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(54) Injection Nozzle

(57) An injection nozzle (20) for an internal combustion engine comprises a nozzle body (22) provided with a bore (24) within which a valve needle (23) is movable along a primary valve needle axis (A-A), the valve needle (23) being engageable with a valve seating (25) defined by the bore (24) to control fuel delivery through a nozzle outlet, and including a first region (36), a second region (38) and a seating region (33) defined by a transition between the first and second regions (36, 38) which seats against the valve seating (25) when the injection nozzle (20) is in a non-injecting state. A relieved region (40) is disposed upstream of the seating region (33), the relieved region (40) and one of the valve seating (25) and the first region (36) defining an anti-cavitation volume (50) therebetween when the injection nozzle (20) is in the non-injecting state. The valve needle (23) and the valve seating (25) together define a restriction (47) upstream of the relieved region (40) for restricting the flow of fuel into and out of the anti-cavitation volume (50) when the injection nozzle (20) is in the non-injecting state in order to reduce pressure wave activity upstream of the seating region (33).

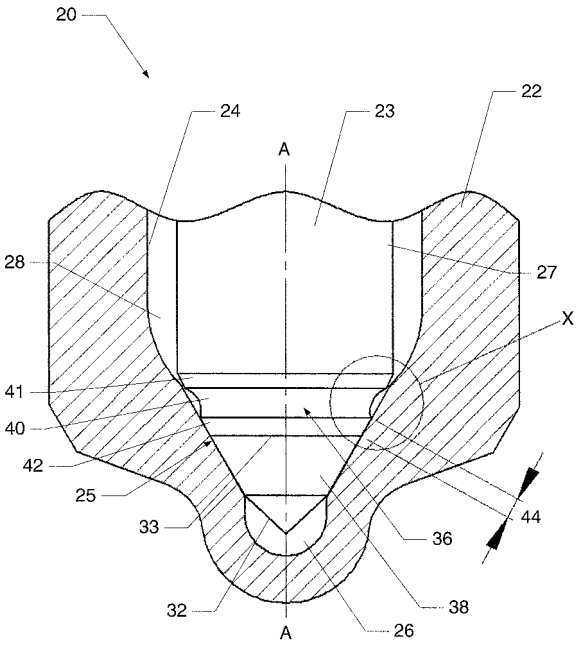


Figure 2

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Description

Technical Field

[0001] The present invention relates to an injection nozzle for an internal combustion engine, in particular for a compression-ignition internal combustion engine, and to a fuel injector having an actuator and such an injection nozzle.

Background to the Invention

[0002] Referring to Figure 1, a known injection nozzle 1 for a compression ignition internal combustion engine comprises a nozzle body 2 and a valve needle 3. The nozzle body 2 is provided with a blind bore 4 within which the valve needle 3 is movable to engage with, and disengage from, a valve needle seating 5 defined towards the blind end of the bore 4. The valve seating 5 is of substantially frusto-conical form, as is known in the art.

[0003] The nozzle body 2 also includes a plurality of nozzle outlets (not shown) through which fuel can be injected into an associated engine cylinder or combustion space, in circumstances in which the valve needle 3 is lifted from the valve seating 5. The blind end of the bore 4 defines a sac volume 6 with which inlet ends of the plurality of nozzle outlets communicate.

[0004] The valve needle 3 includes an upper region 7 of cylindrical form which defines, together with the surface of the bore 4 upstream of the valve seating 5, a delivery chamber 8 for receiving high pressure fuel from an inlet (not shown) to the injector of which the injection nozzle 1 forms a part. Adjacent to the upper region 7, and located further downstream, the valve needle 3 includes a first region 9 of substantially frusto-conical form (also known as the entry region 9 of the nozzle) and, further downstream still, a second region 10 of substantially frusto-conical form (also known as the seat region 10). A third valve region 11 of substantially frusto-conical form is disposed downstream of the seat region 10. The valve needle terminates in a conical valve tip 12, which projects into the sac volume 6 when the valve needle 3 is seated.

[0005] A transition edge between the seat region 10 and the third region 11 forms a seating line 13 which engages with the valve seating 5 when the valve needle 3 is in a non-injecting state. In use, as the valve needle 3 is moved away from the valve seating 5, high pressure fuel is permitted to flow past the valve seating 5 into the sac volume 6 from where it is injected through the nozzle outlets into the associated engine cylinder. When the valve needle 3 is moved to re-engage with the valve seating 5, the flow of fuel into the sac volume 6 is prevented and injection through the nozzle outlets is terminated.

[0006] The known injection nozzle of Figure 1, is typically employed in fuel delivery systems such as electronic unit injectors (EUIs) and electronic unit pumps (EUPs). Such systems experience high levels of pressure wave activity during operation. In the time following an injection event, the pressure in some regions of the injection nozzle 1 will drop to below the vapour pressure of the fuel. This causes cavitation to form as the fuel vapourises or foams locally. When pressure waves return to these regions, the bubbles of vapour collapse. The energy given out during this process is known to cause severe damage to the surfaces of the components, and is known in the art as cavitation damage.

[0007] More specifically, when the valve needle 3 is in the non-injecting state, as shown in Figure 1, a very narrow conical wedge of fuel is formed in the volume defined between the surface of the bore 4 and the valve needle 3, immediately upstream of the seating line 13, as indicated by the dashed line 14. The fuel in this volume is prone to cavitate and damage can occur to the material of the nozzle body 2 and the valve needle 3 in this region. Over a period of time, such damage can cause the seal at the seating line 13 to be broken, resulting in degraded performance.

[0008] It is an object of the present invention to provide an injection nozzle which substantially overcomes or mitigates at least one of the aforementioned problems.

Summary of Invention

[0009] According to a first aspect of the invention, there is provided an injection nozzle for an internal combustion engine, the injection nozzle comprising a nozzle body provided with a bore within which a valve needle is movable along a primary valve needle axis, the valve needle being engageable with a valve seating defined by the bore to control fuel delivery through a nozzle outlet, and including a first region, a second region and a seating region defined by a transition between the first and second regions which seats against the valve seating when the injection nozzle is in a non-injecting state. The invention is characterised by a relieved region disposed upstream of the seating region, the relieved region and one of the valve seating and the first region defining an anti-cavitation volume therebetween when the injection nozzle is in the non-injecting state, and wherein the valve needle and the valve seating together define a restriction upstream of the relieved region for restricting the flow of fuel into and out of the anti-cavitation volume when the injection nozzle is in the non-injecting state in order to reduce pressure wave activity upstream of the seating region.

[0010] Thus, by providing the anti-cavitation volume and the restriction, fuel is prevented from rapidly evacuating the region upstream of the seating region when the pressure in the injection nozzle drops at needle closure. The tendency for the pressure in the anti-cavitation volume to drop low enough in order for cavitation to occur is therefore reduced or prevented. Furthermore, when the pressure wave subsequently returns to the anti-cavitation volume, the energy is dissipated as the wave passes through the restriction. Thus, the pressure wave ac-

tivity in the region upstream of the seating region is dramatically reduced. This significantly reduces any damage from cavitation on or near the seating region.

[0011] In one embodiment, said first region has a substantially frusto-conical form and said relieved region comprises an annular groove formed within the valve seating. Conveniently, said relieved region defines an upstream frusto-conical portion of the first region and a downstream frusto-conical portion of the first region on either side thereof, when the injection nozzle is in the non-injecting state.

[0012] Alternatively, said first region has a substantially frusto-conical form and said relieved region comprises an annular groove formed within said first region of the valve needle. Conveniently, said relieved region defines an upstream frusto-conical portion of the first region and a downstream frusto-conical portion of the first region on either side thereof.

[0013] Preferably, the length of the downstream frusto-conical portion is between about 0.15mm and 0.45mm.

[0014] Conveniently, said restriction is defined by the upstream frusto-conical portion of the first region of the valve needle and the valve seating. Preferably, the width of the restriction is between about 0.01 mm and 0.05mm.

[0015] Preferably, the radius of the bore increases upstream from the upper end of the valve seating, and the restriction is defined by an overlap between the upper end of the valve seating and the downstream end of the upstream frusto-conical portion. More preferably, the length of the overlap is not less than 0.01 mm. Still more preferably, the length of the overlap is approximately 0.06mm.

[0016] Preferably, the valve seating defines a seat cone angle, said first region defines a first cone angle, and a differential angle between the first cone angle and the seat cone angle is between about 1 and 3 degrees.

[0017] Preferably, the depth of the annular groove is between about 0.08mm and 0.15mm and is more preferably approximately 0.11 mm.

[0018] Preferably, the second region is of substantially frusto-conical form.

[0019] Conveniently, the seating region is a seating line defined by a transition edge between the first and second regions.

[0020] The injection nozzle may be one of (i) VCO-type or (ii) sac-type.

[0021] According to a second aspect of the invention, there is provided a fuel injector for an internal combustion engine, the fuel injector having an actuator and an injection nozzle of the invention, wherein the actuator is configured to control movement of the valve needle of the nozzle towards and away from the valve seating.

[0022] Preferably, said actuator is an electromagnetic actuator. Alternatively, said actuator may be a piezoelectric actuator.

[0023] Preferred and/or optional features of the first aspect of the invention may be incorporated within the fuel injector of the second aspect, alone or in appropriate combination.

Brief Description of Drawings

[0024]

Figure 1 is a cross-sectional view of an injection nozzle of the kind known in the art. Embodiments of the present invention will now be described, by way of example only, with reference to Figures 2 to 4 of the accompanying drawings, in which;

Figure 2 is a cross-sectional view of a first embodiment of an injection nozzle according to the present invention;

Figure 3 is an enlarged cross-sectional view of the region labelled "X" in Figure 2; and

Figure 4 is a cross-sectional view of a second embodiment of an injection nozzle according to the present invention.

Detailed Description of Preferred Embodiments

[0025] Referring to Figures 2 and 3, the injection nozzle 20 comprises a nozzle body 22 and a valve needle 23. The nozzle body 22 is provided with a blind bore 24 within which the valve needle 23 is movable to engage with, and disengage from, a valve seating 25 defined by the blind end of the bore 24. The valve seating 25 is of substantially frusto-conical form, as is known in the art.

[0026] The nozzle body 22 also includes a plurality of nozzle outlets (not shown) through which fuel can be injected into an associated engine cylinder or combustion space, in circumstances in which the valve needle 23 is lifted from the valve seating 25. The blind end of the bore 24 defines a sac volume 26 with which inlet ends of the plurality of nozzle outlets communicate.

[0027] The valve needle 23 includes an upper region 27 of cylindrical form which defines, together with the surface of the bore 24 upstream of the valve seating 25, a delivery chamber 28 for receiving high pressure fuel from an inlet (not shown) to the injector of which the injection nozzle 20 forms a part. Adjacent to the upper region 27, and located further downstream, the valve needle 23 includes a first region 36 of substantially frusto-conical form (to be described in more detail later) and, further downstream still, a second region 38 of substantially frusto-conical form. The valve needle terminates in a conical valve tip 32, which projects into the sac volume 26 when the valve needle 23 is seated.

[0028] The frusto-conical first region 36 defines a first cone angle or vertex angle. The valve seating 25 has a generally conical shape and defines a seat cone angle, which is larger than the first cone angle of the first region 36. The differential angle between the first region 36 and the valve seating 25 is preferably between 1 and 3 de-

grees. The optimum value for the differential angle has been found to be 2 degrees.

[0029] A transition between the first region 36 and the second region 38 forms a seating region 33 which engages with the valve seating 25 when the valve needle 23 is in a non-injecting state. In use, as the valve needle 23 is moved away from the valve seating 25, high pressure fuel is permitted to flow past the valve seating 25 into the sac volume 26 from where it is injected through the nozzle outlets into the associated engine cylinder. When the valve needle 23 is moved to re-engage with the valve seating 25, the flow of fuel into the sac volume 26 is prevented and injection through the nozzle outlets is terminated.

[0030] The first region 36 comprises a relieved region 40 in the form of an annular groove. The relieved region 40 is disposed approximately half-way along the first region 36 in the direction of the primary needle axis (A-A). Accordingly, the relieved region 40 defines an upstream frusto-conical portion 41 and a downstream frusto-conical portion 42 of the first region 36 on either side thereof.

[0031] The downstream frusto-conical portion 42 has the seating region 33 at the downstream end thereof. The downstream frusto-conical portion 42 is shaped so as to aid with the absorption of impact energy when the valve needle 23 closes and also to help protect the seating region 33 from pressure waves. The length of the downstream frusto-conical portion 42, as indicated by the dimension labelled "44" in Figure 2, is preferably between 0.15 and 0.45mm. The optimum value for the length of the downstream frusto-conical portion 42 has been found to be 0.31 mm.

[0032] The geometry of the relieved region 40 is selected so as to maximise the volume 50 defined between the relieved region 40 and the valve seating 25 when the valve needle 23 is in the non-injecting position. Furthermore, the relieved region 40 is configured so as to ensure that there is an overlap of land 45 between the upstream frusto-conical portion 41 and the valve seating 25 when the valve needle 23 is in the non-injecting position.

[0033] The depth of the groove of the relieved region 40, indicated by the dimension labelled "46" in Figure 3, may be between about 0.08mm and 0.15mm. For a seat diameter of 2.25mm, the groove depth 46 is preferably 0.11mm. The groove depth 46 is selected so as to allow for optimal manufacturing of the valve needle 23 and to ensure that turbulence flow loss is minimised in use.

[0034] As explained above, when the valve needle 23 is in the non-injecting position there is an overlap of land 45 between the upstream frusto-conical portion 41 and the valve seating 25. Upstream from the conical valve seating 25, the bore 24 of the nozzle body 22 widens so as to define the delivery chamber 28 between the valve needle 23 and the surface of the bore 24. With the valve needle 23 in the non-injecting position, the upstream frusto-conical portion 41 is disposed adjacent to the transition between the upstream end of the valve seating 25 and the downstream end of the delivery chamber 28. The length of the overlap 45 is preferably kept to a minimum, but the mean value should ensure that the minimum overlap 45 is greater than 0.01 mm after assembly of the injection nozzle 20. For example, this can be achieved when a mean value of 0.06mm is used.

[0035] The overlap 45 defines a narrow gap or restriction 47 between the upstream frusto-conical portion 41 and the valve seating 25. The width of the restriction 47 is selected so as to restrict the flow of fuel therethrough as much as possible, whilst being large enough such that, as the downstream frusto-conical portion 42 wears from use, the upstream frusto-conical portion 41 will not contact the valve seating 25 during needle closure and form a new sealing diameter. Preferably, the width of the restriction 47 is between 0.01 and 0.05mm. The optimum value for the width of the restriction 47 has been found to be 0.03mm.

[0036] The operation of the injection nozzle 20 will now be described in detail.

[0037] When the valve needle 23 is in the non-injecting state, as shown in Figures 2 and 3, the seating region 33 of the valve needle 23 rests against the valve seating 25 of the nozzle body 22 and fuel is prevented from flowing to the sac volume 26 and through the nozzle outlets.

[0038] When the injection nozzle 20 is required to inject, the valve needle 23 is lifted from the valve seating 25, i.e. the valve needle 23 is moved in the upstream direction along the primary needle axis (A-A) by means of a suitable actuator, such as a piezoelectric actuator or an electromagnetic actuator. When the valve needle 23 lifts, fuel at high pressure (e.g. 2000 bar) in the delivery chamber 28 is permitted to flow past the seating region 33 and into the sac volume 26 from where it is injected into an associated engine combustion chamber.

[0039] At the end of an injection event, the valve needle 23 closes again, such that the seating region 33 contacts the valve seating 25 so as to prevent the flow of fuel to the sac volume 26. As explained previously, the rapid closure of the valve needle 23 is followed by a rapid fall in the fluid pressure immediately upstream of the seating region 33. However, when the pressure drops, the fuel in the anti-cavitation volume 50 defined between the relieved region 40 and the valve seating 25 is prevented from being evacuated quickly since it must pass through the restriction 47. Accordingly, the tendency for the pressure in the anti-cavitation volume 50 to drop to a low enough level for cavitation to occur is reduced or prevented. Furthermore, when the pressure wave subsequently returns to the anti-cavitation volume 50, the energy is dissipated as the wave passes through the restriction 47. Thus, the pressure wave activity in the region upstream of the seating region 33 is dramatically reduced. This significantly reduces any damage from cavitation on or near the seating region 33.

[0040] Furthermore, any damage which may start to occur will be limited to the upstream end of the upstream frusto-conical portion 41 as any cavities will tend to collapse at this point first. Thus, the seating region 33 will

not experience damage from cavitation and performance will not be degraded.

[0041] In the embodiment described above with reference to Figures 2 and 3, the first region 36 and the relieved region 40 may be formed in separate manufacturing steps. More specifically, in a first step, the valve member 23 is machined so as to produce the first region 36 of substantially frusto-conical form. Thereafter, in a subsequent manufacturing step, the annular groove is machined into the surface of the first region 36 so as to form the relieved region 40. It will be appreciated by those skilled in the art that, when the relieved region 40 is formed in this manner, the resulting upstream and downstream frusto-conical portions 41, 42 will have the same differential angle relative to the valve seating 25.

[0042] In an alternative to the above-described method of manufacture, the first region 36 comprising the upstream frusto-conical portion 41, the relieved region 40, and the downstream frusto-conical portion 42 may be formed in a single manufacturing step, by machining the valve needle 23 to have the desired profile. In this case, the upstream and downstream frusto-conical portions 41, 42 may be formed so as to have the same differential angle relative to the valve seating 25. Alternatively, the upstream and downstream frusto-conical portions 41, 42 may be formed with different differential angles. This may be advantageous in that the differential angles of the upstream and downstream frusto-conical portions 41, 42 can be chosen independently. Accordingly, the differential angle of the upstream frusto-conical portion 41 may be selected so as to provide the optimum width for the restriction 47, whereas the differential angle of the downstream frusto-conical portion 42 may be selected so as to minimise wear at the seating region 33.

[0043] An alternative embodiment of an injection nozzle according to the present invention will now be described. In Figure 4, like reference numerals are used to refer to like parts of the above-described injection nozzle of Figures 2 and 3.

[0044] Referring to Figure 4, the relieved region 40 is defined by an annular groove formed within the valve seating 25 of the nozzle body 22, rather than being formed within the valve needle 23 itself. Accordingly, the first region 36 of the valve needle 23 has a substantially frusto-conical form which defines a substantially constant differential angle with the valve seating 25 across its surface.

[0045] When the injection nozzle 20 is in the non-injecting position, the valve member 23 rests against the valve seating 25 such that the upstream edge of the relieved region 40 defines the limit of the upstream frusto-conical portion 41 of the first region 36, as shown by a dashed line in Figure 4. Similarly, the downstream edge of the relieved region 40 defines the limit of the downstream frusto-conical portion 42 of the first region 36, also shown by a dashed line in Figure 4. Thus, in the embodiment of Figure 4, even though the first region 36 of the valve needle 23 does not comprise physically distinct upstream and downstream frusto-conical portions 41, 42, such portions 41, 42 are nevertheless defined by reference to the relieved region 40 when the injection nozzle 20 is in the non-injecting state. Accordingly, each of the exemplary dimensions described above in relation to the embodiment of Figure 2 and 3, i.e. the length 44 of the downstream frusto-conical portion 42, the width of the restriction 47 and the length of the overlap 45, is equally applicable to the embodiment of Figure 4.

[0046] The operation of the injection nozzle shown in Figure 4 is substantially the same as that described above in relation to the embodiment of Figures 2 and 3. That is, when the valve needle 23 closes at the end of an injection event, the seating region 33 contacts the valve seating 25 so as to prevent the flow of fuel to the sac volume 26. The rapid closure of the valve needle 23 is followed by a rapid fall in the fluid pressure immediately upstream of the seating region 33. However, when the pressure drops, the fuel in the anti-cavitation volume 50 defined between the relieved region 40 and the first region 36 of the valve needle 23 is prevented from being evacuated quickly since it must pass through the restriction 47. Accordingly, the tendency for the pressure in the anti-cavitation volume 50 to drop to a low enough level for cavitation to occur is reduced or prevented. Furthermore, when the pressure wave subsequently returns to the anti-cavitation volume 50, the energy is dissipated as the wave passes through the restriction 47. Thus, the pressure wave activity in the region upstream of the seating region 33 is dramatically reduced. This significantly reduces any damage from cavitation on or near the seating region 33.

[0047] In each of the above-described embodiments, the seating region 33 may be in the form of a seating line defined by a transition edge between the first and second regions 36, 38 of the valve needle 23, as will be appreciated by those skilled in the art. However, it will equally be appreciated that the transition between the first and second regions 36, 38 may extend over a greater area of the surface of the valve needle 23 so as to form an extended seating region 33.

[0048] Although the present invention has been described above with reference to a sac-type injection nozzle, the skilled person will readily appreciate that the present invention may be applied to a VCO-type injection nozzle.

Claims

1. An injection nozzle (20) for an internal combustion engine, the injection nozzle (20) comprising:

   a nozzle body (22) provided with a bore (24) within which a valve needle (23) is movable along a primary valve needle axis (A-A), the valve needle (23) being engageable with a valve seating (25) defined by the bore (24) to control

fuel delivery through a nozzle outlet, and including a first region (36), a second region (38) and a seating region (33) defined by a transition between the first and second regions (36, 38) which seats against the valve seating (25) when the injection nozzle (20) is in a non-injecting state,

characterised by a relieved region (40) disposed upstream of the seating region (33), the relieved region (40) and one of the valve seating (25) and the first region (36) defining an anti-cavitation volume (50) therebetween when the injection nozzle (20) is in the non-injecting state; and

wherein the valve needle (23) and the valve seating (25) together define a restriction (47) upstream of the relieved region (40) for restricting the flow of fuel into and out of the anti-cavitation volume (50) when the injection nozzle (20) is in the non-injecting state in order to reduce pressure wave activity upstream of the seating region (33).

2. An injection nozzle according to claim 1, wherein said first region (36) has a substantially frusto-conical form and said relieved region (40) is defined by an annular groove formed within the valve seating (25).

3. An injection nozzle according to claim 1, wherein said first region (36) has a substantially frusto-conical form and said relieved region (40) is defined by an annular groove formed within said first region (36) of the valve needle.

4. An injection nozzle according to claim 2, wherein said relieved region (40) defines an upstream frusto-conical portion (41) of the first region (36) on one side thereof and a downstream frusto-conical portion (42) of the first region (36) on the other side thereof, when the injection nozzle (20) is in the non-injecting state.

5. An injection nozzle according to claim 3, wherein said relieved region (40) defines an upstream frusto-conical portion (41) of the first region (36) on one side thereof and a downstream frusto-conical portion (42) of the first region (36) on the other side thereof.

6. An injection nozzle according to claim 4 or 5, wherein the length (44) of the downstream frusto-conical portion (42) is between about 0.15mm and 0.45mm.

7. An injection nozzle according to any one of claims 4 to 6, wherein said restriction (47) is defined by the upstream frusto-conical portion (41) of the first region (36) of the valve needle (23) and the valve seating (25).

8. An injection nozzle according to claim 7, wherein the width of the restriction (47) is between about 0.01 mm and 0.05mm.

9. An injection nozzle according to any one of claims 4 to 8, wherein the radius of the bore (24) increases upstream from an upper end of the valve seating (25), and the restriction (47) is defined by an overlap (45) between the upper end of the valve seating (25) and the downstream end of the upstream frusto-conical portion (41).

10. An injection nozzle according to claim 9, wherein the length of the overlap (45) is not less than 0.01 mm.

11. An injection nozzle according to claim 10, wherein the length of the overlap (45) is approximately 0.06mm.

12. An injection nozzle according to any one of claims 2 to 11, wherein the valve seating (25) defines a seat cone angle, said first region (36) defines a first cone angle, and a differential angle between the first cone angle and the seat cone angle is between about 1 and 3 degrees.

13. An injection nozzle according to any one of claims 2 to 12, wherein the depth of the annular groove is between about 0.08mm and 0.15mm and is preferably approximately 0.11 mm.

14. An injection nozzle according to any preceding claim, wherein the second region (38) is of substantially frusto-conical form.

15. An injection nozzle according to any preceding claim, wherein the seating region (33) is a seating line defined by a transition edge between the first and second regions (36, 38).

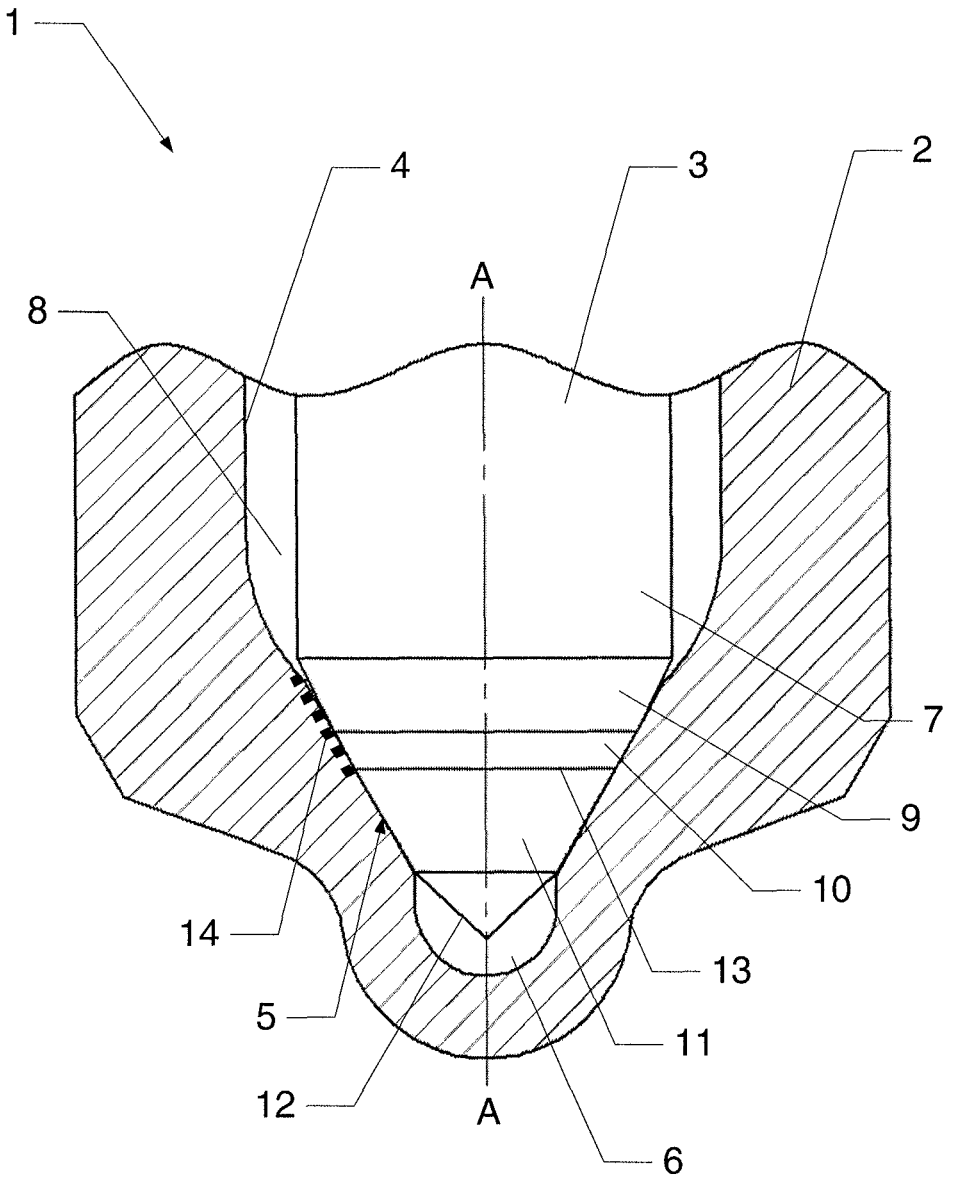


Figure 1
(Prior Art)

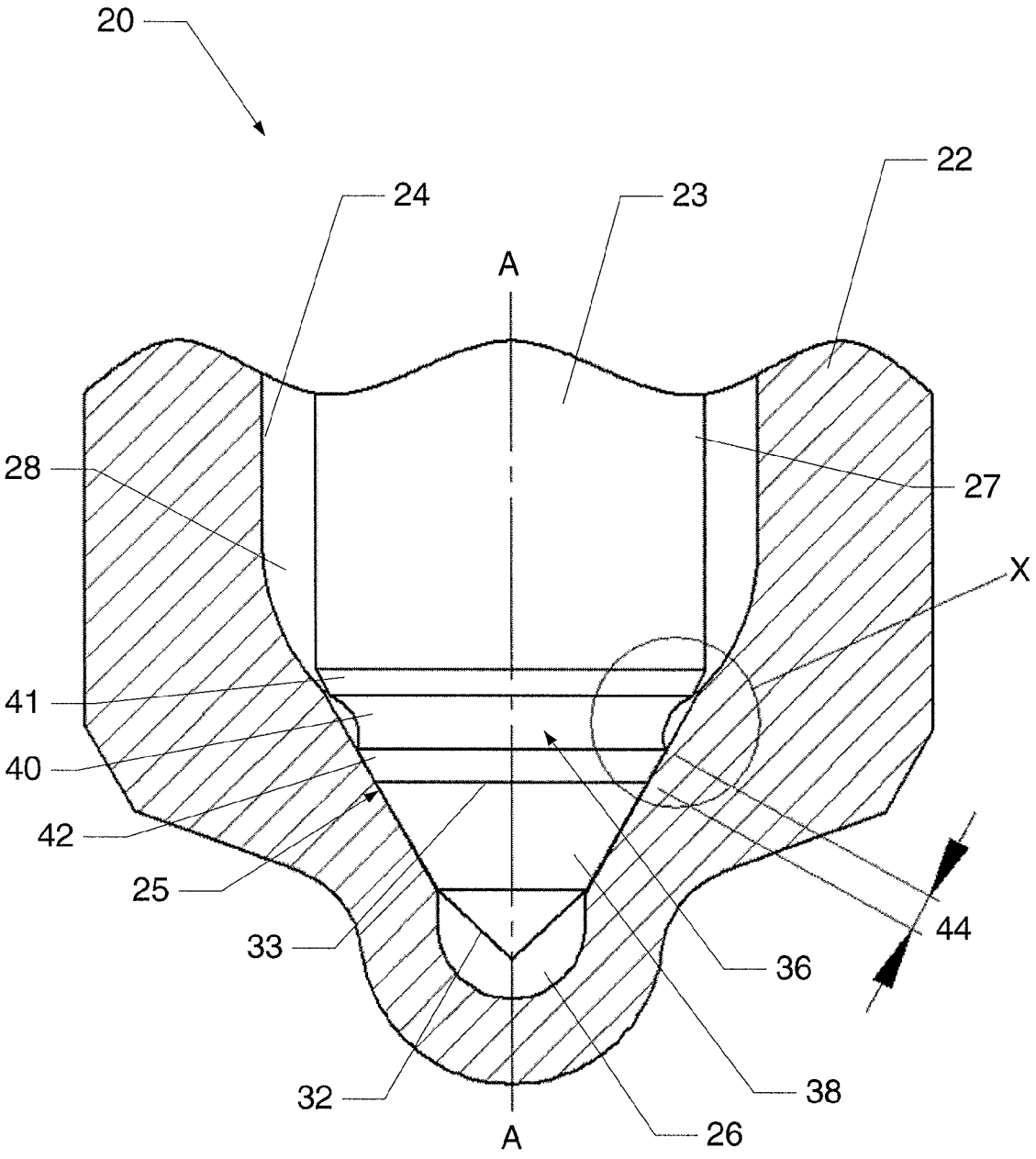


Figure 2

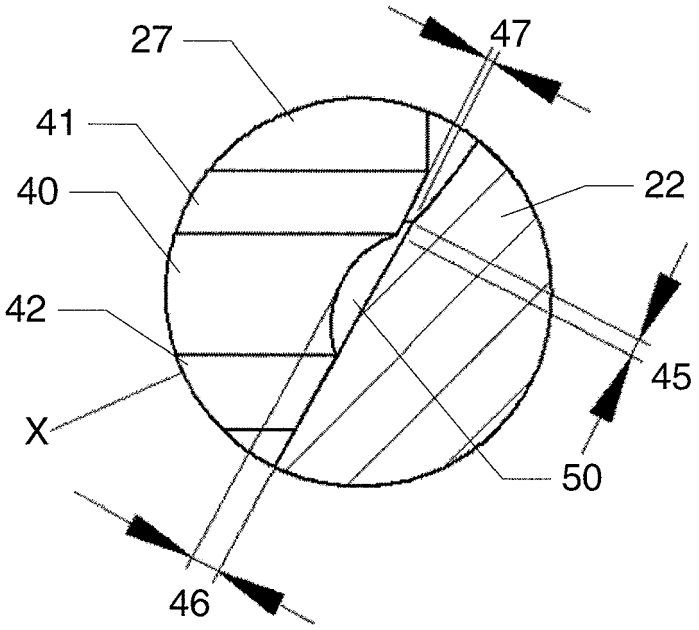


Figure 3

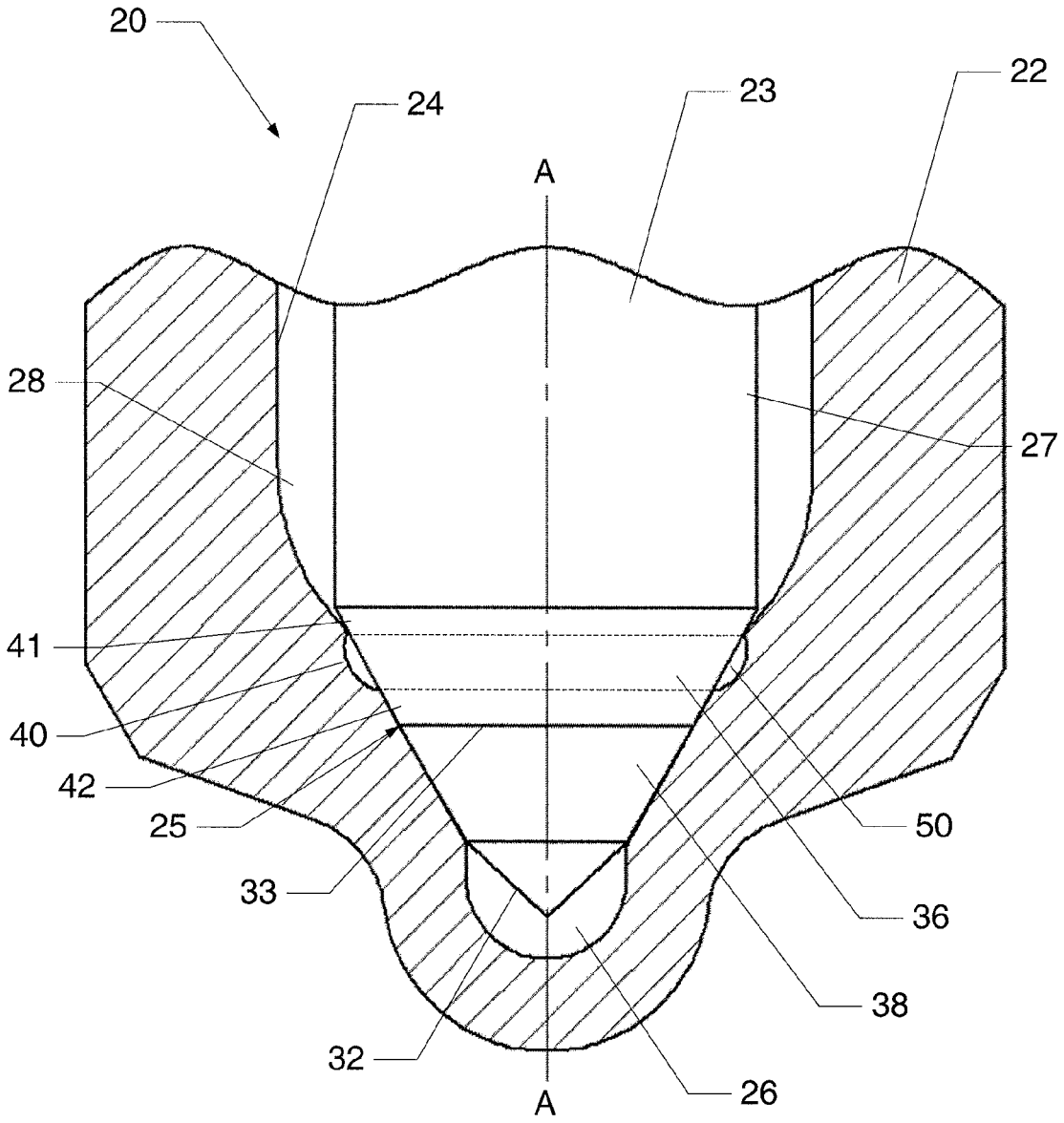


Figure 4

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EUROPEAN SEARCH REPORT

Application Number
EP 09 15 6674

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 102 59 169 A1 (BOSCH GMBH ROBERT [DE]) 1 July 2004 (2004-07-01) * page 3, paragraph 20 - page 4, paragraph 22; figures 1-3 *	1,2,6, 8-15	INV. F02M61/16 F02M61/18
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X	DE 103 18 989 A1 (BOSCH GMBH ROBERT [DE]) 27 November 2003 (2003-11-27) * column 3, paragraph 18 - column 4, paragraph 19; figure 2 *	1,2,6, 8-15	
			TECHNICAL FIELDS SEARCHED (IPC) F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 October 2009	Etschmann, Georg

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 15 6674

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82