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(71) Applicant: **Delphi International Operations Luxembourg S.à r.l.**
4940 Bascharage (LU)

(72) Inventors:
- **PRICE, Kevin**
  Cheltenham, Gloucestershire GL51 8AQ (GB)
- **SULLIVAN, Kris**
  Upton St Leonards, Gloucestershire GL4 8BD (GB)

(74) Representative: **Delphi France SAS**
c/o Delphi Technologies
Campus Saint Christophe
Bâtiment Galilée 2
10, avenue de l'Entreprise
95863 Cergy Pontoise Cedex (FR)

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(54) FUEL INJECTOR

(57) The present invention provides a fuel injector (100) for use in an internal combustion engine, the fuel injector comprising: a nozzle body (3) having a bore (2) for receiving fuel from a supply line (5) for pressurised fuel, an outlet (8) from the bore (2) for delivering fuel to the combustion cylinder, in use, a valve needle (1) slidable within the bore (2) between a closed position in which fuel flow through the outlet (8) into the combustion chamber is prevented, and an open position in which fuel flow through the outlet (8) into the combustion chamber is enabled, wherein the valve needle (100) carries a restrictive element (20) providing at least one restriction (21) for restricting the flow of fuel through the bore (2) such that, during opening movement of the valve needle (1), fuel pressure downstream of the restrictive element (20) is less than a pressure of fuel supplied to the bore (2) from the supply line (5); and at least one valve (30) device which is operable in response to a pressure difference across the restrictive element (20) so as to allow a flow of fuel through the at least one restriction (21) during opening movement of the valve needle (1) but to further restrict the flow of fuel through the at least one restriction (21) during a final phase of closing movement of the valve needle (1), thereby to damp said final phase of closing movement as the valve needle is seated.

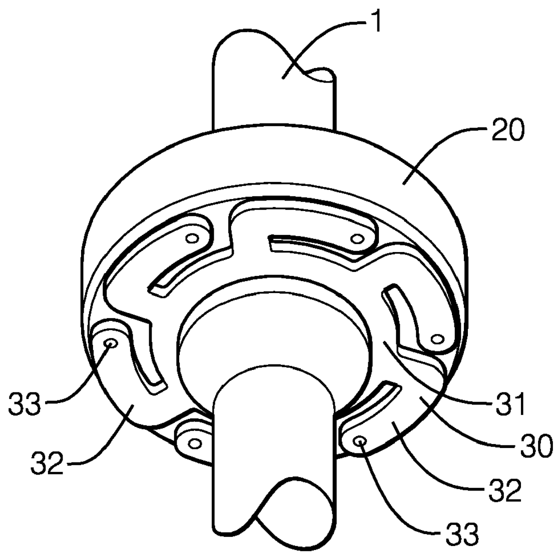

FIG. 5

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Description

Technical field

[0001] The present invention relates to a fuel injector for use in delivering high pressure fuel to an internal combustion engine. In particular, but not exclusively, the invention relates to a fuel injector for use in a compression ignition internal combustion engine.

Background

[0002] In a direct acting injector, an actuator is coupled directly to the valve needle to control needle movement. Both piezoelectric and electromagnetic direct acting injectors are known. In an electromagnetic direct acting injector, a solenoid-operated actuator controls movement of a plunger by applying a current through a solenoid. The plunger acts on a chamber of fuel arranged at the upper end of a valve needle so that, through a hydraulic amplifier, the force of the plunger is transmitted to the valve needle. By varying the force applied to the valve needle, movement of the valve needle towards and away from a valve needle seat is controlled. In an indirect injector, valve needle movement is controlled differently, through an intermediate servo-valve which is operated by the actuator.

[0003] In both types of injector the seat for the valve needle is typically defined by a frusto-conical surface at the end of a bore provided in a nozzle body. When the valve needle is lifted away from the seat fuel is delivered through injector outlets into the combustion chamber, and when the valve needle is closed against the seat fuel injection is terminated.

EP1369579 and US6318646 disclose injectors relevant to the prior art.

One problem in fuel injectors of this type is that the seat for the valve needle is prone to wear due to the repeated closing of the valve needle at the end of injection. In modern fuel injectors, there is an increasing trend towards smaller seat diameters so that wear issues are becoming even more prevalent and significant. Known solutions to improve on this problem include improving the material properties used at the seat, and using special heat treatments and coatings. However, these processes can be costly and still do not solve the problem fully.

[0004] It is an object of the invention to provide a fuel injector which addresses the shortcomings of the prior art.

Summary of the invention

[0005] An aspect of the invention provides a fuel injector for use in an internal combustion engine, the fuel injector comprising a nozzle body having a bore for receiving fuel from a supply line for pressurised fuel, an outlet from the bore for delivering fuel to the combustion cylinder, in use, a valve needle slidable within the bore between a closed position in which fuel flow through the outlet into the combustion chamber is prevented, and an open position in which fuel flow through the outlet into the combustion chamber is enabled, wherein the valve needle carries a restrictive element providing at least one restriction for restricting the flow of fuel through the bore such that, during opening movement of the valve needle, fuel pressure downstream of the restrictive element is less than a pressure of fuel supplied to the bore from the supply line; and at least one valve device which is operable in response to a pressure difference across the restrictive element so as to allow a flow of fuel through the at least one restriction during opening movement of the valve needle but to further restrict the flow of fuel through the at least one restriction during a final phase of closing movement of the valve needle, thereby to damp said final phase of closing movement as the valve needle is seated.

[0006] By restricting the flow of fuel through the bore such that, during opening movement of the valve needle, fuel pressure downstream of the restrictive element is less than a pressure of fuel supplied to the bore from the supply line, the restrictive element acts to impart a net downward force to the valve needle during opening movement of the valve needle to thereby control the speed at which the valve needle moves towards its point of maximum lift. However, by further restricting the flow of fuel through the at least one restriction during a final phase of closing movement (when fuel would otherwise flow in reverse through the at least one restriction from the portion of the bore downstream of the restrictive element to the portion of the bore upstream of the restrictive element), the at least one valve device enables a higher pressure to be maintained in the portion of the bore downstream of the restrictive element than would be possible without the at least one valve device, thereby enabling the restrictive element to impart a greater net upward force to the valve needle than would be possible without the at least one valve device in order to provide a greater damping effect, thereby reducing the impact force of the valve needle against the nozzle seat and minimising wear of the valve needle tip and the nozzle seat.

[0007] The final phase of closing movement (when fuel would otherwise flow in reverse through the at least one restriction from the portion of the bore downstream of the restrictive element to the portion of the bore upstream of the restrictive element), is typically the very end of closing movement of the valve needle, just before the valve needle is seated. For example, the at least one valve device may be arranged to further restrict the flow of fuel through the at least one restriction during the final phase of closing movement of the valve needle which may be over approximately the final 30%, or over approximately the final 20%, or over approximately the final 10% of the valve needle's travel towards the closed position, in normal use of the fuel injector. This final phase of closing movement may be considered to be the very end of closing movement, just before the valve needle is seated, and during which phase, without the presence of the valve device(s), fuel would otherwise flow in reverse through the at least one restriction from the portion of the bore downstream of the restrictive element to the portion of the bore upstream of the restrictive element. This is, typically, for example, over approximately the final 20% or so (e.g. between about the final 17% and about the final 23%) of closing movement of the valve needle (i.e. until it seats).

[0008] The at least one valve device may not act to further restrict the flow of fuel through the at least one restriction (or may only further restrict the flow of fuel to a lesser extent) prior to approximately the final 30% (or approximately the final 20%, or approximately the final 10%) of the valve needle's travel towards the closed position, in normal use of the fuel injector. In this case the at least one valve device may not act to significantly reduce the closing speed of the valve needle until approximately the final 30% (or approximately the final 20%, or approximately the final 10%) of the valve needle's travel towards the closed position.

[0009] The fuel injector may be a diesel injector or a gasoline injector.

[0010] The at least one valve device may be located downstream of the restrictions provided by the restrictive element.

[0011] The at least one valve device may comprise at least one valve element that is arranged to cover at least one of the restrictions when in a closed position to further restrict the flow of fuel through the at least one restriction.

[0012] The at least one valve element may comprise at least one aperture for allowing a further restricted fuel flow through the at least one restriction when in the closed position. The dimensions of the aperture(s) may be selected in order to tune the degree of further restriction for a desired operating characteristic of the fuel injector.

[0013] The at least one valve element may be arranged to further restrict the flow of fuel through the at least one restriction by completely preventing fuel flow through the at least one restriction when in its closed position. In this case no aperture as described above is present in the valve element.

[0014] The at least one valve element may comprise at least one reed valve element.

[0015] The at least one valve element may extend either radially inwardly or radially outwardly from an annular ring.

[0016] The annular ring may be attached to the restrictive element and/or to the valve needle, for example by an adhesive or spot weld(s).

[0017] Alternatively the valve element(s) may be attached to the restrictive element and/or to the valve needle individually, for example by an adhesive or spot weld(s).

[0018] The at least one valve element may comprise an annular disc that is biased towards the restrictive element.

[0019] The annular disc may be biased towards the restrictive device by a spring.

[0020] The spring may be retained by a shoulder provided on the valve needle.

[0021] The restrictive element is preferably fixed with respect to the valve needle. For example, the restrictive element may comprise an annular collar attached to or integrally formed with the valve needle. In other embodiments, a degree of relative movement between the valve needle and the restrictive element may be possible e.g. so that the restrictive element is 'floating'.

[0022] The at least one restriction may take the form of at least one orifice extending through the thickness of the restrictive element and/or at least one groove provided in an outer surface of the restrictive element.

[0023] Typically, the area of the orifice in the restrictive element may be around 7 times greater than the area of the fuel injector outlet(s), and may be around 30 times smaller than the area of the bore. These values are not intended to be limiting, but are given just to illustrate one possible example.

[0024] The combined cross-sectional area of the aperture(s) may be significantly less than 50% of the combined cross sectional area of the restriction(s) and/or significantly less than 25% of the combined cross-sectional area of the outlet(s). Other values are also possible. It will be appreciated that the relative dimensions of the bore, the restrictive element, the restriction(s), the aperture(s) and the outlet(s) may be varied in order to select the desired damping performance.

[0025] Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any aspect or embodiment can be combined in any way and/or combination with those in other aspects and/or embodiments, unless such features are incompatible.

Brief description of the drawings

[0026] In order that the present invention may be more readily understood, an example of the invention will now be described in detail with reference to the accompanying figures, in which:

Figure 1 illustrates a fuel injector according to one possible embodiment of the present invention;

Figure 2 illustrates a restrictive element of a valve needle of the fuel injector of Figure 1;

Figures 3a to 3d schematically illustrate various stages during the operation of the fuel injector of Figure 1;

Figures 4 to 6 illustrate a valve device associated with the restrictive element of the valve needle of the fuel injector of Figure 1;

Figure 7 illustrates an alternative valve device; and

Figures 8 to 10 illustrate a further alternative valve device.

Detailed description

[0027] For the purpose of the following description it will be appreciated that references to upper, lower, upward, downward, above and below, for example, are not intended to be limiting and relate only to the orientation of the injector as shown in the illustration.

[0028] The present invention relates to a fuel injector 100 of the type generally shown in Figure 1. The fuel injector 100 is suitable for use in a fuel injection system of an internal combustion engine, and particularly a diesel engine in which fuel is typically injected into the engine at high pressure levels in excess of 2000 bar, and commonly as high as 3000 bar.

[0029] The fuel injector 100 comprises a valve needle 1 that is slidable within a bore 2 of a nozzle body 3. A proximal end of the nozzle body 3 is coupled to a piston guide 4. The proximal end of the bore receives high pressure fuel, in use, from a supply line 5 provided in the piston guide. The bore includes a section of comparatively small diameter 2a towards its distal end and a section of comparatively large diameter 2b towards its proximal end.

[0030] The bore 2, at its distal end, defines a nozzle seat 6 of generally frusto-conical form with which a tip 7 of the valve needle 1 is engageable. Downstream of the nozzle seat 6, the nozzle body is provided with a plurality of outlets 8 for delivering fuel to a combustion cylinder, in use. When the valve needle 1 is in its closed position, the tip 7 of the valve needle is engaged with the nozzle seat 6 to prevent fuel from being delivered from the bore 2 through the outlets 8. However, when the valve needle 1 is lifted away from the nozzle seat 6, as described below, the tip 7 of the valve needle 1 moves out of engagement with the nozzle seat 6 to allow fuel to be delivered from the bore 2 through the outlets 8. A spring 9 is provided towards a proximal end of the valve needle 1, which acts to urge the valve needle 1 towards its closed position.

[0031] The valve needle 1 comprises a valve needle guide 10 towards its distal end. The valve needle guide 10 slidingly engages the bore 2 in the section of comparatively small diameter 2a to prevent lateral movement of the valve needle 1 within the bore. The valve needle guide 10 includes a plurality of grooves to permit the passage of fuel past the valve needle guide. The valve needle 1 also comprises a proximal guide portion 11 at is proximal end that slidingly engages the piston guide 4 to prevent lateral movement of the valve needle 1 within the bore 2.

[0032] The valve needle 1 is provided with a plurality of thrust surfaces 12 of generally frusto-conical form that are exposed to fuel pressure within the bore 2 in order to provide an upward force to urge the valve needle 1 away from its closed position.

[0033] The valve needle 1 is further provided with a restrictive element 20 (shown more clearly in Fig. 2) in the form of an annular collar extending around the valve needle and located within the bore 2 in the section of comparatively large diameter 2b. The restrictive element 20 is fixed with respect to the valve needle, and may be integrally formed with the valve needle 1, or alternatively may be a separate component that is attached to the valve needle (for example by press fitting). The restrictive element is arranged to move together with the valve needle as the valve needle slides within the bore 2. The restrictive element 20 has a diameter that is slightly smaller than that of the bore 2 at the section of comparatively large diameter 2b and so extends almost up the side-wall of the bore. The restrictive element 20 divides the bore 2 into a portion located upstream of the restrictive element (the upstream portion) and a portion located downstream of the restrictive element (the downstream portion). The restrictive element 20 comprises an upper surface 20a facing towards the proximal end of the bore, and a lower surface 20b facing towards the distal end of the bore. The restrictive element 20 acts to restrict the flow of fuel through the bore 2 such that the fuel pressure downstream of the restriction is generally less than a pressure of fuel supplied to the bore 2 from the supply line 5 during opening movement of the valve needle, as described below.

[0034] The restrictive element 20 is provided with a plurality of passages or orifices 21 extending through its thickness to allow the restricted flow of fuel through the restrictive element 20 and through the bore 2. The orifices 21 act as a plurality of restrictions because the combined cross-sectional area of the orifices is significantly smaller than the cross-sectional area of the bore 2. The orifices 21 are spaced around the restrictive element 20 in a circle. However, it will be appreciated that the number and spatial arrangement of the orifices 21 is not critical, and that in other embodiments there may only be one orifice.

[0035] The restrictive element 20 is provided with a valve device 30 (not shown in Figure 1 but illustrated in Figures 4 to 6). The valve device 30 comprises an annular ring 31 that surrounds the valve needle 1 and is spot welded to the valve needle and/or to the lower surface of the restrictive element and/or held between the restrictive element 20 and a shoulder provided on the valve needle. The valve device 30 further comprises a plurality of reed valve elements 32 extending outwardly from the annular ring 31, each of which is arranged to cover a respective one of the orifices 21.

[0036] Each reed valve element 32 is biased towards a closed position in which it covers its respective orifice 21, but is arranged to move away from its respective orifice when the difference between the fuel pressure in the upstream portion of the bore (above the restrictive element 20 in the orientation shown) and the fuel pressure in the downstream portion of the bore (below the restrictive element 20 in the orientation shown) is sufficient to overcome the pre-load of the reed valve elements 32, thereby opening the orifices 21 to allow fuel to flow, in use, through the orifices. When the reed valve elements 32 have moved away from the orifices 21 they do not provide a significant further restriction to the flow of fuel through the orifices. However, when the reed valve elements 32 are in their closed positions, they act to further restrict the flow of fuel through the orifices 21.

[0037] In order to allow some fuel flow through the orifices 21 when the reed valve elements 32 are in their closed positions (albeit at a further restricted rate), each reed valve element 32 is provided with an aperture 33 at a position corresponding to its respective orifice 21. The apertures 33 of the reed valve elements 32 have significantly smaller cross-sectional areas than those of the orifices 21 in the restrictive element 20 in order to ensure that the flow of fuel is further restricted when the reed valve elements 32 are in their closed positions. The dimensions of the apertures 33 may be selected in order to tune the degree of further restriction for a desired operating characteristic of the fuel injector 100.

[0038] Movement of the valve needle 1 is controlled by varying the fuel pressure in a control chamber 13 located at a proximal end of the valve needle. In an indirect injector, fuel pressure within the control chamber 13 is controlled by means of an actuation system (not shown) including a three-way valve which is controlled by, for example, a solenoid actuator or a piezoelectric actuator. The three-way valve is operable to supply high pressure fuel from the supply line without any connection to a low pressure drain in order to generate a high pressure within the control chamber 13, and to connect the control chamber 13 to the low pressure drain without any connection to the supply line in order to reduce the pressure within the control chamber.

[0039] Operation of the fuel injector 100 will now be described with reference to Figures 3a to 3d, which provide a highly schematic representation of the fuel injector during various stages of operation.

[0040] Before the fuel injector 100 is opened to commence delivery of fuel, the tip 7 of the valve needle 1 is held in engagement with the nozzle seat 6 under the action of the spring 9 and high fuel pressure within the control chamber 13, as shown in Fig 3a. At this point no fuel is flowing through the bore 2 or out of the outlets 8, and the fuel pressure in the upstream portion of the bore is equal to the fuel pressure in the downstream portion of the bore.

[0041] When it is desired to open the fuel injector 100 to commence the delivery of fuel from the outlets 8, the three-way valve is operated to reduce the fuel pressure in the control chamber 13. As the fuel pressure in the control chamber 13 is reduced, the downward force applied to the top of the valve needle 1 is reduced. Once the upward force exerted on the valve needle 1 by the thrust surfaces 12 is sufficient to overcome the downward force exerted by the spring 9 and other downward forces exerted by the fuel on other parts of the valve needle, the valve needle moves away from the nozzle seat 6, as shown in Figure 3b. When the valve needle 1 moves away from the nozzle seat 6, fuel is permitted to flow out of the downstream portion of the bore via the outlets 8. As fuel flows out from the downstream portion of the bore and the restrictive element 20 moves upwardly together with the valve needle 1, the fuel pressure in the downstream portion of the bore falls below the fuel pressure in the upstream portion of the bore (which is maintained at supply pressure through the supply line 5). This causes the reed valve elements 32 to move away from their respective orifices, thereby permitting fuel to flow through the orifices 21 from the upstream portion of the bore to the downstream portion of the bore. However, due to the restriction provided by the restrictive element 20, the fuel pressure in the downstream portion of the bore remains lower than the fuel pressure in the upstream portion of the bore. Since the pressure exerted on the upper surface 20a of the restrictive element 20 is higher than the pressure exerted on the lower surface 20b of the restrictive element 20, the restrictive element 20 imparts a net downward force to the valve needle 1 and so generally acts to decrease the speed at which the valve needle moves away from the nozzle seat 6, thereby reducing the velocity of the valve needle as it reaches its point of maximum lift.

[0042] When it is desired to close the fuel injector 100, the three-way valve is operated to increase the fuel pressure in the control chamber 13. As the fuel pressure in the control chamber increases, the downward force applied to the top of the valve needle 1 is increased. Once the downward force exerted on the valve needle 1 by the fuel in the control chamber 13 in combination with other downward forces exerted by the spring 9 and by fuel in the bore (for example on the upper surface 20a of the restrictive element 20) is sufficient to overcome the upward forces exerted on the valve needle 1 at the thrust surfaces and lower surface 20b of the restrictive element, the valve needle 1 starts to move downwardly back towards the nozzle seat 6, as shown in Fig. 3c. As this happens, fuel continues to flow out of the downstream portion of the bore via the outlets 8, and to be supplied into the upstream portion of the bore from the supply line.

[0043] During the first part of the closing movement of the valve needle 1, the fuel pressure in the upstream portion of the bore remains higher than the fuel pressure in the downstream portion of the bore, and the reed valve elements 32 remain open allowing fuel to flow through the orifices 21, as shown in Figure 3c. Since the pressure exerted on the upper surface 20a of the restrictive element 20 is higher than the pressure exerted on the lower surface 20b of the restrictive element 20, the restrictive element 20 imparts a net downward force on the valve needle 1 and so generally acts to increase the speed at which the valve needle moves towards the nozzle seat 6, thereby increasing the rate at which the fuel injector 100 may be closed.

[0044] As the valve needle 1 continues to move towards its closed position, the difference in fuel pressure between the upstream and downstream portions of the bore 2 is reduced due to the piston-like action of the restrictive element 20 on the fuel in the downstream portion of the bore 2 and a reduction in the rate at which fuel is dispensed from the downstream portion of the bore as the tip 7 of the valve needle 1 approaches the nozzle seat 6. Once the difference in fuel pressure has decreased to a sufficiently low level, the reed valve elements 32 move into their closed positions, as shown in Figure 3d, thereby further restricting the flow of fuel through the orifices 21. During a final phase of closing movement of the valve needle, and at the very end of the closing movement of the valve needle 1, the fuel pressure in the downstream portion of the bore 2 becomes greater than the fuel pressure in the upstream portion of the bore 2. Once the fuel pressure in the downstream portion of the bore exceeds the fuel pressure in the upstream portion of the bore 2, the pressure exerted on the lower surface 20b of the restrictive element 20 becomes greater than the pressure exerted on the upper surface 20a of the restrictive element 20, and so at this stage the restrictive element 20 imparts a net upward force on the valve needle 1 to damp the closing movement of the valve needle, thereby reducing the impact force of the valve needle 1 against the nozzle seat and minimising wear of the valve needle tip 7 and the nozzle seat 6. At this point, the further restriction provided by the reed valve elements 32 reduces the rate at which fuel can flow in reverse through the orifices 21 from the downstream portion of the bore back into the upstream portion of the bore. In this way the valve device 30 acts to generate a higher pressure difference between the fuel in the downstream portion of the bore and the fuel in the upstream portion of the bore, thereby increasing the damping effect during the final phase of closing movement.

[0045] In the above-described embodiment, the valve device 30 comprises multiple reed valve elements 32 projecting outwardly from an annular ring 31, each reed valve element being arranged to cover an individual orifice 21 in the restrictive element 20 in order to further restrict the flow of fuel through the orifice 21 when in its closed position. However, many other valve devices are possible within the scope of the present invention. For example, Figure 7 illustrates a valve device 130 for use in another embodiment of the present invention comprising a plurality of reed valve elements 132 projecting inwardly from an annular ring 131 which may be spot welded to a restrictive element 21 on the valve needle 1. In other embodiments, the valve device 30 may not comprise separate valve elements for each of the orifices, but may instead comprise one or more valve elements each arranged to cover multiple orifices. In other embodiments, the valve device 130 may not comprise reed valve elements 32, but may instead include one or more valves of a different type.

[0046] By way of example, Figures 8 to 10 illustrate an alternative valve device 230 comprising an annular valve element 232 arranged to cover each of the orifices 21 in order to further restrict the flow of fuel through the orifices when in its closed position, the annular valve element being 232 biased towards its closed position by a disc spring 234 retained against a shoulder provided on the valve needle. Other valve devices are also possible.

[0047] In the above-described embodiment, each of the orifices 21 extending through the restrictive element 20 is arranged to be covered by a valve element 32 when the valve elements are in their closed positions. However, in other embodiments the restrictive element 20 may additionally include one or more further orifices that are not covered by any valve element.

[0048] In the above-described embodiment, each valve element 32 that covers an orifice 21 comprises an aperture 33 for allowing some fuel flow through the orifices 21 when the valve elements are in their closed positions (albeit at a further restricted rate). However, in other embodiments, one or more valve elements covering one or more orifices may not comprise any aperture, in which case the valve elements may further restrict the flow of fuel through the orifices by completely preventing fuel flow through the orifices when in their closed positions. (In this case a small flow of fuel may still be permitted between the outer edge of the restrictive element 20 and the bore 2.)

[0049] In the above-described embodiment, the restrictions provided by the restrictive element 20 take the form of orifices extending through the thickness of the restrictive element. However, in other embodiments one or more restrictions may instead be provided by one or more grooves provided in the outer surface of the restrictive element 20, the restrictions being provided between the grooves and the bore of the nozzle body. Such restrictions may be covered by any of the valve devices described above if modified to extend up to the outer edge of the restrictive element.

Claims

1. An indirect fuel injector (100) for use in an internal combustion engine, the fuel injector comprising:

    a nozzle body (3) having a bore (2) for receiving fuel from a supply line (5) for pressurised fuel, an outlet (8) from the bore (2) for delivering fuel to the combustion cylinder, in use,
    a valve needle (1) slidable within the bore (2) between a closed position in which fuel flow through the outlet (8) into the combustion chamber is prevented, and an open position in which fuel flow through the outlet (8) into the combustion chamber is enabled, wherein, in use, movement of the valve needle (1) is controlled by varying the fuel pressure in a control chamber (13) located at a proximal end of the valve needle and wherein the valve needle (100) carries a

restrictive element (20) providing at least one restriction (21) for restricting the flow of fuel through the bore (2) such that, during opening movement of the valve needle (1), fuel pressure downstream of the restrictive element (20) is less than a pressure of fuel supplied to the bore (2) from the supply line (5); and
at least one valve device (30) which is operable in response to a pressure difference across the restrictive element (20) so as to allow a flow of fuel through the at least one restriction (21) during opening movement of the valve needle (1) but to further restrict the flow of fuel through the at least one restriction (21) during a final phase of closing movement of the valve needle (1), thereby to damp said final phase of closing movement as the valve needle is seated **characterised in that**,
the at least one valve device (30) comprises at least one valve element (32) arranged to cover at least one of the restrictions (21) when in a closed position to further restrict the flow of fuel through the at least one restriction (21) and wherein,
the at least one valve element (32) is arranged to further restrict the flow of fuel through the at least one restriction (21) by completely preventing fuel flow through the at least one restriction (21) when in its closed position.

2. An indirect fuel injector (100) according to claim 1, wherein the at least one valve device (30) is arranged to further restrict the flow of fuel through the at least one restriction (21) during the final phase of closing movement which is approximately the final 30%, or approximately the final 20%, or approximately the final 10%, of the valve needle travel towards the closed position in normal use of the fuel injector.

3. An indirect fuel injector (100) according to claim 1 or claim 2, wherein the at least one valve device (30) is located downstream of the at least one restriction (21) provided by the restrictive element (20).

4. An indirect fuel injector (100) according to any of claims 1 to 3, wherein the at least one valve element (32) comprises at least one reed valve element.

5. An indirect fuel injector (100) according to any of claims 1 to 4, wherein the at least one valve element (32) extends either radially inwardly or radially outwardly from an annular ring (31).

6. An indirect fuel injector (100) according to any claim 5, wherein the annular ring (31) is attached to the restrictive element (20) and/or to the valve needle (1).

7. An indirect fuel injector (100) according to any of claims 1 to 3, wherein the at least one valve element comprises an annular disc (232) that is biased towards the restrictive element.

8. An indirect fuel injector (100) according to claim 7, wherein the annular disc (232) is biased towards the restrictive device by a spring (234).

9. An indirect fuel injector (100) according to claim 8, wherein the spring (234) is retained by a shoulder provided on the valve needle.

10. An indirect fuel injector (100) according to any preceding claim, wherein the restrictive element (20) comprises an annular collar attached to or integrally formed with the valve needle (1).

11. An indirect fuel injector (100) according to any preceding claim, wherein the at least one restriction (21) takes the form of at least one orifice extending through the thickness of the restrictive element (20).

12. An indirect fuel injector (100) according to any preceding claim, wherein the at least one restriction (21) takes the form of at least one groove provided in an outer surface of the restrictive element (20) to define the restriction (21) together with the bore.

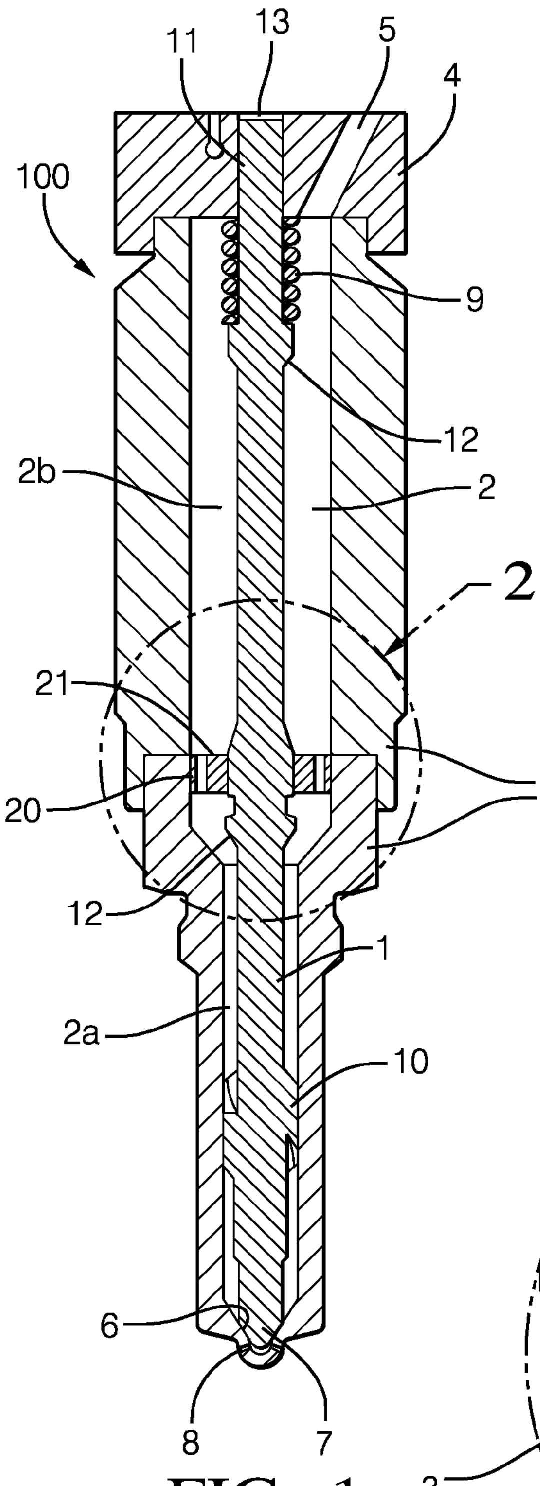

FIG. 1

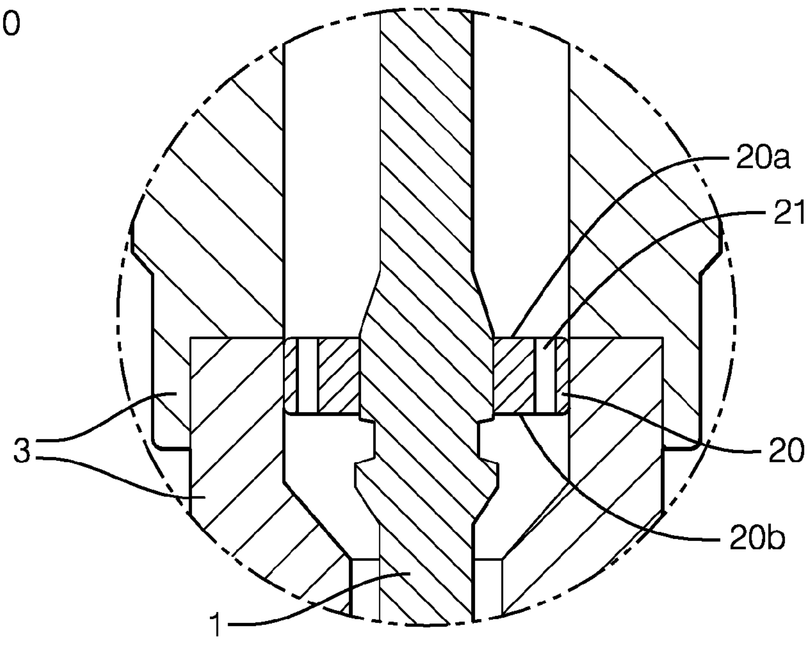

FIG. 2

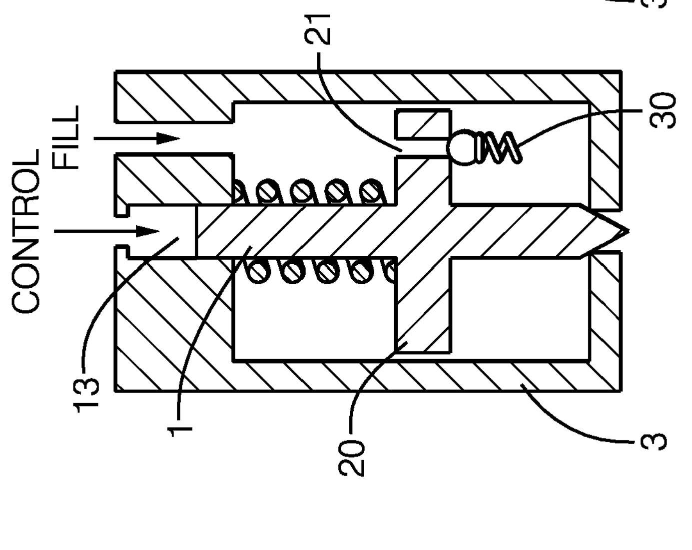

FIG. 3a

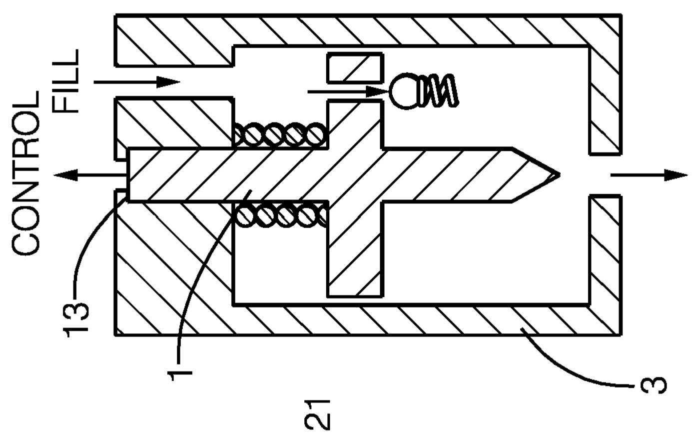

FIG. 3b

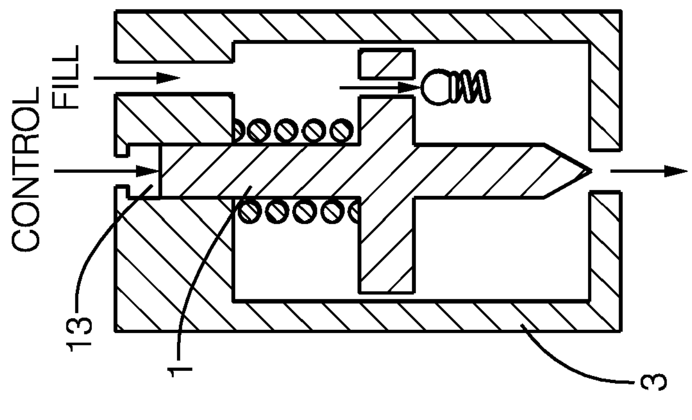

FIG. 3c

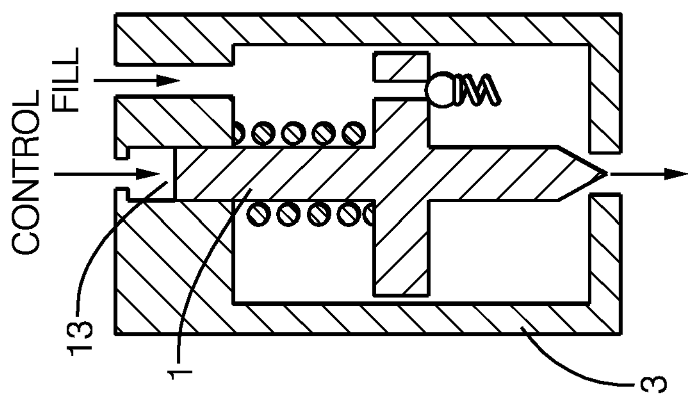

FIG. 3d

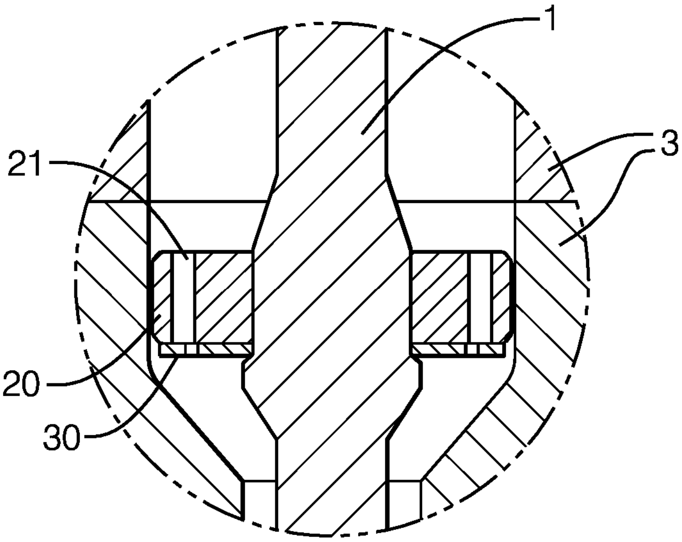

FIG. 4

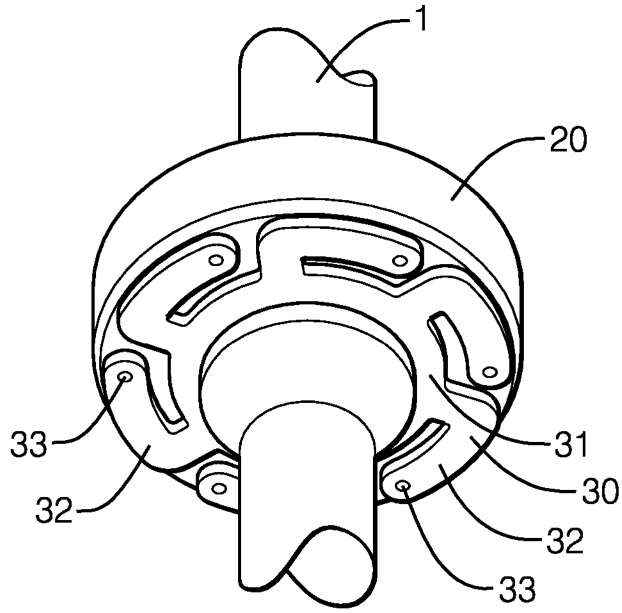

FIG. 5

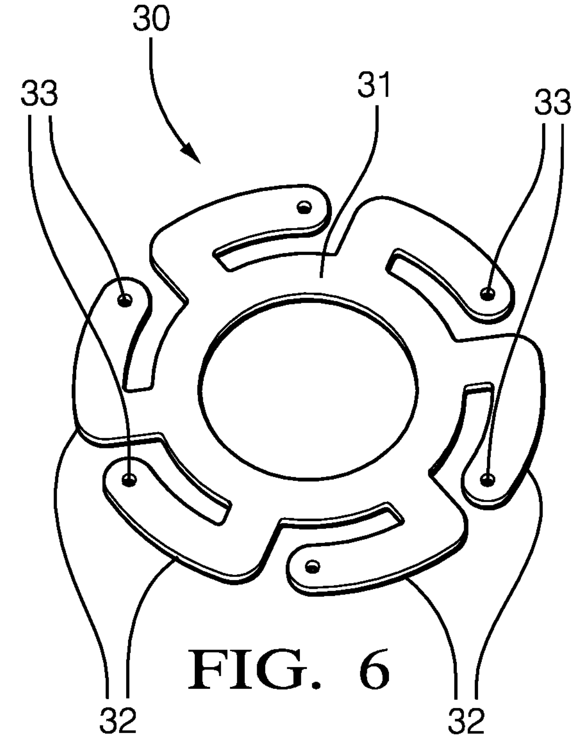

FIG. 6

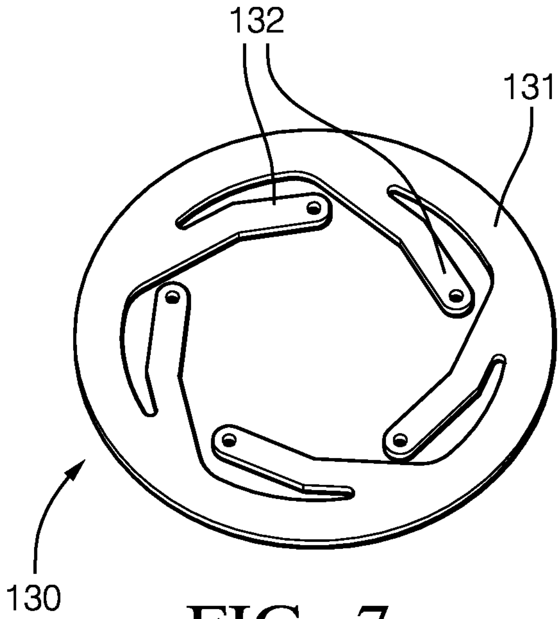

FIG. 7

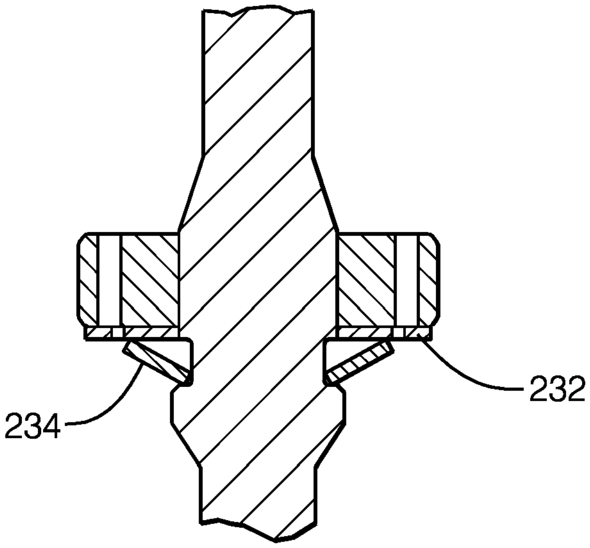

FIG. 8

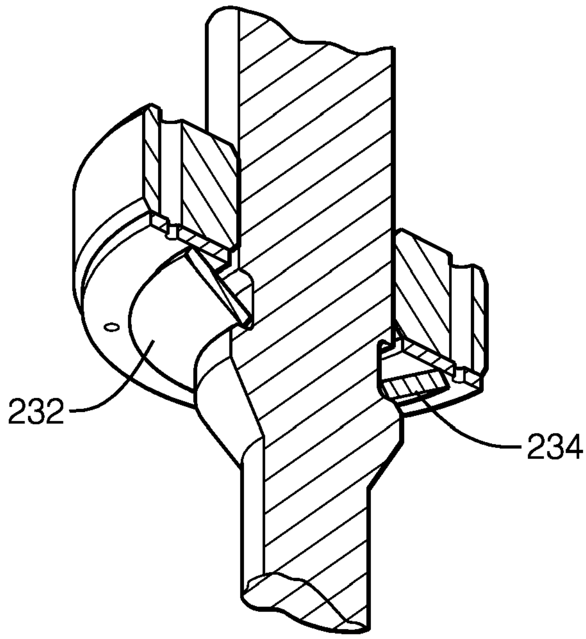

FIG. 9

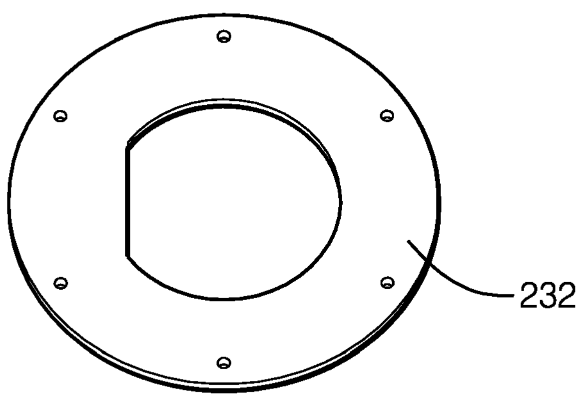

FIG. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 18 17 3371

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The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
The Hague	13 July 2018	Hermens, Sjoerd

CATEGORY OF CITED DOCUMENTS

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