative to the annular feed groove; and a second control chamber in communication between the annular feed groove and the annular return groove, the second input channel including a primary input section formed in the outer valve body and a secondary input section formed in the intermediate body, wherein an outlet of the primary input section and an inlet of the secondary input section are respectively in communication with the annular feed groove, wherein the outlet of the secondary input section is in communication with the second pressure chamber, wherein the secondary input section is arranged along a first radial direction of the outer valve body.

4. The dual fuel injector according to claim 3, wherein a radial distance between the inlet of the secondary input section and the longitudinal axis of the fuel injector is greater than a radial distance between the outlet of the secondary input section and the longitudinal axis of the fuel injector, wherein the outlet of the secondary input section is disposed along the longitudinal axis between the inlet of the secondary input section and the secondary fuel nozzle such that the secondary input section is arranged obliquely relative to the longitudinal axis and is arranged converged in a direction toward the second fuel nozzle.

5. The dual fuel injector according to claim 3, wherein the annular feed groove comprises a first inner groove formed surround an inner wall of the outer valve body; and a first outer groove surround an outer wall of the intermediate body, the first outer groove being aligned with the first inner groove along the longitudinal axis.

6. The dual fuel injector according to claim 5, wherein the first inner groove and the first outer groove are in a fitting engagement with each other at a first segment gap between the outer valve body and the intermediate body to form a liquid communication between the annular feed groove and the first segment gap.

7. The dual fuel injector according to claim 5, wherein the annular return groove comprises a second inner groove formed on and surround an inner wall of the outer valve body and a second outer groove formed on and surround an outer wall of the intermediate body, the second outer groove being aligned with the first inner groove along the longitudinal axis.

8. The dual fuel injector according to claim 7, wherein the second inner groove and the second outer groove are in a fitting engagement with each other at a second segment gap between the outer valve body and the intermediate body to form a liquid communication between the annular return groove and the second segment gap.

9. The dual fuel injector according to claim 3, wherein the second return channel is formed in the outer valve body and arranged along a third radial direction, wherein the third radial direction is angularly offset relative to the first radial direction and the second radial direction along a third circumferential direction of the outer valve body about the longitudinal axis of the fuel injector.

10. The dual fuel injector according to claim 9, wherein the second return channel comprises a primary return section formed in the intermediate body and a secondary return section formed in the outer valve body, an inlet of the primary return section being in communication with the second control chamber, an outlet of the primary return section and an inlet of the secondary return section being respectively in communication with the annular return groove, the primary return section and the secondary return section being arranged along the third radial direction.

11. The dual fuel injector according to claim 9, further comprising a first control channel in communication with the second input channel and the first control chamber, the first control channel forming a first damping through-hole between the second input channel and the first control chamber.

12. The dual fuel injector according to claim 11, wherein the first control channel being arranged along the third radial direction.

13. The dual fuel injector according to claim 9, wherein the intermediate body includes a second control channel in communication with the second input channel and the second control chamber, the second control channel being arranged along the third radial direction.

14. The dual fuel injector according to claim 13, wherein the second control channel comprises a second damping through-hole between the second input channel and the second control chamber, wherein the second damping through-hole includes an aperture sized for providing a pressure difference between the second input channel and the second control chamber.

15. The dual fuel injector according to claim 1, wherein the inner chamber of the intermediate body has a guiding inner surface, wherein the needle valve has a plurality of guiding ridges parallel to a longitudinal axis of the fuel injector, the plurality of guiding ridges being linearly movable relative to the guiding inner surface cooperatively and being distributed circumferentially, a connection portion being formed between respective adjacent guiding ridges, a radial gap being formed between the respective connection portions and the guiding inner surface, the radial gap forming a liquid channel.

16. The dual fuel injector according to claim 15, wherein the guiding ridges abut against the guiding inner surface of the intermediate body.

17. The dual fuel injector according to claim 16, wherein a portion of the needle valve corresponding to the guiding inner surface of the intermediate body comprises a prismatic segment, the prismatic segment comprising a plurality of guiding ridges distributed circumferentially and a connection portion between respective adjacent guiding ridges.

18. The dual fuel injector according to claim 15, wherein an envelope surface of the guiding ridges forms a tight translationally movable fit with a cylindrical inner surface of the inner chamber of the intermediate body such that the intermediate body provides guiding support to the needle valve.

19. The dual fuel injector according to claim 1, further comprising a secondary housing, a first fuel inlet opening on a top portion of the secondary housing and a second fuel inlet opening on a side wall of the main housing, the second fuel inlet being disposed between the first fuel inlet and the first fuel nozzle.

20. The dual fuel injector according to claim 1, further comprising a return outlet opening on the main housing, wherein a communication between the return outlet and each of the first return channel and the second return channel is turned on or turned off controllably through a respective solenoid valve.

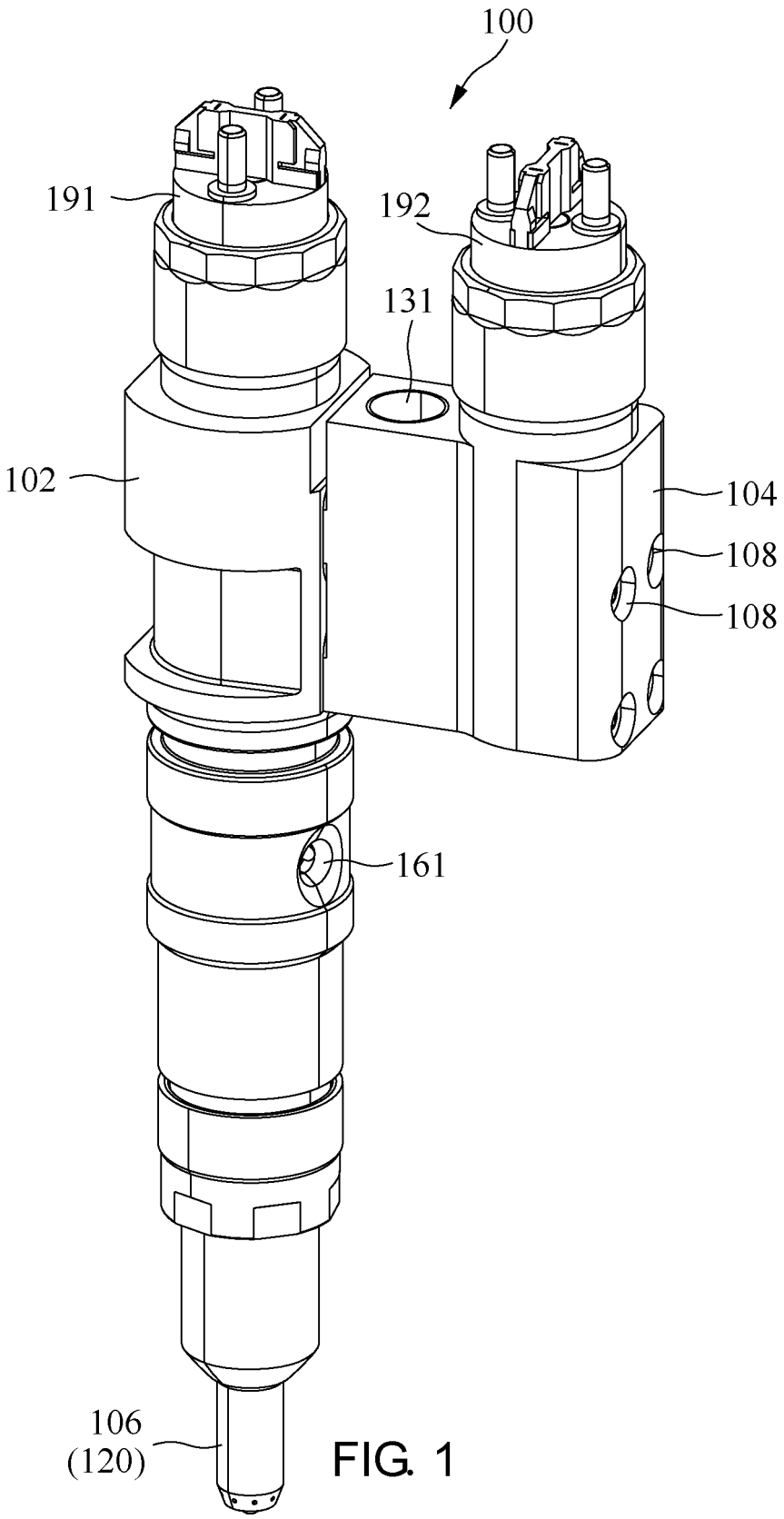
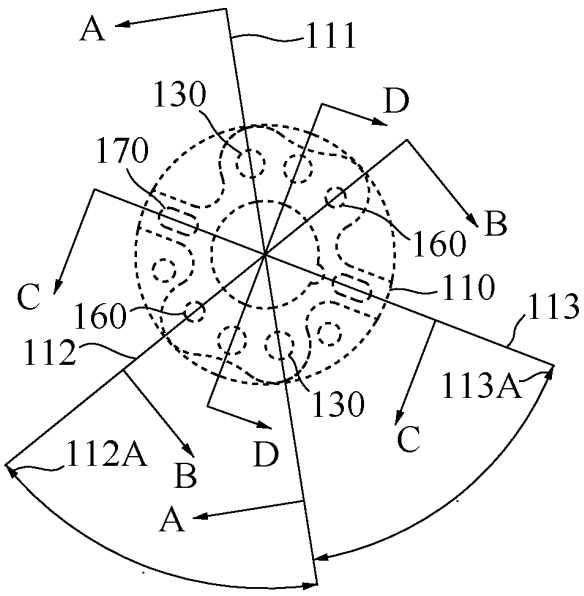


FIG. 1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112A
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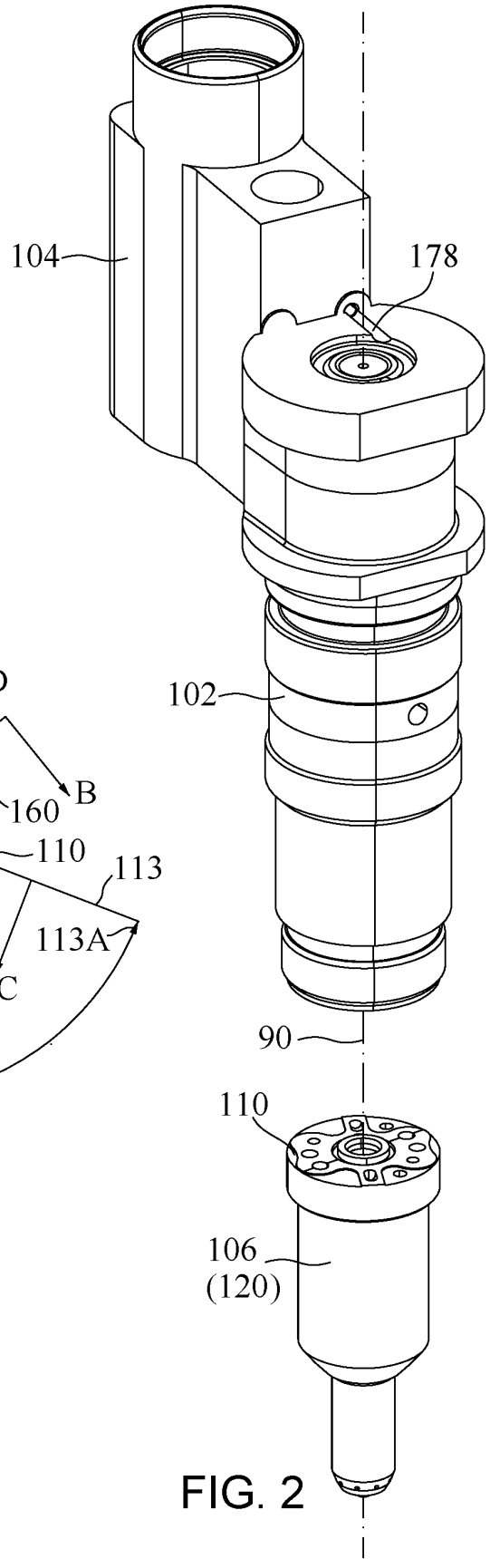
D
A

FIG. 3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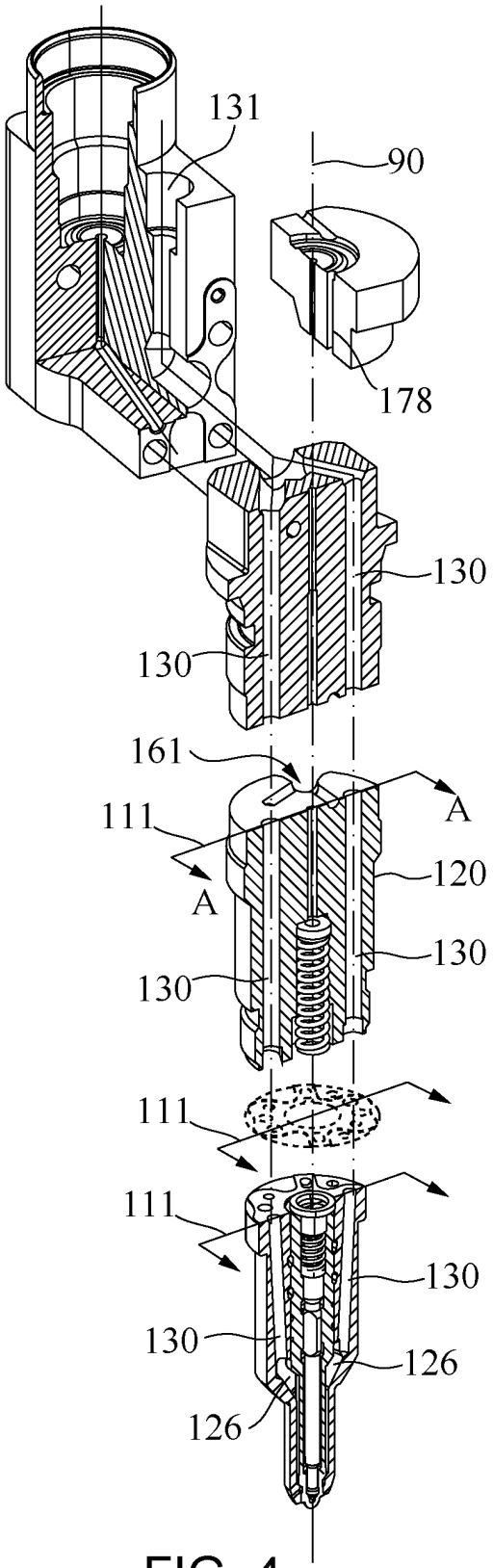
(120)

FIG. 2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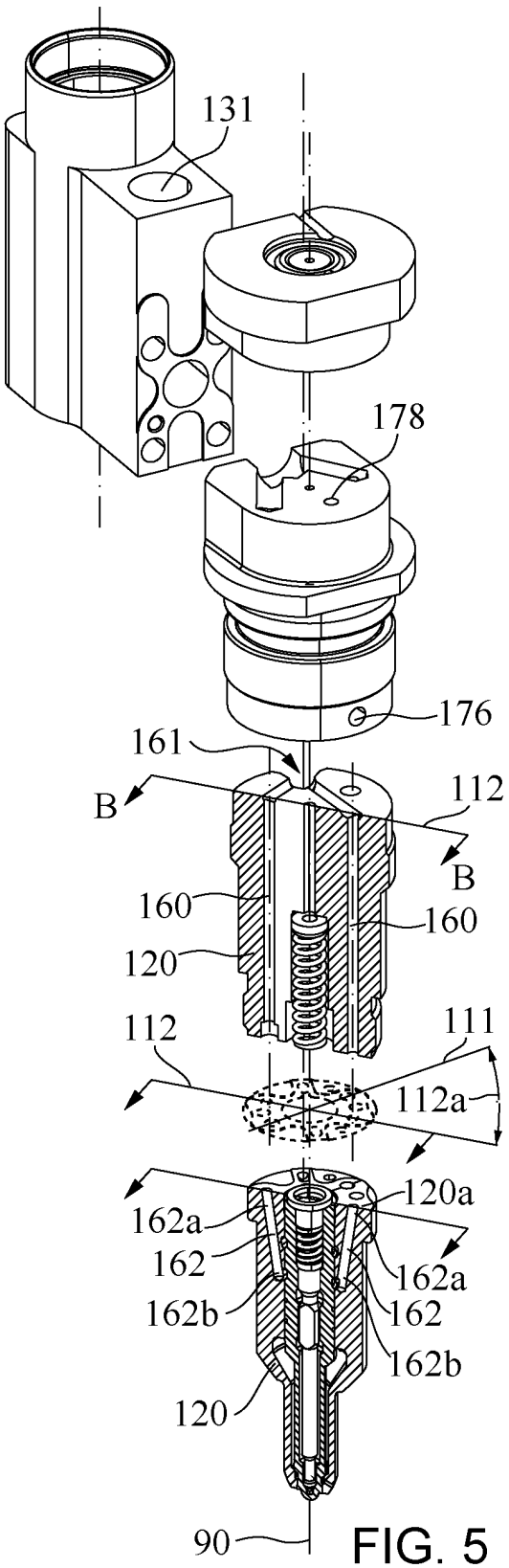
126

FIG. 4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B
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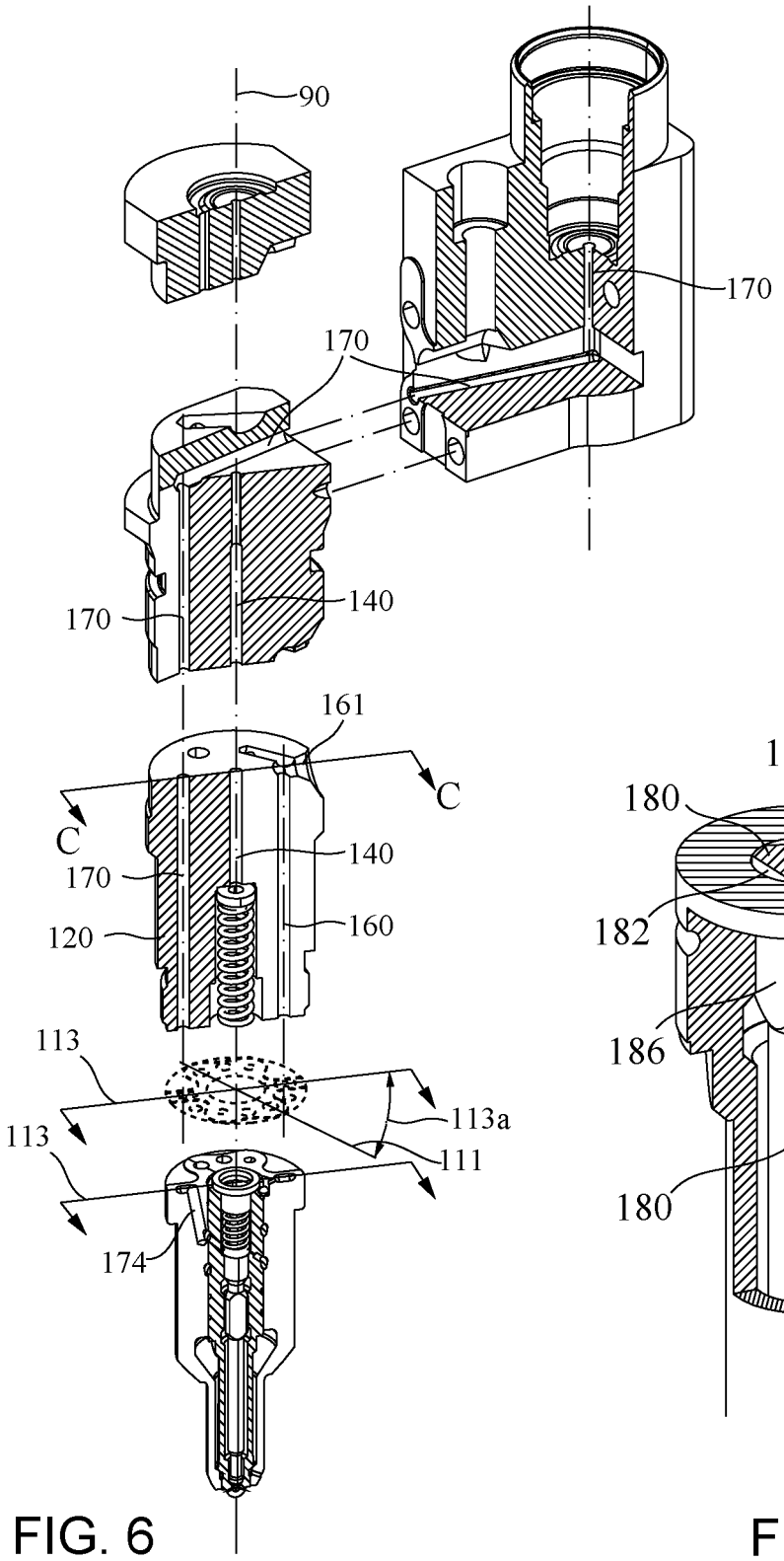
120
90

FIG. 5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C
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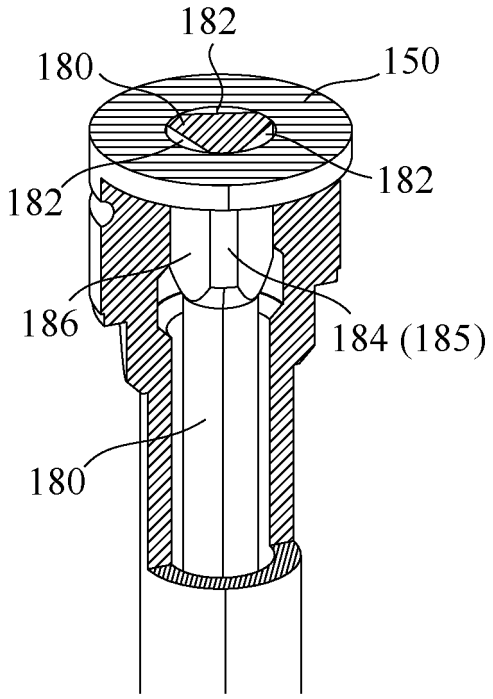
111
174

FIG. 6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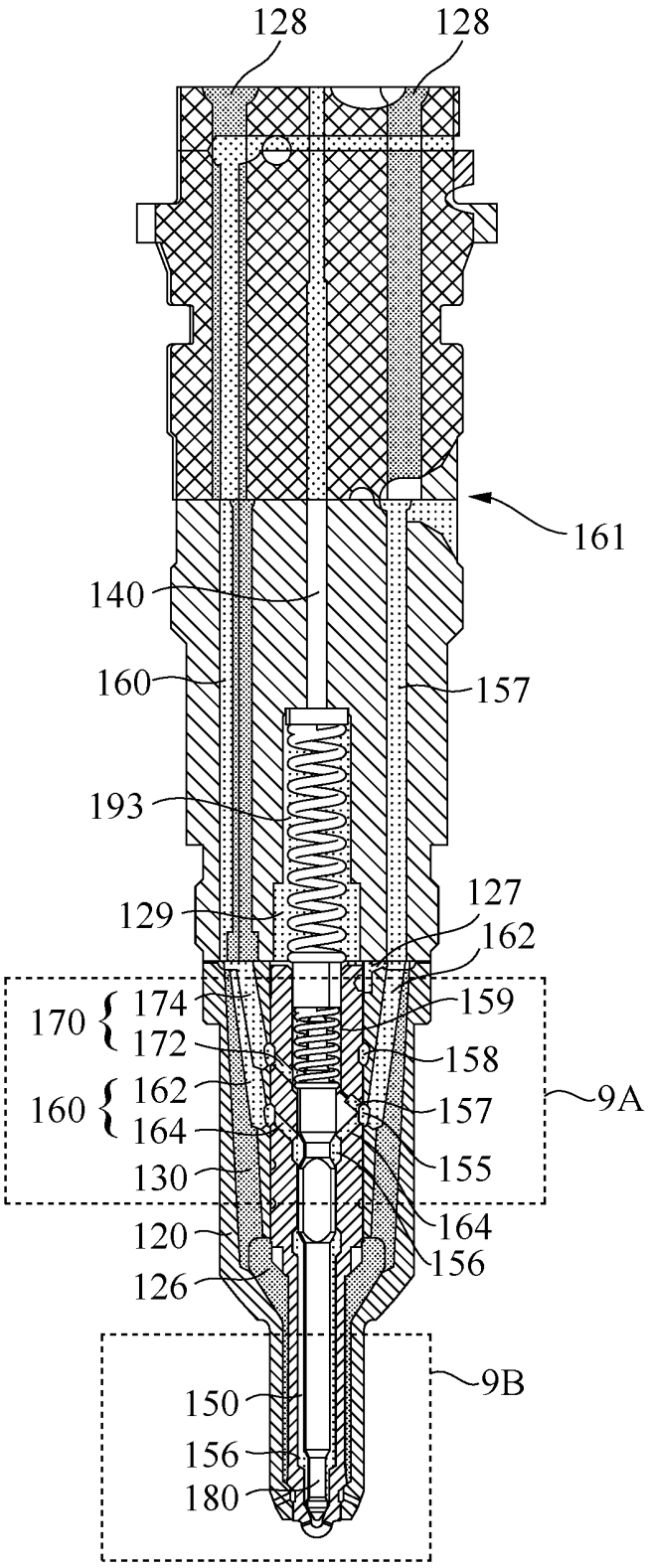
180

FIG. 7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170
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172
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162
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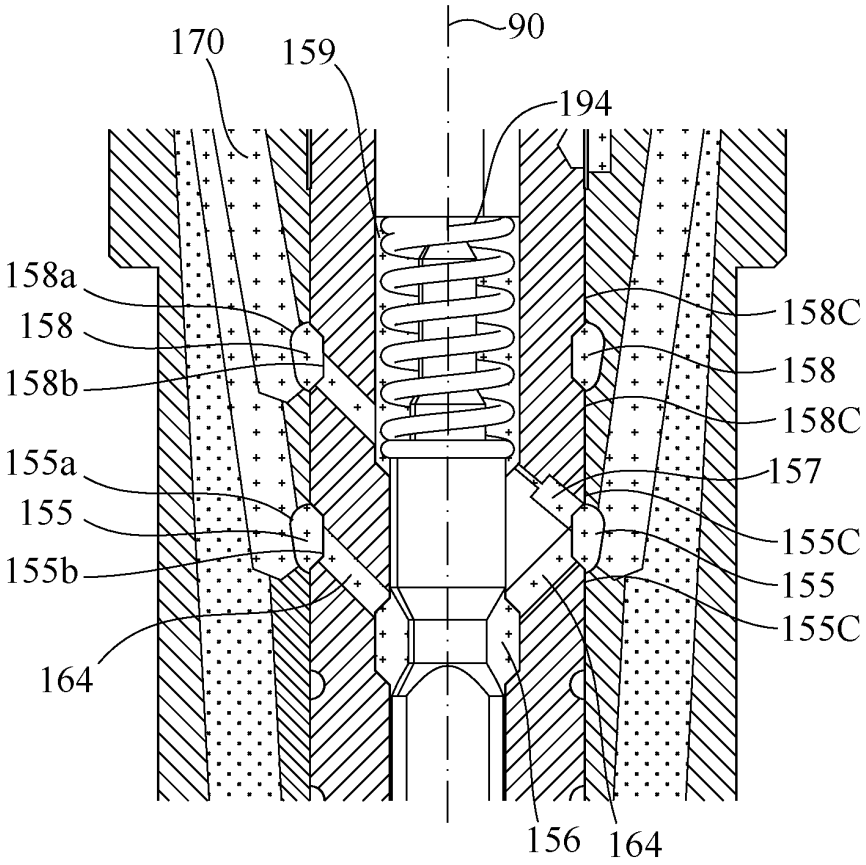
157
9A
130
155
120
164
126
156
9B
150
156
180

FIG. 8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159
194
158a
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155b
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158C
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158C
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155C
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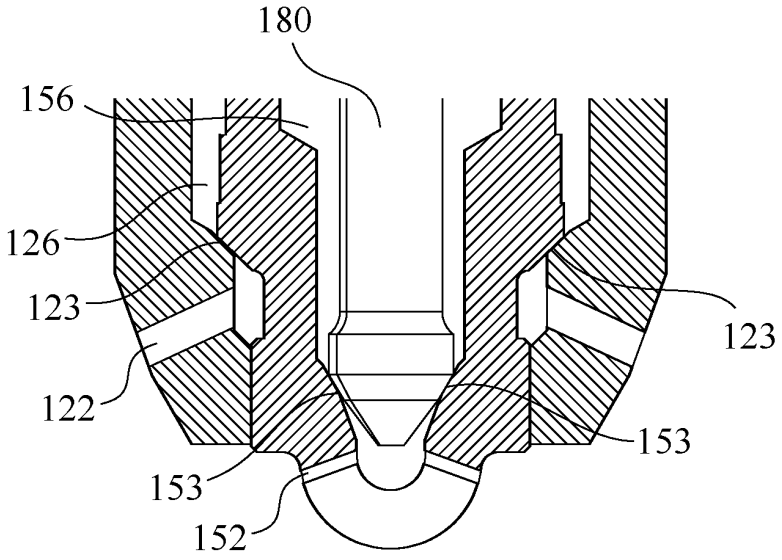
155C
156
164

FIG. 9A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152
123
153

FIG. 9B

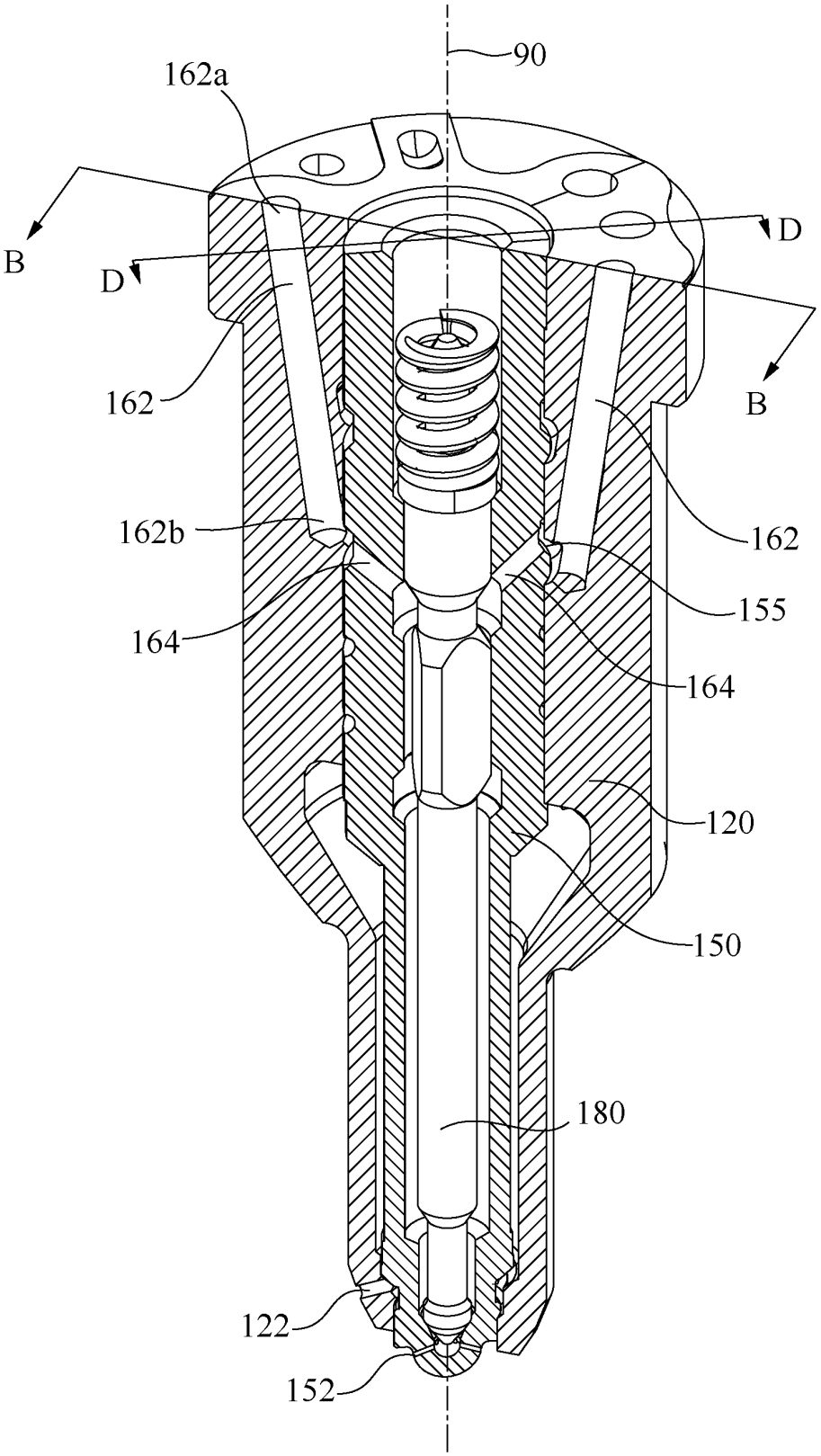
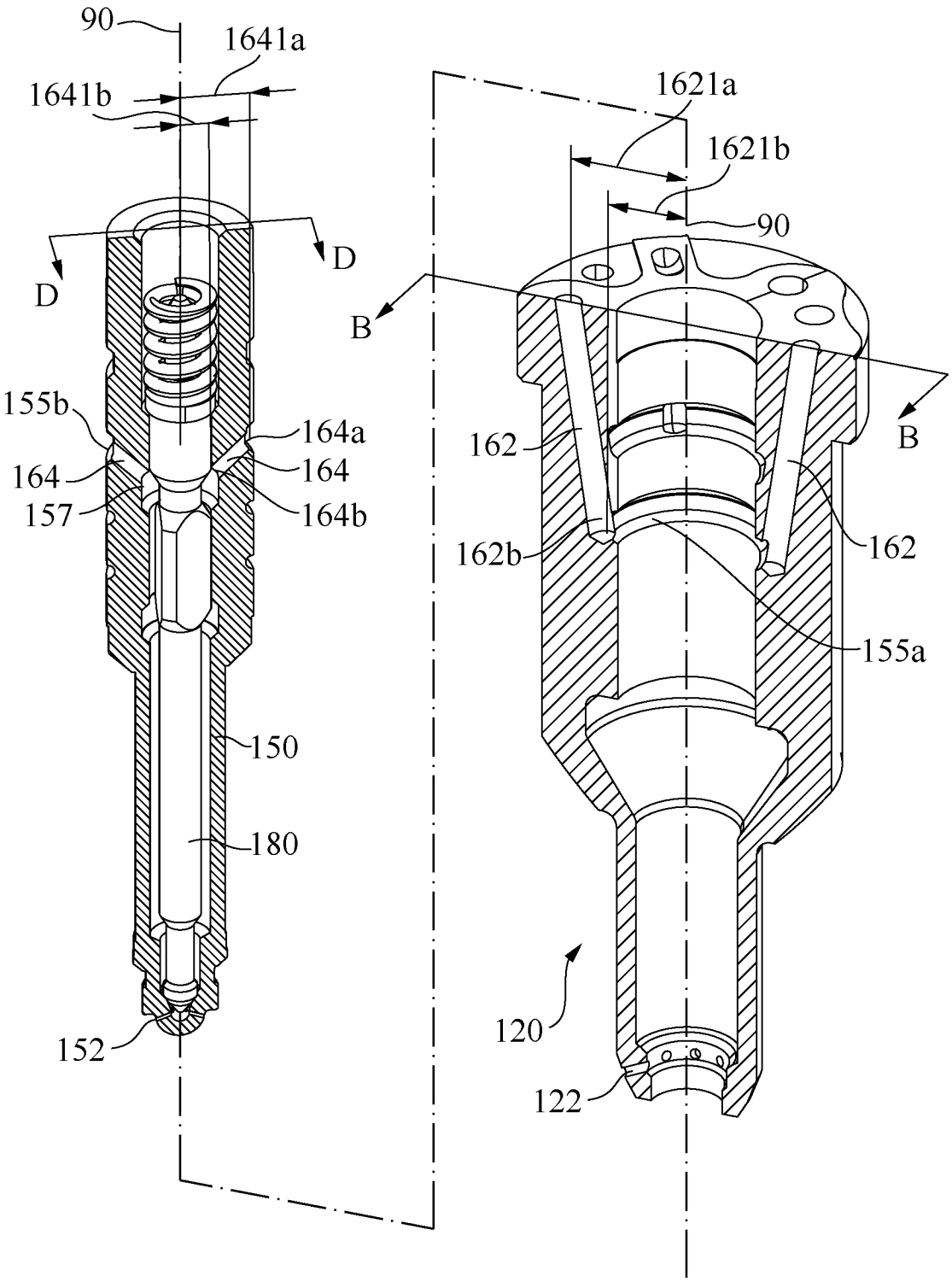


FIG. 10A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D
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164a
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164b
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162b
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120
122

FIG. 10B

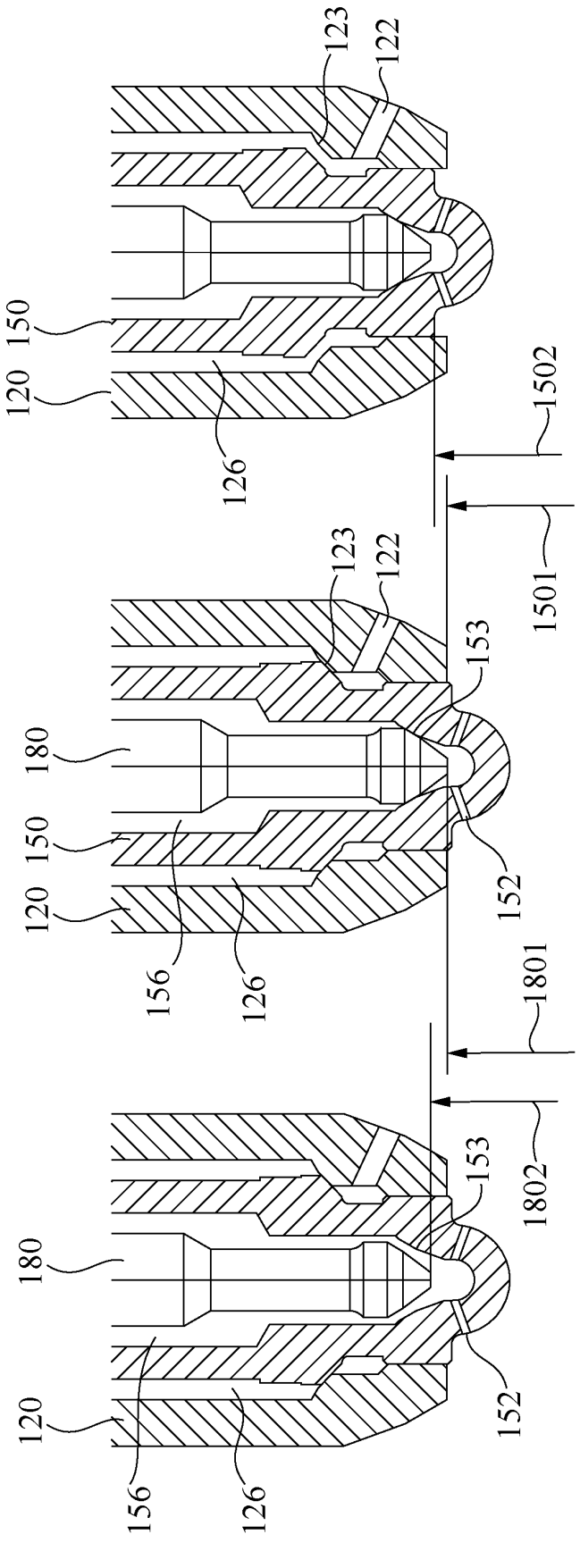

FIG. 11

FIG. 12

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2021/050816

A. CLASSIFICATION OF SUBJECT MATTER

Please see the additional box

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02M, F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: spray, injector, dual, double, second, fuel, fluid, liquid, needle, valve, gate, internal combustion engine, hydraulic, pressure, compression, control, chamber, passage, backflow, reflow, ring, slot, groove, trench, electromagnet valve, 喷嘴, 喷口, 喷孔, 双, 两, 二, 另, 燃料, 燃油,液体, 流体, 针阀, 内燃机, 发动机, 液压, 压力, 控制腔, 孔道, 回流, 环, 圈, 槽, 沟, 直电磁阀 and similar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 849325 C (BOSCH GMBH ROBERT) 15 September 1952	1-2, 15-20
A	machine translation, figure 1, and description, paragraphs [0005]-[0007], [0009], and [0012]	3-14
A	CN 110594061 A (CHONGQING HONGJIANG MACHINERY CO., LTD.) 20 December 2019, original text, figure 3, and description, paragraph [0030]	
A	CN 204900133 U (THE ENGINEERING ACADEMY OF ARMORED FORCES OF THE PEOPLE'S LIBERATION ARMY) 23 December 2005 entire text	

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2022	22/03/2022

Name and mailing address of the ISA/SG	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2021/050816

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1435702 A (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 12 May 1976 entire text	
A	CN 103244321 A (HARBIN ENGINEERING UNIVERSITY) 14 August 2013 entire text	

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SG2021/050816

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
DE 849325 C	15/09/1952	None	
CN 110594061 A	20/12/2019	FI 20215086 A1	27/03/2021
		DE 112020000639 T5	21/10/2021
		WO 2021/057018 A1	01/04/2021
		GB 2596882 A	12/01/2022
CN 204900133 U	23/12/2015	None	
GB 1435702 A	12/05/1976	JP S4949025 A	13/05/1974
		FR 2188067 A1	18/01/1974
		DE 2329768 A1	03/01/1974
CN 103244321 A	14/08/2013	None	

Form PCT/ISA/210 (patent family annex) (July 2019)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2021/050816

F02M43/04 (2006.01)

F02M51/06 (2006.01)

F02M47/02 (2006.01)

F02M 61/10 (2006.01)

F02M 61/18 (2006.01)

F02D19/06 (2006.01)

F02M 51/06 (2006.01)