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(54) FUEL INJECTOR

KRAFTSTOFFEINSPRITVENTIL

INJECTEUR DE CARBURANT

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(73) Proprietor: **Meyer, Andrew, E.**
Harpers Ferry, WV 25425 (US)

(72) Inventor: **Meyer, Andrew, E.**
Harpers Ferry, WV 25425 (US)

(74) Representative: **Sackin, Robert**
Reddie & Grose LLP
The White Chapel Building
10 Whitechapel High Street
London E1 8QS (GB)

(56) References cited:
EP-A1- 2 087 228
EP-A2- 1 111 230
EP-A2- 1 111 230
EP-A2- 1 335 129
WO-A1-2011/022821
DE-A1- 10 159 750
DE-A1-102004 044 820
JP-A- H04 179 855
US-A- 4 270 257
US-A- 5 833 142
US-A1- 2004 075 001
US-A1- 2004 124 274
US-A1- 2008 245 902
US-A1- 2008 245 902
US-A1- 2009 032 622
US-A1- 2009 032 622
US-B1- 7 942 349
US-B2- 7 137 571
US-B2- 7 188 788
US-B2- 8 950 694

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Description

BACKGROUND

[0001] The field of the present invention relates to fuel injectors. In particular, fuel injectors are disclosed herein that can maintain a fuel flow rate that is substantially independent of fuel source pressure, or that can deliver fuel in a desired spray pattern.

[0002] A wide variety of fuel injectors have been disclosed previously.

[0003] It would be desirable to provide a fuel injector having reduced dependence of fuel flow rate on fuel inlet pressure. It would be desirable to provide a fuel injector that has fuel flow rate that can be varied electronically during the injection. It would be desirable to provide a fuel injector having at least one spray-shaping surface to yield a desired fuel spray shape. It would be desirable to provide a fuel injector with an improved high-pressure seal to allow improved pressure balancing with lower leakage. Known patent references appear to lack those features.

[0004] For example, known fuel injectors include those described in EP 1 335 129 A2 and US 2009/0032622 A1. EP 1335 129 A2 describes a fuel injector that enables an axially symmetric spray shape to be provided even when the injection hole is inclined. The fuel injector of EP 1 335 129 A2 further enables the spray shape to be adjusted by adjusting the swirling force of the fuel spray. US 2009/0032622 A1 describes a fuel injector having a needle valve element. The fuel injector has a fluid flow restricting device to create a fluid pressure differential between fluid upstream and downstream of the fluid flow restricting device. JP H04 179855 A and US 2004/075001 describe fuel injectors that enable an axially asymmetric fuel spray shape.

SUMMARY

[0005] According to one aspect of the present invention, there is provided a fuel injector having an injector body, a valve passage, a fuel inlet connected to the valve passage, a fuel outlet connected to the valve passage, a reciprocating valve having a central, longitudinal axis and extending through the valve passage and through the fuel outlet, and a valve seat around the fuel outlet, wherein the valve and injector body are arranged so that movement of the valve in a first direction relative to the injector body causes engagement of the valve and the valve seat and substantially prevents fuel flow through the fuel outlet and movement of the valve in a second direction relative to the injector body, the second direction being opposite the first direction, causes disengagement of the valve and the valve seat and enables fuel flow through the fuel outlet in a pattern that is rotationally symmetric around the axis as the fuel exits from the valve body.

[0006] The injector may comprise a fuel chamber having primary and secondary fuel chambers, and the fuel injector can further comprise a primary valve seal and a metering member. The primary and secondary fuel chambers are connected by a valve passage, the fuel inlet is connected to the primary fuel chamber, and the fuel outlet is connected to the secondary fuel chamber. The primary valve seal is engaged with the primary fuel chamber and is positioned and arranged to substantially prevent fuel flow around the valve stem through the engaged portion of the primary fuel chamber. The metering member is positioned and arranged to restrict fuel flow from the primary fuel chamber into the secondary fuel chamber.

[0007] The injector body comprises a spray-shaping surface arranged in a ring around the fuel outlet; positioned and shaped to be struck by the rotationally symmetric pattern of fuel flowing through the fuel outlet after exiting from the valve body; and rotationally asymmetric around the axis, including multiple circumferential segments arranged to create, from the rotationally symmetric pattern of fuel flow exiting from the valve body, a rotationally asymmetric spray pattern by deflecting corresponding circumferential portions of the fuel spray flowing through the fuel outlet at differing corresponding angles relative to the axis for different of the multiple circumferential segments.

[0008] Objects and advantages pertaining to fuel injectors may become apparent upon referring to the exemplary embodiments illustrated in the drawings and disclosed in the following written description or appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is a cross-sectional view of an exemplary fuel injector.

Figs. 2A and 2B are calculated plots of fuel flow rate versus fuel inlet pressure for the exemplary fuel injector of Fig. 1.

Fig. 3 is a cross-sectional view of a fuel outlet and valve body of the exemplary fuel injector of Fig. 1.

Fig. 4 is a cross-sectional view of a fuel outlet and valve body of a fuel injector, according to Claim 1.

Fig. 5 is a cross-sectional view of a fuel outlet and valve body of an exemplary fuel injector.

Fig. 6 is a perspective view of a fuel outlet and spray-shaping surface of a fuel injector, according to Claim 2.

Fig. 7 is a perspective view of a fuel outlet and spray-shaping surface of an exemplary fuel injector.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] An exemplary fuel injector 10 is shown in Fig. 1 and comprises injector body 102 and reciprocating valve 110. An axial bore through injector body 102 forms a fuel chamber (in this example a primary fuel chamber 104 and a secondary fuel chamber 116 connected by a radially constricted valve passage 118; other examples can include any suitable arrangement of one or more fuel chambers). A fuel inlet 106 is connected to primary fuel chamber 104, and fuel outlet 101 is connected to secondary fuel chamber 116. During operation of this example, fuel (or a fuel/air mixture) flows from a fuel supply (not shown) through fuel inlet 106, into primary fuel chamber 104, into secondary fuel chamber 116, and then out through fuel outlet 101. Valve seat 140 (labelled in Figs. 3-5) is arranged around fuel outlet 101.

[0011] Valve 110 comprises valve body 114, positioned just outside fuel outlet 101, and valve stem 112, which extends through fuel outlet 101, fuel chambers 104 and 116, and valve passage 118. Axial movement of valve 110 in a first direction (up, as shown in the figures) causes valve body 114 to engage valve seat 140, thereby substantially preventing fuel flow through the fuel outlet (i.e., closing the injector). Movement of valve 110 in the other direction (down, as shown in the figures) causes disengagement of valve body 114 from valve seat 140, thereby enabling fuel flow through fuel outlet 101 (i.e., opening the injector). The fuel outlet typically is defined by the engagement of valve body 114 and valve seat 140, and the fuel injector can include additional passages, channels, or other flow-directing structures after the fuel outlet 101 (i.e., outside the secondary fuel chamber 116).

[0012] A resilient spring member of any suitable type or arrangement is typically employed to bias valve 110 in the first direction, keeping the fuel injector closed. In the exemplary fuel injector of Fig. 1, a compressed coil spring 134 is employed. When it is desired to open the fuel injector, an actuator responsive to a control signal applies an opening force to valve 110 in the second direction, overcoming the spring closing force and opening fuel injector 10. In the example of Fig. 1 the actuator comprises solenoid 130 and armature 132.

[0013] Any other suitable actuator can be employed, e.g., a piezoelectric actuator. Any other suitable arrangement can be employed for opening or closing the fuel injector. For example, the spring can be arranged to apply the force in the second (i.e., opening) direction and the actuator can be arranged to apply the force in the first (i.e., closing) direction. In another example, one or more actuators can be employed to supply forces in both directions.

[0014] In an example, primary valve seal 108 engages primary fuel chamber 104 to substantially prevent fuel flow around valve stem 112 through that portion of fuel chamber 104 that engages valve seal 108. Valve seal 108 is wider at the top (referring to Fig. 1) so that it engages spring 134. A crimp having a tapered bottom end is pressed against valve 110 above seal 108, thus engaging seal 108 and forcing seal 108 to move with valve stem 112 as valve 110 reciprocates. Seal 108 is machined to fit snugly within primary fuel chamber 104, to reduce leaking in the small gap between seal 108 and the wall of primary fuel chamber 104. Likewise, valve seal 108, in the example shown in Fig. 1, is not affixed to valve stem 112, but it is machined to fit snugly against it.

[0015] A circumferential member or flange 119 extending radially inward forms a radially constricted valve passage 118. Such radial constriction can be achieved by uniformly narrowing the bore or by any other structure that reduces the cross-sectional area of valve passage 118 at one or more points where flange 119 extends radially inward. In some embodiments, flange 119 can engage (that is, come close to, with clearance that is held to a tight tolerance) valve stem 112 at least partially, to nearly entirely prevent fuel flow around valve stem 112 in the area of such engagement.

[0016] Valve stem 112 can optionally also include a circumferential flange attached to and extending radially outward to engage valve passage 118. In such optional embodiment, care should be taken so that the relative areas of such an outwardly extending flange, the primary valve seal 108, and that portion of the valve body 114 subject to fuel pressure in secondary fuel chamber 116 result in suitable forces exerted on the valve 110 (see below).

[0017] Metering member 120 is arranged to restrict fuel flow from primary fuel chamber 104 to secondary fuel chamber 116. In the examples of Figs. 3 and 5, metering member 120 comprises the radially constricted valve passage 118 that engages valve stem 112, that is, a fuel-metering passage positioned between the primary and secondary fuel chamber 104 and 116 arranged to permit only restricted fuel flow from the primary fuel chamber 104 into secondary fuel chamber 116.

[0018] Flange 119 or the engaged portion of valve stem 112 can be provided with at least one axially extending groove or flat portion that extends the length of flange 119. Flange 119 and valve stem 112 do not engage one another at such a groove or flat portion, thereby leaving a metering orifice 122 that permits restricted fuel flow between primary and secondary fuel chambers 104 and 116. In the example of Fig. 4, metering member 120, or the fuel-metering passage restricting flow, comprises a metering orifice 122 that is formed by a bore or passage through flange 119 that connects primary fuel chamber 104 and secondary fuel chamber 116. Any passage or orifice connecting primary fuel chamber 104 and secondary fuel chamber 116 can be employed that permits suitably restricted fuel flow between them. Such a passage or orifice can be formed, for example, in injector body 102, flange 119, valve stem 112, or between the flange 119 and valve stem 112 (e.g., formed by a groove or flat portion as described above).

[0019] When fuel injector 10 is closed, fuel pressure is equalized between primary fuel chamber 104 and secondary fuel chamber 116 through metering orifice 122. Fuel pressure in primary fuel chamber 104 exerts a force in the first direction on valve 110 against primary valve seal 108. Fuel pressure in secondary fuel chamber 116 exerts a force in the second direction on valve 110 against that portion of valve body 114 that lies within valve seat 140 and is not occupied by valve stem 112. If the projected areas (perpendicular to valve stem 112) where those forces are applied are substantially equal to one another, then the fuel pressure exerts no net force on valve 110. Fuel injector 10 is considered pressure-balanced when it substantially meets this condition.

[0020] When fuel is flowing under pressure through inlet 106, there is fluid pressure in the upward direction of Fig. 1. In that condition, the fluid force slightly expands valve body 102, thus slightly increasing the bore diameter of chamber 104, which ordinarily would cause the small gap between seal 108 and body 102 (the seal/body gap) to expand, increasing seepage or leakage past seal 108, which is undesired. With the arrangement of seal 108 shown in Fig. 1, however, the fluid force will expand both (a) the body 102, and (b) the gap between seal 108 and valve stem 112 (the seal/stem gap). Because the seal/stem gap is plugged at the top end (in Fig. 1) by the tapered crimp, it forms a dead end, causing no additional leakage. Advantageously, however, expansion of the seal/stem gap tends to offset the widening of the seal/body gap, thus lessening the seepage or leakage past seal 108 through the seal/body gap when the fuel injector is pressurized.

[0021] In the absence of a force applied by an actuator, the only force applied to valve 110 is that of spring 134, which biases the fuel injector's valve 110 into a closed position. When sufficient force is applied to valve 110 in the second direction by solenoid 130 (i.e., when the actuator force exceeds the spring force), valve 110 moves in the second direction (down) and opens. If the force applied by spring 134 varies linearly with displacement (as is the case with most springs over limited ranges of motion), then the displacement of valve 110 is typically proportional to the difference between the spring and actuator forces.

[0022] Without the action of metering member 120, the fuel flow rate would typically vary approximately proportionally with the square root of the fuel inlet pressure, and at higher fuel pressure often depends only weakly on the actuator force. It is desirable in many instances to reduce or substantially eliminate such dependence of the fuel flow rate on the fuel inlet pressure. It is also desirable for the fuel flow rate to depend upon the actuating force (i.e., the net force exerted by solenoid 130 and spring 134 in the example of Fig. 1). Metering member 120 serves those functions, as further described below.

[0023] The restricted metering orifice 122 provides restricted fuel flow between primary fuel chamber 104 and secondary fuel chamber 116. As described above, when fuel injector 10 is closed, fuel pressure in those chambers is equalized and no additional pressure-induced force is exerted on valve 110. However, when fuel injector 10 is open and fuel is flowing, a pressure differential develops between primary fuel chamber 104 (higher pressure) and secondary fuel chamber 116 (lower pressure), due to the flow-dependent pressure drop through restricted metering orifice 122. That pressure differential results in a flow-dependent force that tends to urge valve 110 in the first (i.e., closing) direction. The result is a kind of negative feedback arrangement. Higher fuel inlet pressure leads to higher fuel flow, in turn resulting in an increase of the flow-dependent force tending to move valve 110 toward the closed position, thereby reducing the fuel flow. Conversely, a lower fuel inlet pressure leads to lower fuel flow, in turn resulting in a reduction of the flow-dependent closing force on valve 110, thereby increasing fuel flow.

[0024] The negative feedback can reduce the dependence of the fuel flow rate through fuel injector 10 (for a given actuator force and spring force constant) on the fuel inlet pressure. For example, plots of calculated fuel flow rate versus fuel pressure for fuel injectors with negative feedback (dotted) and without negative feedback (solid) are shown in Figs. 2A and 2B. The fuel flow rate through the fuel injector of Fig. 1 depends on the flow resistance of metering orifice 122 (metering flow area of 0.021 mm^2 for Fig. 2A and 0.105 mm^2 for Fig. 2B), the valve-position-dependent flow resistance at fuel outlet 110, the net non-flow-dependent force applied to valve 110 by spring 134 and the valve actuator (about 22.25 N for Figs. 2A and 2B), and the areas of primary valve seal 108 and valve body 114 subject to the fuel pressures of each of the fuel chambers (pressure active area of 1.128 mm^2 for Figs. 2A and 2B). The feedback can also reduce the effect on the fuel flow rate of injector temperature variations, which can be substantial in an internal combustion engine. The area of any outwardly extending flange on valve stem 112 decreases the influence of the negative feedback arrangement. Any set or subset of those parameters can be selected to yield a desired dependence of fuel flow on fuel inlet pressure.

[0025] In an exemplary embodiment, fuel injector 10 can include a spray-shaping surface or surfaces arranged to direct the fuel sprayed from the fuel outlet 101. The spray-shaping surface can be arranged on the injector body 102 around all or part of the valve seat 140, or the spray-shaping surface can be arranged around all or part of the valve-seat-engaging portion of the valve body 114.

[0026] In the example of Fig. 3, a spray-shaping surface 142 is formed on injector body 102 just outside valve seat 140; two differing spray-shaping surfaces 142a and 142b are shown in Fig. 4, according to the invention. The indicated angle A in Fig. 3 (angles A1 and A2 in Fig. 4) between spray-shaping surface 142 (surfaces 142a and 142b in Fig. 4) and a lateral surface of valve body 114 can be selected to yield a desired geometry for the spray of fuel exiting fuel outlet 101 when injector 10 is open. Spray-shaping surface 142 can be rotationally symmetric (not in accordance with the present invention), so that the cross-section of Fig. 3 would remain constant regardless of the rotation of fuel injector 10 about an axis defined by valve stem 112. The resulting fuel spray also would be rotationally symmetric about that axis. Alternatively, spray-shaping surfaces 142a and 142b can vary with angular position about its axis, resulting in a fuel spray that is not symmetric. Cross-sectional views of such an embodiment can resemble that of Fig. 4, with the angles A1 and A2 between surface 142 and valve body 114 varying depending on the rotational position of fuel injector 10 about its axis. A valve seat angle (angle S as shown in Fig. 3) can vary from 90° (i.e., a flat valve seat) down to any desired angle that does not cause the valve body to stick in the seat due to wedging. The angle of the valve seat 140 can also substantially affect the shape of the spray, e.g., if the seat angle S is less than the angle A.

[0027] One suitable shape for surface 142 includes a curved portion characterized by a radius and that begins tangent to the valve seat 140 and redirects the fuel spray toward the axis of the injector. A radius on the order of a quarter of a millimeter can be employed, for example; any suitable radius can be employed as needed or desired. In addition, a single radius can be used, or the radius can vary circumferentially, radially, or axially, as needed or desired. The curved portion of the surface can be truncated at a point to yield the desired angle between the spray-shaping surface and the side of the valve body. If the curved portion of the surface is truncated at the same length around the entire circumference of the surface 142 (yielding angle A in Fig. 3, which is not in accordance with the present invention), a rotationally symmetric spray pattern results. If the curved portion of the surface is truncated at differing lengths around the circumference of surfaces 142a and 142b (yielding angles A1 and A2 in Fig. 4), a rotationally asymmetric spray pattern can be created.

[0028] In an embodiment, an undulating, cam-like surface can be formed on the end of the fuel injector to truncate the curved surface at varying lengths (e.g., surface 143 shown in Fig. 6). In the example of Fig. 6, only a portion of the end of the fuel injector bears the cam-like surface 143, and those portions might resemble the cross section of Fig. 4. The remainder of the end of the injector, including surface 142a, might resemble the cross section of Fig. 3. Many differing cam-like shapes, combinations of differing cam-like shapes, or combinations of cam-like shapes and other shapes can be employed to produce a wide array of differing spray patterns. Any of those shapes can include additional surfaces features, e.g., radial grooves on the cam-like surface.

[0029] By employing a spray-shaping surface that varies around the circumference of the valve seat, a spray pattern results that is dispersed over a range of "elevation angles" (i.e., angles with respect to the injector axis). Such a "corrugated" spray pattern has been observed to provide a large surface area spray for mixing fuel and air, and exhibits a lesser tendency to collapse toward the injector axis than a wide-angle conical spray. A wide variety of shapes can be implemented to yield a correspondingly wide array of desired fuel spray shapes for fuel injector 10.

[0030] Angles A, A1, and A2 can vary from 0° (creating a spray directed substantially axially) to 90° (creating a spray directed substantially radially). In some instances an angle greater than 90° could be employed. In one example, valve seat 140 is arranged with a seat angle of about a 45°, a radius of a curved portion of surface 142 of about 125 micrometers, a diameter of about 1.6mm for valve body 114, and an angle A of about 0°, yielding a spray directed generally axially and subtending a cone angle of about 10° (half-angle).

[0031] In various different fuel injection arrangements in various internal combustion engine types, differing angular ranges may provide desirable spray shapes or improved fuel injection. For example, angle A (or A1 and A2) can be made larger than about 60° or smaller than about 85° for use in a directly injected, conventional compression-ignition engine (e.g., a piston diesel engine). In another example, angle A (or A1 and A2) can be made larger than about 5° or smaller than about 60° for use in a two-stroke gasoline engine. In another example, angle A (or A1 and A2) can be made larger than about 15° or smaller than about 45° for use in a gasoline, direct-injected engine. In another example, angle A (or A1 and A2) can be made larger than about 0° or smaller than about 25° for use in a pre-chamber-injected engine. Those angular ranges can be employed in any suitable engine type (including those not listed above), or other suitable angular ranges can be employed for any suitable engine type (including those listed above).

[0032] In the example of Fig. 5, a spray-shaping surface 144 is formed on valve body 114 just outside the area where it engages valve seat 140. The indicated angle B between spray-shaping surface 144 and a substantially vertical lateral surface of valve body 114 can be selected to yield a desired geometry for the spray of fuel exiting fuel outlet 101 when injector 10 is open. Such an arrangement would be typically employed in an injector having a conical valve seat, and the angle B might typically vary between about 30° and 90°; other suitable angles can be employed. As described above, spray-shaping surface 144 can be rotationally symmetric (not in accordance with the present invention), or it can vary with angular position about its axis (not shown). Simple or complex curved surfaces or grooved surfaces can be employed. More generally, spray-shaping surfaces can be formed in any desired configuration on either or both of injector body 102 or valve body 114. If a spray-shaping surface is formed on valve body 114, the force exerted on that surface by the fuel spray typically should be accounted for when implementing the negative feedback mechanism described above.

[0033] In addition to spray-shaping surfaces 142 or 144 positioned near the valve seat 140, other spray-shaping surfaces or structures can be employed to shape or guide the fuel spray. In the example of Fig. 7, spray-guiding surfaces 152 are arranged as a set of radially extending slots arranged around valve seat 140 and spray-shaping surface 142. Any suitable arrangement of such surfaces or structures for shaping or guiding the fuel spray shall fall within the scope of the term "spray-shaping" in the present disclosure or appended claims.

[0034] The arrangements and adaptation disclosed (i) for providing a desired dependence (or lack thereof) of fuel flow rate versus fuel inlet pressure or actuator force, or (ii) for providing a spray-shaping surface to yield a desired fuel spray pattern, can be implemented together in a single fuel injector. Alternatively, only one or the other of those arrangements or adaptations might be implemented in a given fuel injector.

[0035] Thus, in a first embodiment of one aspect of the fuel injector disclosed, a fuel injector comprises (a) an injector body comprising a primary fuel chamber, a fuel inlet connected to the primary fuel chamber, a secondary fuel chamber, an inwardly extending member separating the primary and secondary fuel chambers and at least partially surrounding a valve passage connecting the primary and secondary fuel chambers, a fuel outlet connected to the secondary fuel chamber, and a valve seat around the fuel outlet; (b) a reciprocating valve extending through the fuel outlet, secondary fuel chamber, valve passage, and primary fuel chamber; and (c) a fuel-metering passage extending between said fuel chambers and arranged to permit only restricted fuel flow from the primary fuel chamber into the secondary fuel chamber.

[0036] In the first embodiment, the valve and injector body are arranged so that movement of the valve in a first direction relative to the injector body causes engagement of the valve and the valve seat and substantially prevents fuel flow through the fuel outlet, and movement of the valve in a second direction relative to the injector body, the second direction being opposite the first direction, causes disengagement of the valve and the valve seat and enables fuel flow through the fuel outlet.

[0037] In the first embodiment, the fuel injector is structured so that, with the valve disengaged from the valve seat and fuel flowing through the fuel outlet, the restricted fuel flow from the primary fuel chamber into the secondary fuel chamber results in a fuel pressure differential between the primary and secondary fuel chambers that in turn results in a flow-dependent force on the valve in the first direction, which force increases with increasing fuel flow through the fuel outlet.

[0038] In an optional extension of the first embodiment, the inwardly extending member at least partially engages the valve as it passes through the valve passage. In another optional extension of the first embodiment, the injector is structured so that the flow-dependent force on the valve in the first direction varies substantially proportionally with a square of the rate of fuel flow through the fluid passage.

[0039] In some instances of the first embodiment, a valve seal can be positioned and arranged to substantially prevent fuel flow along the valve through the primary fuel chamber past the valve seal, and the fuel injector is structured so that, with the valve engaged with the valve seat, the valve is substantially pressure balanced.

[0040] In some instances of the first embodiment, or in other pressure-balanced embodiments, the valve seal can extend along and reciprocate with the valve stem but be positioned with a gap between the valve seal and the valve stem, so that increasing pressure tends to expand the seal at the same time as it expands the bore plugged by the seal, reducing leakage.

[0041] In the first embodiment, further, the fuel-metering passage can optionally be within the valve passage and comprise a gap between the injector body and the valve, and if so, the gap can be an axially extending groove in the inwardly extending member, or an axially extending flat surface of the valve facing a concave surface of the inwardly extending member. Alternatively, the fuel-metering passage can comprise a passage or orifice formed in the injector body.

[0042] In the first embodiment, further, the inwardly extending member can be integrally formed as part of the injector body.

[0043] In a second embodiment of another aspect of the fuel injector disclosed, a fuel injector comprises: an injector body, a valve passage, a fuel inlet connected to the valve passage, a fuel outlet connected to the valve passage, a reciprocating valve extending through the valve passage and through the fuel outlet, and a valve seat around the fuel outlet. In that embodiment, the valve and injector body are arranged so that movement of the valve in a first direction relative to the injector body causes engagement of the valve and the valve seat and substantially prevents fuel flow through the fuel outlet, and movement of the valve in a second direction relative to the injector body, the second direction being opposite the first direction, causes disengagement of the valve and the valve seat and enables fuel flow through the fuel outlet.

[0044] In the second embodiment, further, the fuel injector further has a spray-shaping surface arranged in a ring around the fuel outlet, positioned and shaped to be struck by fuel flowing through the fuel outlet, rotationally asymmetric around an axis defined by the valve, and including multiple circumferential segments arranged to deflect corresponding circumferential portions of the fuel spray flowing through the fuel outlet at differing corresponding angles relative to an axis defined by the valve.

[0045] In the second embodiment, the spray-shaping surface can be (a) a surface of the valve adjacent to a valve-seat-engaging portion of the valve (not in accordance with the present invention), or (b) a surface of the valve body, or (c) a combination of the two.

Claims

1. A fuel injector (10) having an injector body (102), a valve passage (104, 118, 122, 116), a fuel inlet connected to the valve passage (106), a fuel outlet (101) connected to the valve passage, a reciprocating valve (110, 112) having a central, longitudinal axis and extending through the valve passage and

through the fuel outlet, and a valve seat (140) around the fuel outlet, wherein the valve and injector body are arranged so that movement of the valve in a first direction relative to the injector body causes engagement of the valve and the valve seat and substantially prevents fuel flow past the valve seat (140) and movement of the valve in a second direction relative to the injector body, the second direction being opposite the first direction, causes disengagement of the valve and the valve seat, **characterised in that** the injector body (102) further comprises a spray-shaping surface (142) surrounding the axis and extending from a proximal end tangent to the valve seat (140) to a rotationally asymmetric distal end,

wherein, at the distal end, (i) a first portion (142a) of the spray-shaping surface, at a first location around the axis, has a first angle (A1) relative to the axis, and (ii) a second portion (142b) of the spray-shaping surface, at a second location around the axis different from the first location, has a second angle (A2) relative to the axis, the second angle (A2) being different from the first angle (A1),
wherein the first portion and the second portion of the spray-shaping surface of the injector body are each curved and convex between the proximal end and the distal end,
wherein the first portion and the second portion of the spray-shaping surface of the injector body have different lengths from one another between the proximal end and the distal end,
whereby the spray-shaping surface is shaped to redirect the fuel spray toward the axis at the first portion and the second portion and to create a rotationally asymmetric spray pattern by deflecting circumferential portions of the fuel spray at differing angles relative to the axis.

2. The fuel injector of claim 1, wherein the distal end undulates around the axis at least at a portion of the circumference.

3. The fuel injector of any of claims 1 or 2, wherein:

(a) the fuel injector comprises primary (104) and secondary (116) fuel chambers with the fuel inlet connected to the primary fuel chamber and the fuel outlet connected to the secondary fuel chamber;
(b) the fuel injector further comprises a fuel-metering passage (122) positioned and arranged to permit only restricted fuel flow from the primary fuel chamber into the secondary fuel chamber; and
(c) the fuel injector is structured so that, with the valve disengaged from the valve seat and fuel flowing through the fuel outlet, the restricted fuel flow from the primary fuel chamber into the secondary fuel chamber results in a fuel pressure differential between the primary and secondary fuel chambers that in turn results in a flow-dependent force on the valve in the first direction, which force increases with increasing fuel flow through the fuel outlet, and
(d) an actuator (130, 132) coupled to the valve and exerting a controllable force on the valve; wherein the force is variable and the fuel flow rate depends on the force.

4. The fuel injector of claim 3, wherein the actuator comprises a solenoid (130) and wherein the force, and hence the fuel flow rate, is controlled by a current of the solenoid.

5. The fuel injector of claim 3, further comprising a resilient spring member (134) arranged to urge the valve in the first direction, and wherein the actuator is arranged to urge the valve in the second direction in response to a control signal.

6. The fuel injector of any of claims 3 to 5, wherein the fuel-metering passage is within the valve passage and comprises a gap (118) between the injector body and the valve.

7. The fuel injector of any of claims 3 to 5, wherein the fuel-metering passage is formed by a circumferential flange (119) that extends radially inward from the injector body.

8. The fuel injector of any of claims 3 to 5, wherein the fuel-metering passage is formed by a circumferential flange that extends radially outward from the valve.

9. The fuel injector of any of claims 3 to 8, further comprising a valve seal (108) positioned and arranged to substantially prevent fuel flow along the valve through the primary fuel chamber past the valve seal, and wherein the fuel injector is structured so that, with the valve engaged with the valve seat, the valve is substantially pressure balanced.

Patentansprüche

1. Kraftstoff-Einspritzventil (10), das einen Einspritzventilkörper (102), einen Ventilkanal (104, 118, 122, 116), einen mit dem Ventilkanal (106) verbundenen Kraftstoffeinlass, einen mit dem Ventilkanal verbundenen Kraftstoffauslass (101), ein hin- und hergehendes Ventil (110, 112), das eine zentrale Längsachse hat und sich durch den Ventilkanal und durch den Kraftstoffauslass erstreckt, und einen Ventilsitz (140) um den Kraftstoffauslass hat, wobei das Ventil und der Einspritzventilkörper so angeordnet sind,

dass die Bewegung des Ventils in einer ersten Richtung relativ zum Einspritzventilkörper den Eingriff des Ventils und des Ventilsitzes miteinander verursacht und Kraftstofffluss am Ventilsitz (140) vorbei im Wesentlichen verhindert und die Bewegung des Ventils in einer zweiten Richtung relativ zum Einspritzventilkörper, wobei die zweite Richtung der ersten Richtung entgegengesetzt ist, das Trennen des Ventils und des Ventilsitzes veranlasst, **dadurch gekennzeichnet, dass** der Einspritzventilkörper (102) ferner eine sprühnebelformende Oberfläche (142) aufweist, die die Achse umgibt und sich von einem zum Ventilsitz (140) tangentialen proximalen Ende zu einem rotationsasymmetrischen distalen Ende erstreckt,
wobei am distalen Ende (i) ein erster Teil (142a) der sprühnebelformenden Oberfläche an einer ersten Position um die Achse einen zur Achse relativen ersten Winkel (A1) hat und (ii) ein zweiter Teil (142b) der sprühnebelformenden Oberfläche an einer zweiten Position um die Achse, die von der ersten Position verschieden ist, einen zur Achse relativen zweiten Winkel (A2) hat, wobei der zweite Winkel (A2) vom ersten Winkel (A1) verschieden ist,
wobei der erste Teil und der zweite Teil der sprühnebelformenden Oberfläche des Einspritzventilkörpers jeweils zwischen dem proximalen Ende und dem distalen Ende gekrümmt und konvex sind,
wobei der erste Teil und der zweite Teil der sprühnebelformenden Oberfläche des Einspritzventilkörpers zwischen dem proximalen und dem distalen Ende voneinander verschiedene Längen haben,
so dass die sprühnebelformende Oberfläche zum Umlenken des Kraftstoffsprühnebels hin zur Achse am ersten Teil und am zweiten Teil und zum Erzeugen eines rotationsasymmetrischen Sprühbilds durch Ablenken von Umfangsteilen des Kraftstoffsprühnebels mit unterschiedlichen Winkeln relativ zur Achse gestaltet ist.

2. Kraftstoffeinspritzventil nach Anspruch 1, wobei das distale Ende wenigstens an einem Teil des Umfangs wellenförmig um die Achse verläuft.

3. Kraftstoffeinspritzventil nach einem der Ansprüche 1 oder 2, wobei:

(a) das Kraftstoff-Einspritzventil eine primäre (104) und eine sekundäre Kraftstoffkammer (116) aufweist, wobei der Kraftstoffeinlass mit der primären Kraftstoffkammer verbunden ist und der Kraftstoffauslass mit der sekundären Kraftstoffkammer verbunden ist;
(b) das Kraftstoff-Einspritzventil ferner einen kraftstoffdosierenden Kanal (122) aufweist, der positioniert und angeordnet ist, um nur beschränkten Kraftstofffluss aus der primären Kraftstoffkammer in die sekundäre Kraftstoffkammer zuzulassen; und
(c) das Kraftstoff-Einspritzventil so aufgebaut ist, dass bei außer Eingriff mit dem Ventilsitz gebrachtem Ventil und durch den Kraftstoffauslass strömendem Kraftstoff der beschränkte Kraftstofffluss von der primären Kraftstoffkammer in die sekundäre Kraftstoffkammer zu einer Kraftstoffdruckdifferenz zwischen der primären und der sekundären Kraftstoffkammer führt, die wiederum zu einer durchflussabhängigen Krafteinwirkung auf das Ventil in der ersten Richtung führt, wobei diese Kraft mit zunehmendem Kraftstofffluss durch den Kraftstoffauslass zunimmt, und
(d) ein Stellglied (130, 132) mit dem Ventil gekoppelt ist und eine kontrollierbare Kraft auf das Ventil ausübt; wobei die Kraft variabel ist und der Kraftstoffdurchsatz von der Kraft abhängt.

4. Kraftstoff-Einspritzventil nach Anspruch 3, wobei das Stellglied eine Zylinderspule (130) aufweist und wobei die Kraft und somit der Kraftstoffdurchsatz von einem Strom der Zylinderspule gesteuert wird.

5. Kraftstoff-Einspritzventil nach Anspruch 3, das ferner ein elastisches Federelement (134) aufweist, das zum Drängen des Ventils in die erste Richtung angeordnet ist, und wobei das Stellglied zum Drängen des Ventils in die zweite Richtung als Reaktion auf ein Steuersignal angeordnet ist.

6. Kraftstoff-Einspritzventil nach einem der Ansprüche 3 bis 5, wobei der kraftstoffdosierende Kanal innerhalb des Ventilkanals ist und einen Spalt (118) zwischen dem Einspritzventilkörper und dem Ventil aufweist.

7. Kraftstoff-Einspritzventil nach einem der Ansprüche 3 bis 5, wobei der kraftstoffdosierende Kanal von einem Umfangsflansch (119) gebildet wird, der sich vom Einspritzventilkörper radial einwärts erstreckt.

8. Kraftstoff-Einspritzventil nach einem der Ansprüche 3 bis 5, wobei der kraftstoffdosierende Kanal von einem Umfangsflansch gebildet wird, der sich vom Ventil radial nach außen erstreckt.

9. Kraftstoff-Einspritzventil nach einem der Ansprüche 3 bis 8, der ferner einen Ventilsitz (108) aufweist, der positioniert und angeordnet ist, um Kraftstofffluss entlang des Ventils durch die primäre Kraftstoffkammer am Ventilsitz vorbei im Wesentlichen zu verhindern, und wobei das Kraftstoff-Einspritzventil so aufgebaut ist, dass das Ventil bei mit dem Ventilsitz in Eingriff befindlichem Ventil im Wesentlichen druckausgeglichen ist.

Revendications

1. Injecteur de carburant (10) présentant un corps d'injecteur (102), un passage de soupape (104, 118, 122, 116), une entrée de carburant connectée au passage de soupape (106), une sortie de carburant (101) connectée au passage de soupape, une soupape à mouvement alternatif (110, 112) présentant un axe central longitudinal et s'étendant à travers le passage de soupape et à travers la sortie de carburant, et un siège de soupape (140) autour de la sortie de carburant, dans lequel la soupape et le corps d'injecteur sont agencés de telle sorte que le mouvement de la soupape dans une première direction relativement au corps d'injecteur entraîne la mise en prise de la soupape et du siège de soupape et empêche sensiblement un passage de carburant audelà du siège de soupape (140) et un mouvement de la soupape dans une seconde direction relativement au corps d'injecteur, la seconde direction étant opposée à la première direction, entraîne une séparation de la soupape et du siège de soupape, **caractérisé en ce que** le corps d'injecteur (102) comprend en outre une surface de conformation de pulvérisation (142) entourant l'axe et s'étendant depuis une extrémité proximale tangente au siège de soupape (140) jusqu'à une extrémité distale asymétrique en rotation,
dans lequel, à l'extrémité distale, (i) une première partie (142a) de la surface de conformation de pulvérisation, à un premier emplacement autour de l'axe, forme un premier angle (A1) avec l'axe, et (ii) une seconde partie (142b) de la surface de conformation de pulvérisation, à un second emplacement autour de l'axe différent du premier emplacement, forme un second angle (A2) avec l'axe, le second angle (A2) étant différent du premier angle (A1),
dans lequel la première partie et la seconde partie de la surface de conformation de pulvérisation du corps d'injecteur sont chacune courbes et convexes entre l'extrémité proximale et l'extrémité distale,
dans lequel la première partie et la seconde partie de la surface de conformation de pulvérisation du corps d'injecteur ont des longueurs différentes l'une de l'autre entre l'extrémité proximale et l'extrémité distale,
moyennant quoi la surface de conformation de pulvérisation est conformée pour rediriger la pulvérisation de carburant vers l'axe au niveau de la première partie et de la seconde partie et créer un motif de pulvérisation asymétrique en rotation en déviant des parties circonférentielles de la pulvérisation de carburant à des angles différents par rapport à l'axe.

2. Injecteur de carburant selon la revendication 1, dans lequel l'extrémité distale ondule autour de l'axe au moins au niveau d'une partie de la circonférence.

3. Injecteur de carburant selon n'importe laquelle des revendications 1 ou 2, dans lequel

(a) l'injecteur de carburant comprend des chambres à carburant primaire (104) et secondaire (116), l'entrée de carburant étant connectée à la chambre à carburant primaire et la sortie de carburant étant connectée à la chambre à carburant secondaire ;
(b) l'injecteur de carburant comprend en outre un passage de dosage de carburant (122) positionné et agencé pour permettre uniquement un flux de carburant restreint depuis la chambre à carburant primaire jusque dans la chambre à carburant secondaire ; et
(c) l'injecteur de carburant est structuré de telle sorte que, quand la soupape est séparée du siège de soupape et le carburant s'écoule à travers la sortie de carburant, le flux de carburant restreint depuis la chambre à carburant primaire jusque dans la chambre à carburant secondaire entraîne un différentiel de pression de carburant entre les chambres à carburant primaire et secondaire qui à son tour entraîne une force dépendant de l'écoulement sur la soupape dans la première direction, laquelle force augmente avec l'augmentation du flux de carburant à travers la sortie de carburant, et
(d) un actionneur (130, 132) couplé à la soupape et exerçant une force régulable sur la soupape ; la force étant variable et le débit d'écoulement de carburant dépendant de la force.

4. Injecteur de carburant selon la revendication 3, dans lequel l'actionneur comprend un solénoïde (130) et dans lequel la force, et de ce fait le débit d'écoulement de carburant, sont régulés par un courant du solénoïde.

5. Injecteur de carburant selon la revendication 3, comprenant en outre un élément ressort élastique (134) agencé pour pousser la soupape dans la première direction, et dans lequel l'actionneur est agencé pour pousser la soupape dans la seconde direction en réponse à un signal de commande.

6. Injecteur de carburant selon n'importe laquelle des revendications 3 à 5, dans lequel le passage de dosage de carburant est situé au sein du passage de soupape et comprend un espace (118) entre le corps d'injecteur et la soupape.

7. Injecteur de carburant selon n'importe laquelle des revendications 3 à 5, dans lequel le passage de dosage de carburant est formé par une bride circonférentielle (119) qui s'étend radialement vers l'intérieur depuis le corps d'injecteur.

8. Injecteur de carburant selon n'importe laquelle des revendications 3 à 5, dans lequel le passage de dosage de carburant est formé par une bride circonférentielle qui s'étend radialement vers l'extérieur depuis la soupape.

9. Injecteur de carburant selon n'importe laquelle des revendications 3 à 8, comprenant en outre un siège de soupape (108) positionné et agencé pour sensiblement empêcher un écoulement de carburant le long de la soupape à travers la chambre à carburant primaire au-delà du siège de soupape, et l'injecteur de carburant étant structuré de telle sorte que, lorsque la soupape est en prise avec le siège de soupape, la soupape soit sensiblement équilibrée en pression.

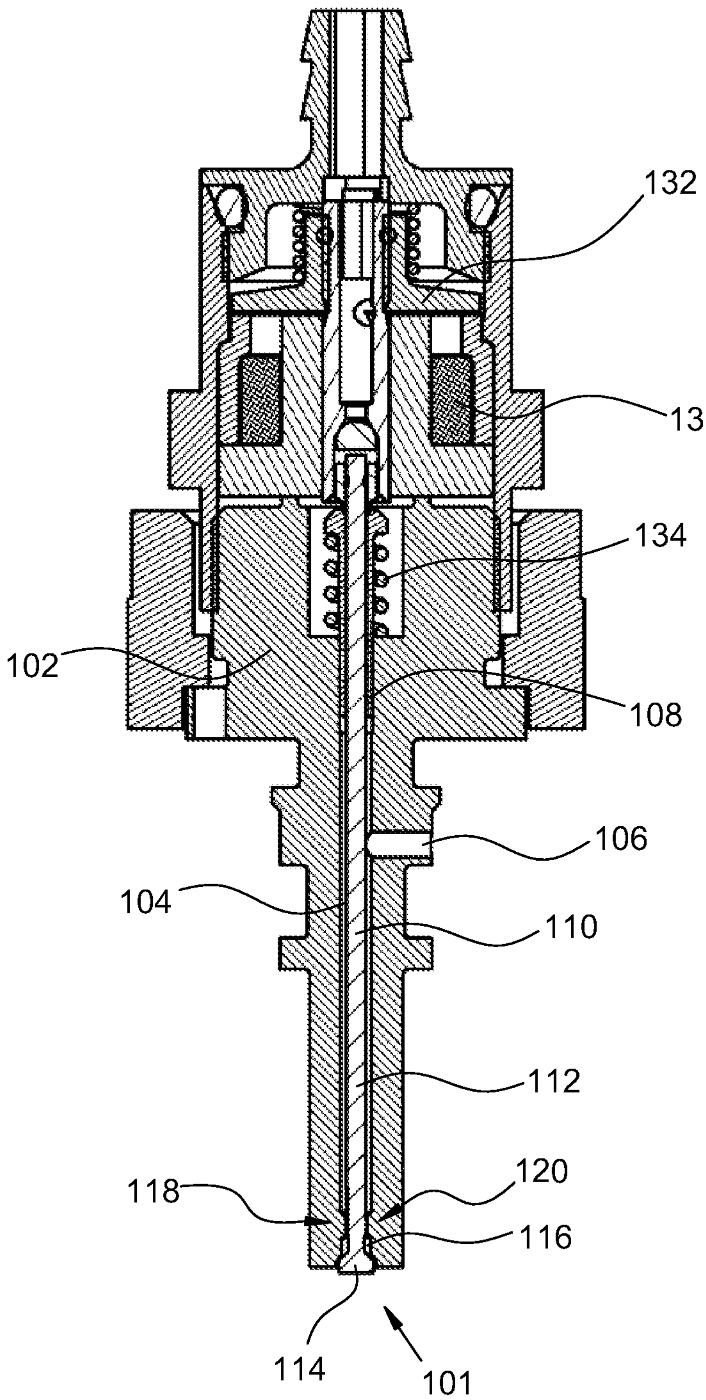
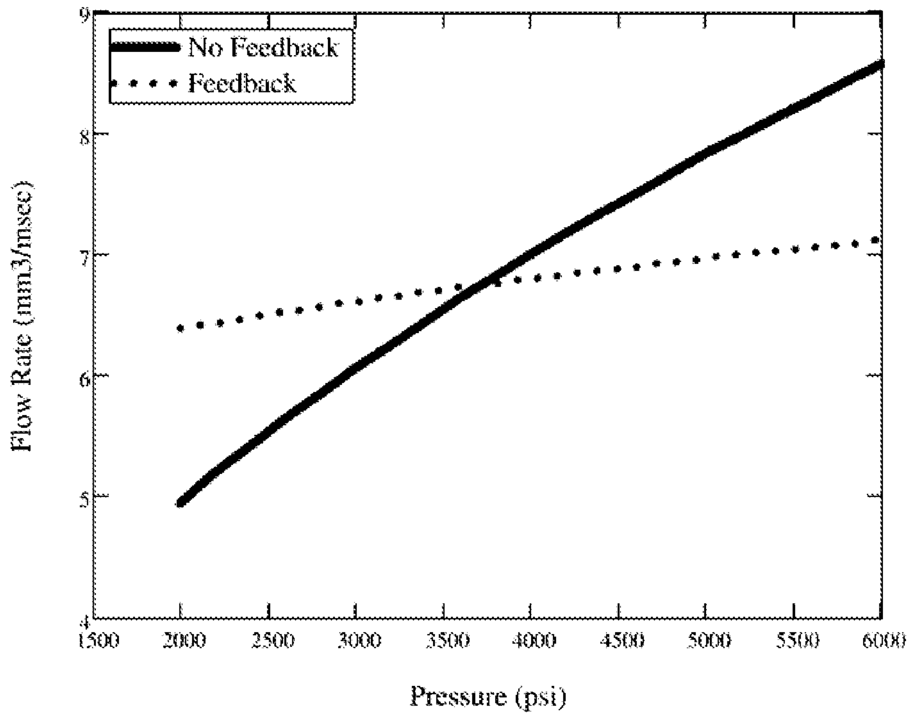


FIG. 1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Feedback
Flow Rate (mm3/msec)
Pressure (psi)
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7
6
5
4
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2000
2500
3000
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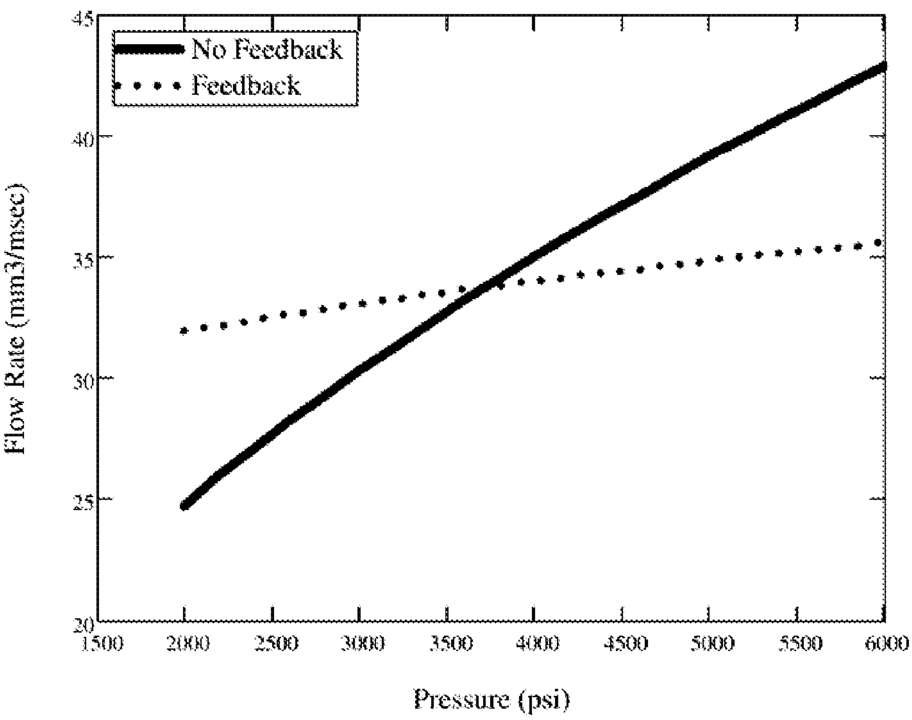
5000
5500
6000

FIG. 2A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Feedback
Flow Rate (mm3/msec)
Pressure (psi)
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5000
5500
6000

FIG. 2B

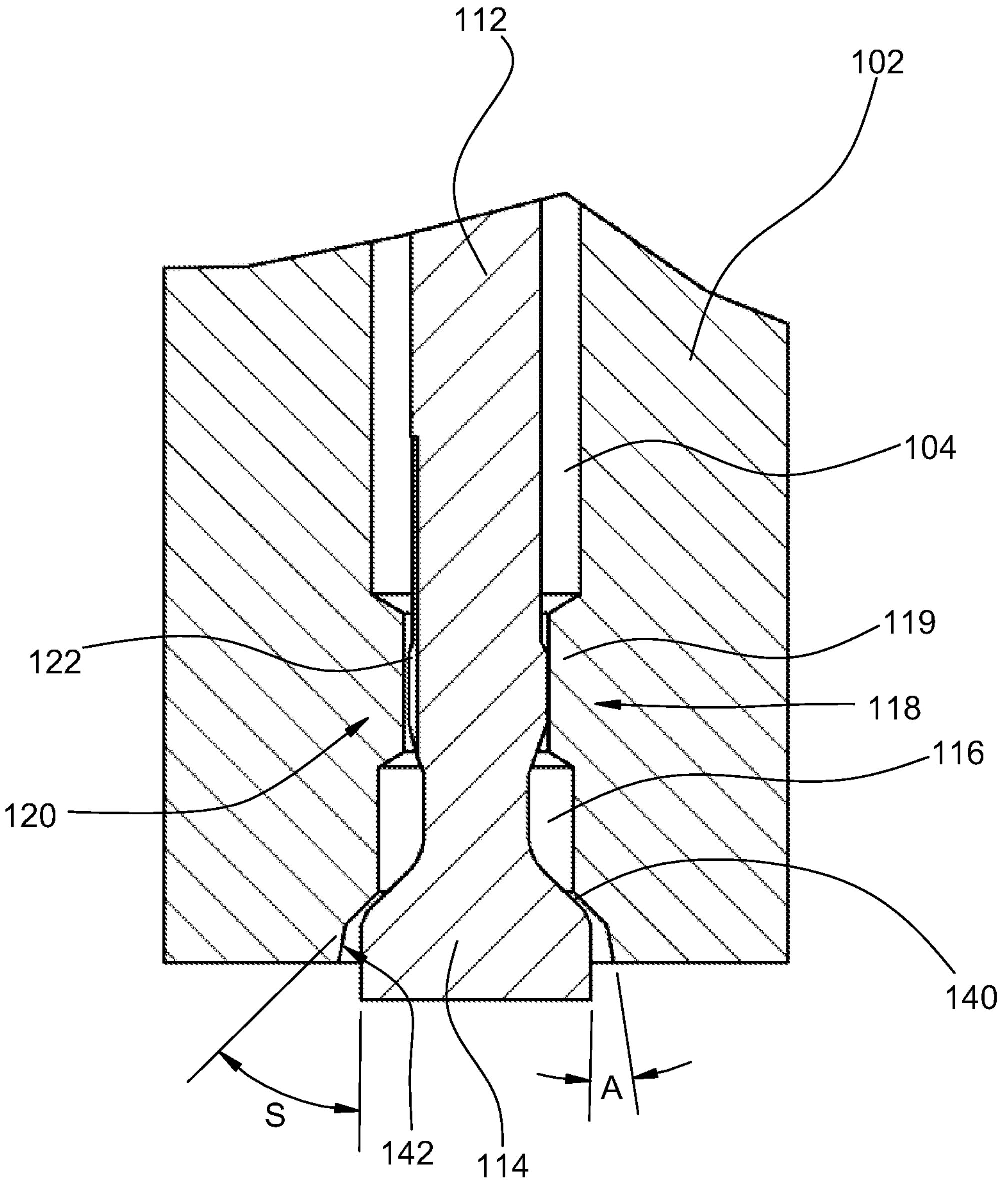

FIG. 3

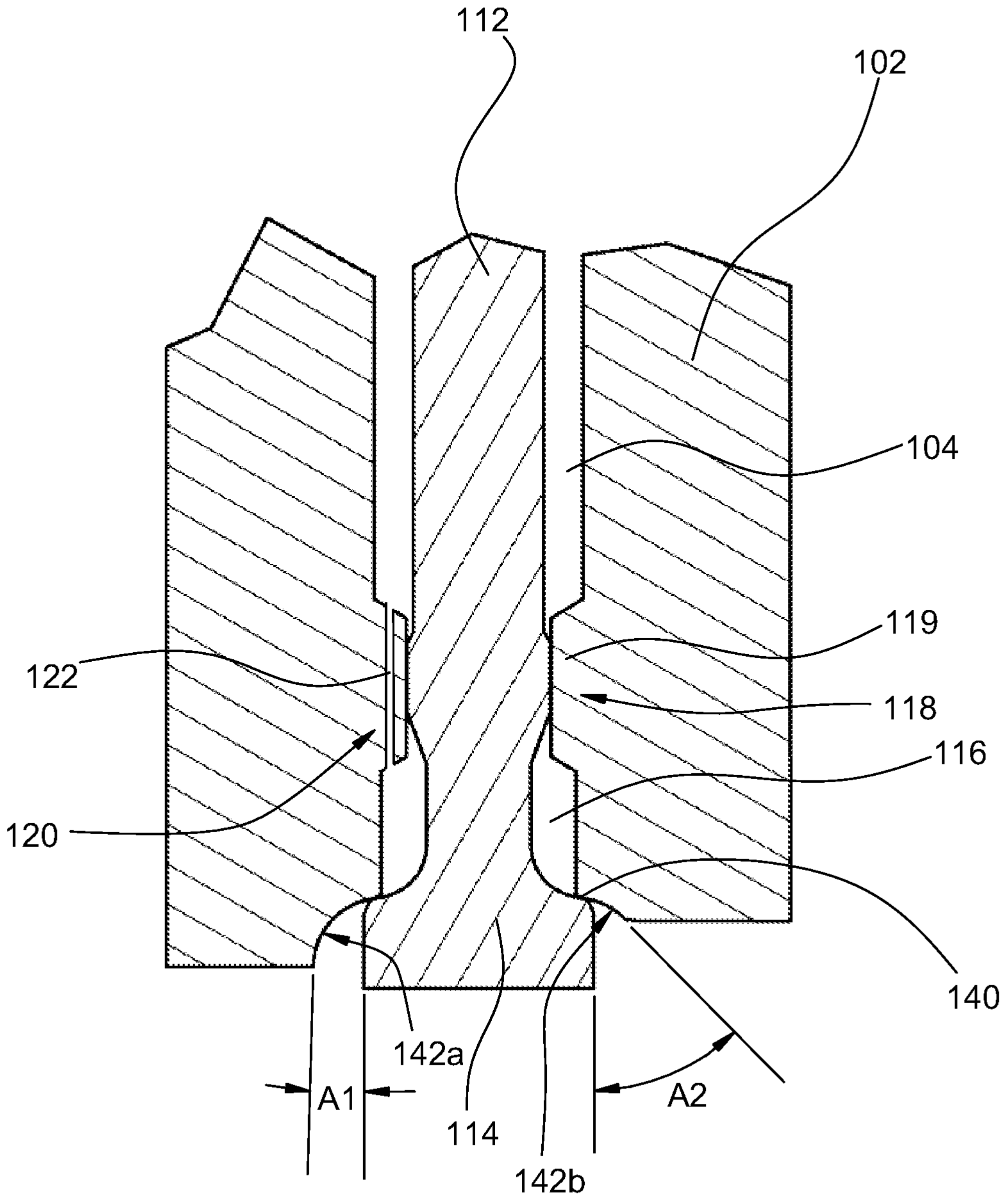

FIG. 4

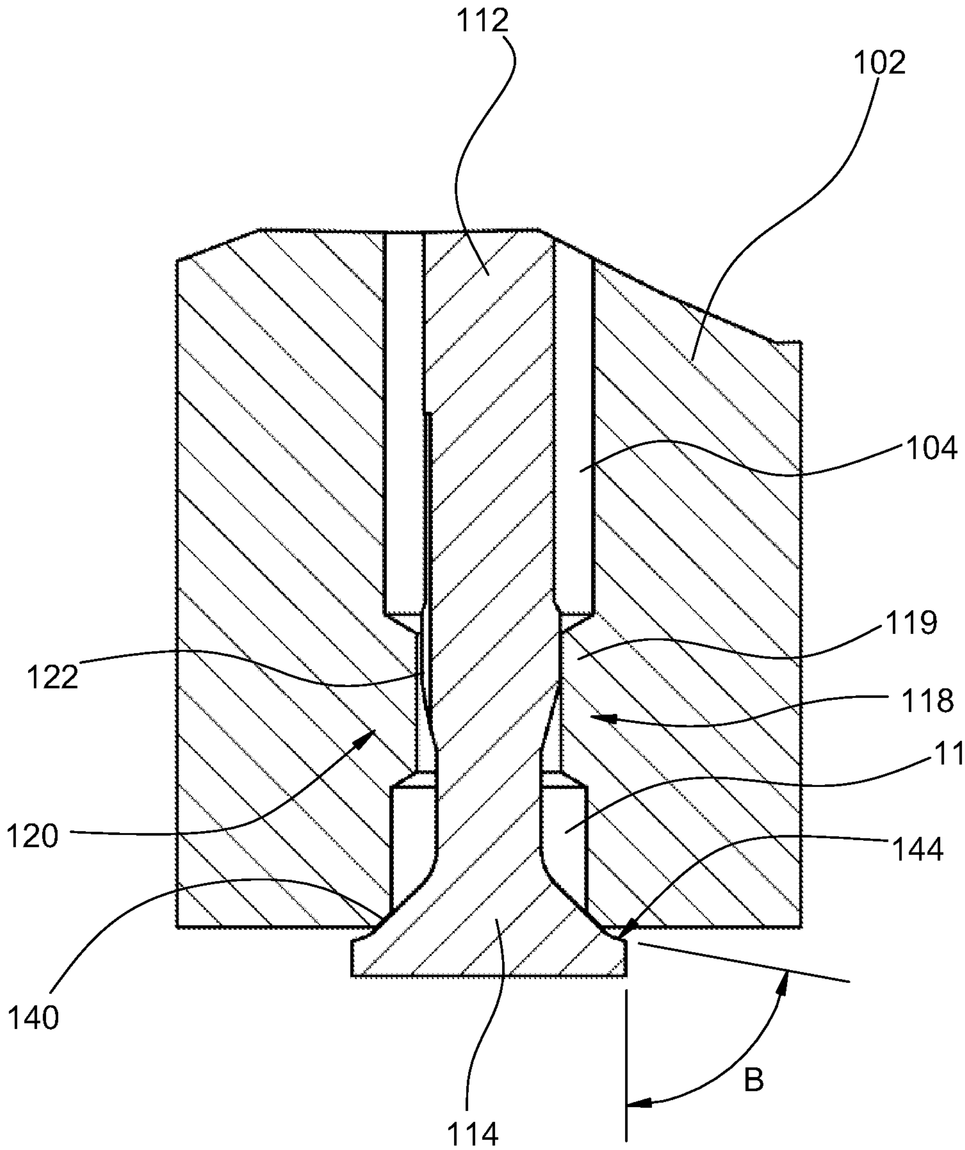

FIG. 5

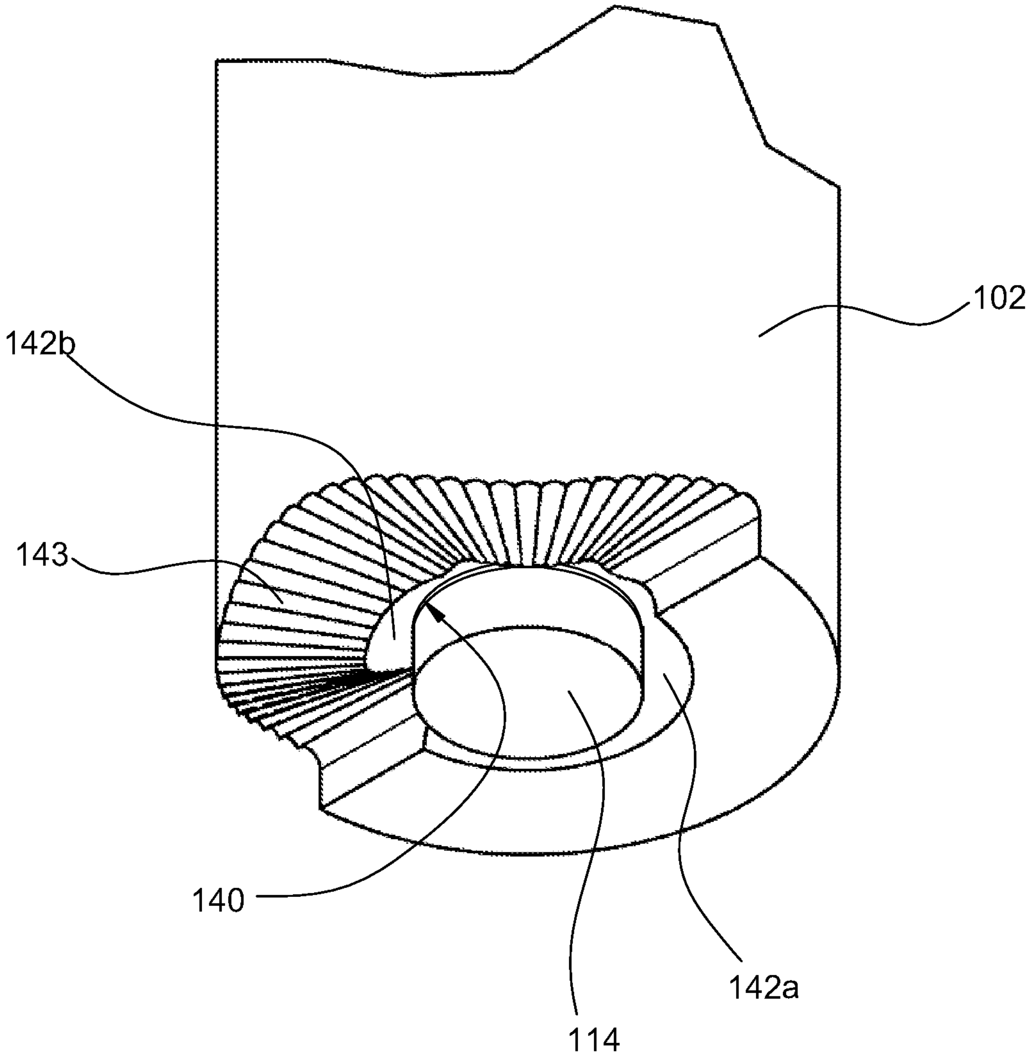

FIG. 6

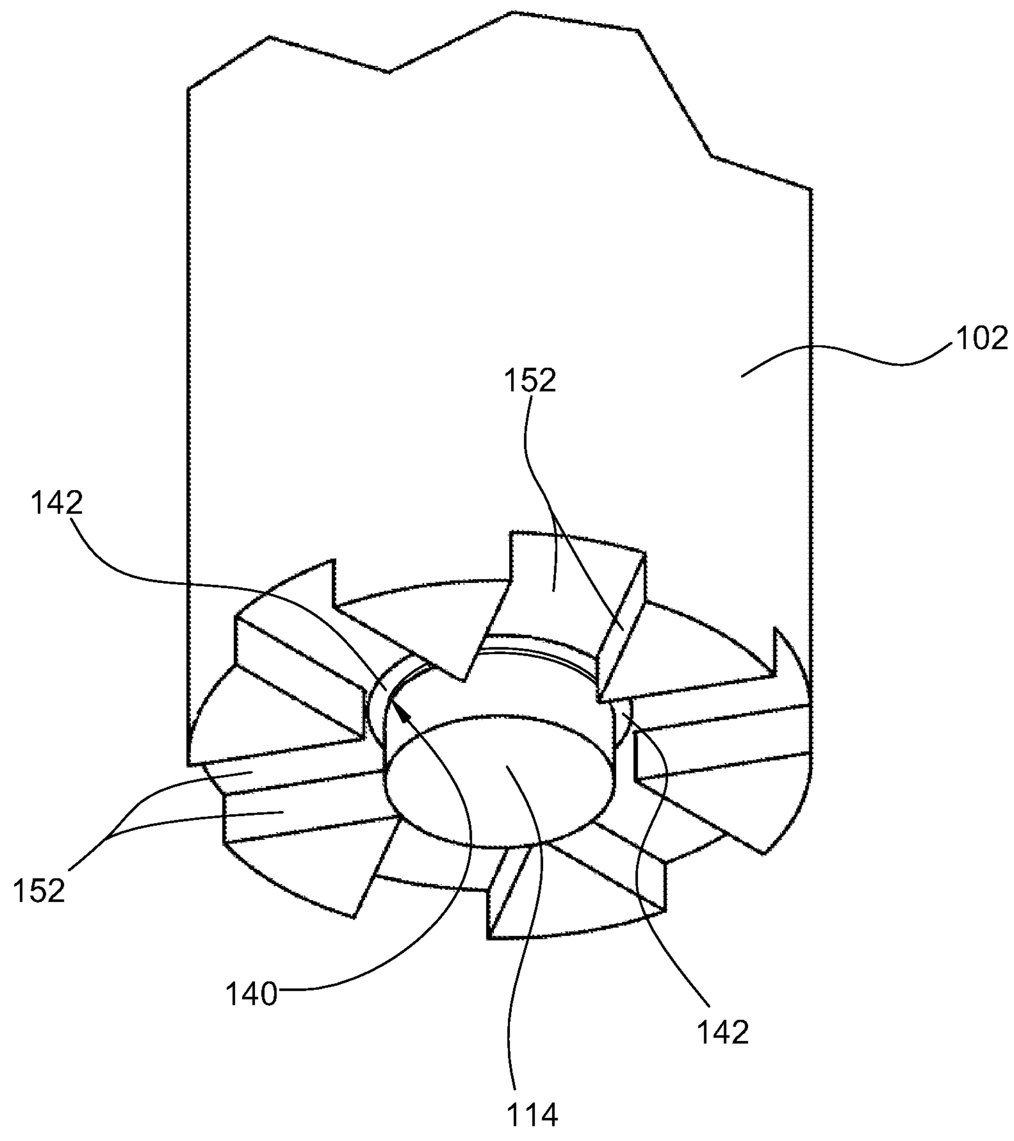

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 1335129 A2 **[0004]**
- US 20090032622 A1 **[0004]**
- JP H04179855 A **[0004]**
- US 2004075001 A **[0004]**