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(54) **Fuel injector**

(57) A variable orifice nozzle assembly (12) of a fuel injector (10) having an upper set of spray holes (18) and a lower set of spray holes (20), and being provided with an outer valve member (36) controlling the upper holes (18) and, an inner valve member (40) coaxially slidably arranged inside the outer valve member (36) for controlling the lower holes (18). The outer (36) and the inner valve members (40) are able to be independently translated between a closed position (PC) prohibiting fuel spray and an open position (PO) enabling fuel spray and, the nozzle assembly (12) is provided with an expansion means (50,52,54, 56, 58) enlarging the outer valve member (36) when being in closed position (PC).

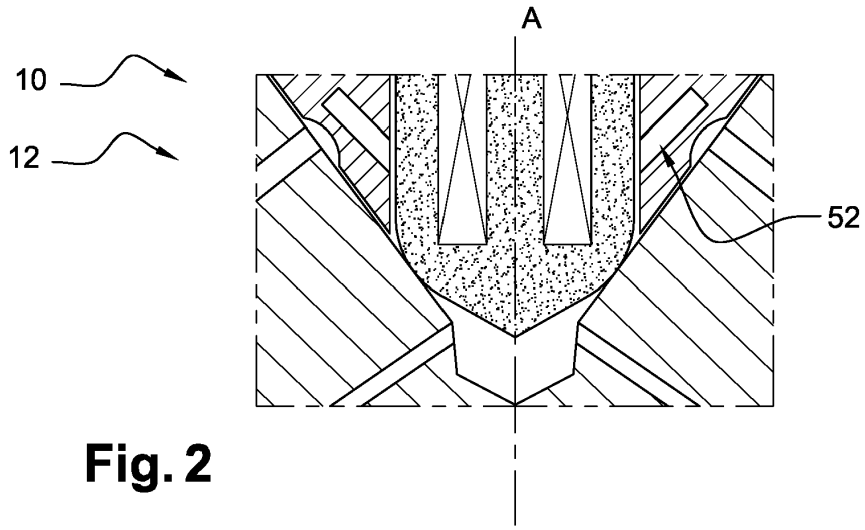


**Fig. 2**

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## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a variable orifice nozzle provided with a twin valve member for a fuel injector.

### BACKGROUND OF THE INVENTION

**[0002]** Fuel injectors with variable orifice nozzle have a body provided with an upper set of spray holes controlled by an outer valve member, also named needle, and a lower set of spray holes controlled by an inner valve member coaxially arranged inside the outer valve member. The outer and inner valve members form a twin needle slidably arranged in the body, and able to be displaced between and open position and a closed position. The valve members have lower ends provided with valve seats and, when the valve members are in closed position, the valve seats cooperate with seating surfaces provided on the nozzle body prohibiting fuel injection through the spray holes.

**[0003]** The outer valve member is provided with an upper valve seat cooperating with an upper seating surface which is above the upper holes, and also with a middle valve seat cooperating with a middle seating surface that is just below the upper holes. The sealing of these upper holes is often not totally achieved since when the outer valve member contacts the upper seating surface, the middle seat either remains at a small distance from the middle seating surface or is not pressed onto the middle seating surface with sufficient force so that undesirable leakage through said upper holes occurs. To improve the sealing of the upper spray holes, the two valve seats of the outer valve member must be pressed in contact against their respective seating surfaces with a sufficient force so pressurized fuel is unable to leak below the valve member.

### SUMMARY OF THE INVENTION

**[0004]** Accordingly, it is an object of the present invention to solve the above mentioned problem in providing a variable orifice nozzle (VON) assembly of a fuel injector adapted to spray fuel in a combustion chamber. The VON has a body extending along a main axis toward a lower end where are arranged an upper set of spray holes and a lower set of spray holes. The VON is further provided with an outer valve member slidably arranged in the body for controlling the opening and closing of the upper holes and, an inner valve member coaxially slidably arranged inside the outer valve member for controlling the opening and closing of the lower holes.

**[0005]** The outer and the inner valve members are able to be independently translated between a closed position prohibiting fuel spray and an open position enabling fuel spray and, the nozzle assembly is further provided with an expansion means enlarging the outer valve member when being in closed position so that, the outer valve member is firmly biased against the nozzle body preventing any leakage through the upper holes.

**[0006]** The expansion means comprises a large annular cavity arranged in the outer valve member, the cavity reducing the wall thickness of the extremity of the outer valve member in the area where said valve member cooperates with the a seating surface arranged just below the upper set of holes. In use, pressurized fuel is able to fill the cavity and to generate on said area having a reduced wall thickness a force elastically enlarging the size of said valve member.

**[0007]** To enable a resilient deformation the reduced wall thickness may be chosen smaller than 0.5 mm and preferably smaller than 0.3 mm.

**[0008]** The expansion means comprises a large annular cavity arranged in the outer valve member and, the cavity reduces the wall thickness of the extremity of the outer valve member in the area where said valve member cooperates with the middle valve seat. In use, pressurized fuel is able to fill the cavity generating on said outer valve member area having a reduced wall thickness a force augmenting elastically the size of said valve member.

**[0009]** The expansion means further comprises, in the outer valve member, a radial through hole arranged upstream the upper valve seat and, in the inner valve member, an annular groove in fluid communication with said hole and an axial fluid passage downwardly extending from said grove to said large annular cavity.

**[0010]** The invention extends to a fuel injector comprising a variable orifice nozzle assembly as set in the preceding paragraphs.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** The present invention is now described by way of example with reference to the accompanying drawings in which:

Figures 1 is a schematic axial section of the nozzle of a fuel injector as per the invention.
Figure 2 is a second embodiment of the invention.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0012]** In the following description, similar elements will be designated with the same reference numbers. Also, to ease and clarify the description a top-down orientation will be followed in reference to the orientation of the figures. Words and expressions such as "top, upper, lower, over, under"... may be utilized without any intention to limit the scope of the invention.

**[0013]** The lower extremity of a fuel injector 10 having a variable office nozzle 12, hereafter abbreviated VON, is represented on figure 1. The VON 12 extends along a main axis A. It has a body 14 with a pointy lower extremity

15 and is provided with an inner axial bore 16. In the pointy extremity 15 are arranged an upper set of holes 18 and a lower set of holes 20. As visible on the figure, the upper holes 18 are above the lower holes 20 and, each of the holes 18, 20, extends through the wall of the body 14 from an entry 22, 24, arranged in the bore 16 to an exit 26, 28, arranged on the outer face of the body 14. The entries 22 of the upper holes 18 are arranged along an upper virtual plan circle perpendicular to the main axis A and, similarly, the entries 24 of the lower holes are arranged along a lower virtual plan circle whose diameters are perpendicular to the main axis A.

**[0014]** In the close vicinity of the entries 22, 24, the bore is provided with three seating surfaces 31, 33, 35 that are from top to bottom, a first "upper" seating surface 31 arranged just above the upper entries 22 and, a second "middle" seating surface 33 arranged just below the upper entries 22 and, a third "lower" seating surface 35 arranged just above the lower entries 24, both the middle 33 and the lower 35 seating surfaces being between the upper 22 and the lower entries 24.

**[0015]** In the large bore 16 is slidably guided an outer cylindrical valve member 36, itself provided with an axial cylindrical smaller bore 38 wherein is slidably guided an inner valve member 40. At its lower extremity, the inner valve member 40 has a full conical end 42 while, the outer valve member 36, because of the downward opening of the smaller bore 38, has a truncated conical end 44 extending between an upper circular edge 46 and a lower circular edge 48. As visible on the figure, the two valve members 36, 40, have complementary shapes enabling to form a complete cone.

**[0016]** The outer valve member 36 is further provided with a fluid passage 50 that comprises at least one radial through hole 50 arranged above the upper circular edge 46. The hole 50 creates a fluid communication through the wall of the outer valve member 36, between the large bore 16 of the body 14 and the smaller bore 38 of the outer valve member 36.

**[0017]** The outer valve member 36 is further provided with an inner circular cavity 52 arranged in the smaller bore 38 in the vicinity of lower edge 48. Because of the cavity 52, the most downward portion 54 of the outer valve member 36, the portion in the vicinity to the lower edge 48 is thinner, having a reduced wall thickness inferior to 0.5mm, and preferably inferior to 0.3mm.

**[0018]** Figure 2 presents an alternative embodiment where the cavity 52 is a conical groove forming a volume parallel to the conical end 44 of the outer valve member 36. Other non-represented alternatives of shapes can be made.

**[0019]** The inner valve member 40 is provided on its external face with a complementary annular groove 56 from which downwardly extend a fluid passage 58 ending before reaching the lower valve seat 34. The represented fluid passage 58 comprises two parallel flats provided at the surface of the inner valve member 40 but, alternatives of other types and other number such as one, or three or more, grooves or channels, straight, helicoid or other shapes are also possible.

**[0020]** As shown on the figure, the radial hole 50 arranged in the outer valve member 36, the annular groove 56, the fluid passage 58 and the cavity 52 are in fluid communication and therefore, fuel can flow from the large bore 16 into the cavity 52.

**[0021]** The operation of the VON 12 is now described. The outer and inner valve members 36, 40, can be independently piloted in translation to displace between a closed position PC, where the valve member is at its most downward position, and a fully open position PO (not represented) where the valve member is lifted to its most upward position. The outer valve member 36 and the inner valve member 40 being able to be displaced independently from each other, although all configurations are not in use today, nothing prevents the outer 36 and inner 40 valve members to be simultaneously in closed position PC or simultaneously in open position PO or, the inner valve member to be in open position PO while the outer valve member is in closed position PC or, to the opposite, the inner valve member to be in closed position PC while the outer valve member is in open position PO.

**[0022]** In use, pressurized fuel flows in the body of the injector 10, from an inlet to the injection holes 18, 20. In closed position PC of both valve members 36, 40, the upper valve seat 30 is firmly biased against the upper seating surface 31 and, the lower valve seat 34 is firmly biased against the lower seating surface 35. Pressurized fuel fills the large bore 16 of the body 14, the through hole 50, the annular groove 56 of the inner valve member 20 and downwardly flows into the fluid passage 58 until filling the circular cavity 52. The pressurized fuel present in the circular cavity 52 generates forces F perpendicular to the surfaces of the cavity 52 and, said forces applied on the thinner portion 54 of the wall of the outer valve member 36 elastically deform said thinner portion 54 firmly biasing the middle valve seat 32 onto the middle seating surface 33 and therefore, the upper holes 18 are well sealed prohibiting any fuel leakage.

**[0023]** When the outer valve member 36 is piloted to the open position PO, its conical end 44 moves away from the upper 31 and from the middle 33 seating surfaces and, fuel is enabled to flow through the upper holes 18.

**[0024]** In the above description the following references have been utilized:

| | |
|---|---|
| 10 | fuel injector |
| 12 | variable orifice nozzle |
| 14 | body |
| 15 | lower extremity of the body |
| 16 | bore |
| 18 | upper set of holes |
| 20 | lower set of holes |
| 22 | entry of the upper hole |
| 24 | entry of the lower hole |

| | |
|---|---|
| 26 | exit of the upper hole |
| 28 | exit of the lower hole |
| 30 | upper valve seat |
| 31 | upper seating surface |
| 32 | middle valve seat |
| 33 | middle seating surface |
| 34 | lower valve seat |
| 35 | lower seating surface |
| 36 | outer valve member |
| 38 | smaller bore in the outer valve member |
| 40 | inner valve member |
| 42 | conical end of the inner valve member |
| 44 | frustoconical end of the outer valve member |
| 46 | upper edge of the frustoconical end |
| 48 | lower edge of the frustoconical end |
| 50 | fluid passage |
| 52 | inner circular cavity |
| 54 | thinner portion of the outer valve member |
| 56 | annular groove in the inner valve member |
| 58 | flat |

| | |
|---|---|
| A | main axis |
| PO | position fully open |
| PC | position closed |
| F | force |

**Claims**

**1.** Variable orifice nozzle assembly (VON) (12) of a fuel injector (10) adapted to spray fuel in a combustion chamber, the VON (12) having a body (14) extending along a main axis (A) toward a lower end (15) where are arranged an upper set of spray holes (18) and a lower set of spray holes (20), the VON (12) being further provided with an outer valve member (36) slidably arranged in the body (14) for controlling the opening and closing of the upper holes (18) and, an inner valve member (40) coaxially slidably arranged inside the outer valve member (36) for controlling the opening and closing of the lower holes (18), **characterized in that**
the outer (36) and the inner valve members (40) are able to be independently translated between a closed position (PC) prohibiting fuel spray and an open position (PO) enabling fuel spray and **in that** the nozzle assembly (12) is further provided with an expansion means (50,52,54, 56, 58) enlarging the outer valve member (36) when being in closed position (PC) so that, the outer valve member (36) is firmly biased against the nozzle body (14) preventing any leakage through the upper holes (18).

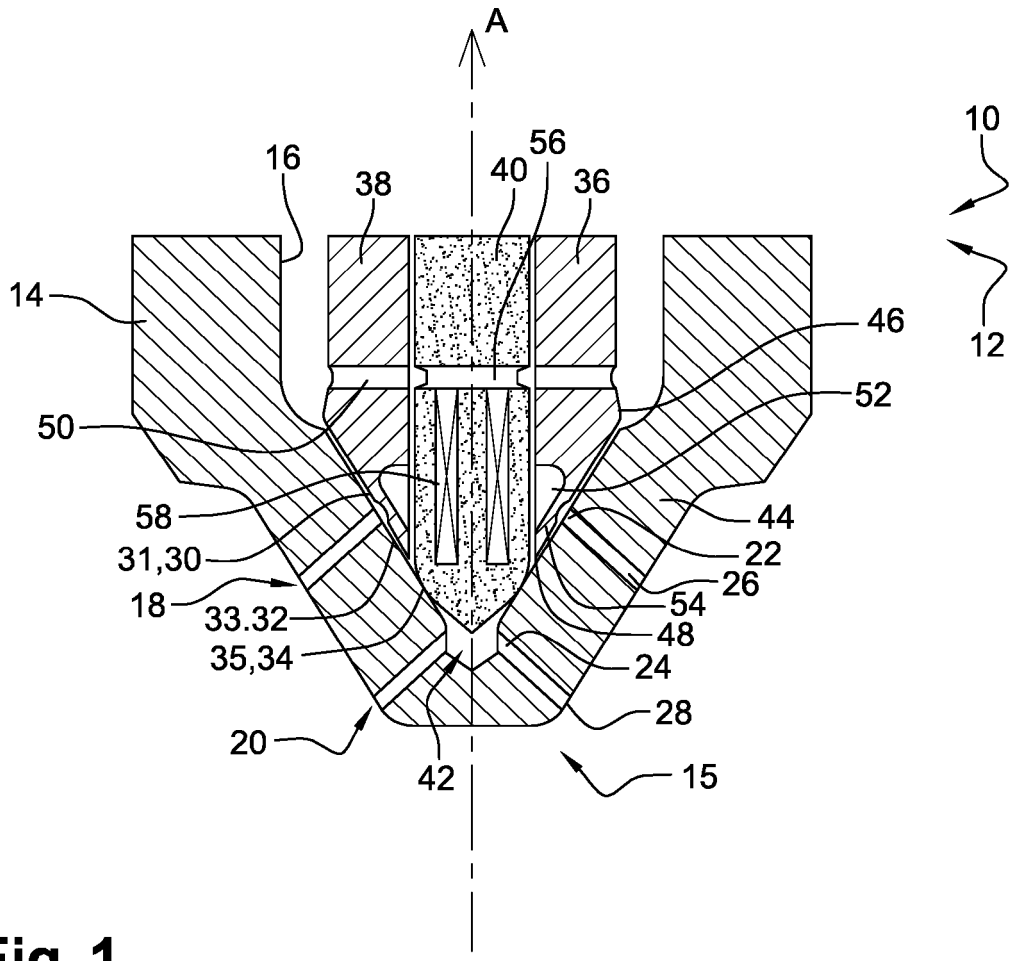
**2.** Nozzle assembly (12) as set in the preceding claim wherein the expansion means (50-58) comprises an annular cavity (52) arranged in the outer valve member (36), the cavity (52) reducing the wall thickness of the extremity of the outer valve member in the area (54) where said valve member (36) cooperates with the a seating surface (33) arranged just below the upper holes (18) so that, in use, pressurized fuel is able to fill the cavity (52) generating on said outer valve member area (54) having a reduced wall thickness a force elastically enlarging said valve member (36).

**3.** Nozzle assembly (12) as set in claim 2 wherein said reduced wall thickness is smaller than 0.5 mm.

**4.** Nozzle assembly (12) as set in claim 2 or 3 wherein said reduced wall thickness is preferably smaller than 0.3 mm.

**5.** Nozzle assembly (12) as set in any of the claims 2 to 4 wherein the expansion means (50-58) further comprises, in the outer valve member (36), a radial through hole (50) arranged upstream the upper valve seat (30) and, in the inner valve member (40), an annular groove (56) in fluid communication with said hole (50), and an axial fluid passage (58) downwardly extending from said groove (56) to said large annular cavity (52).

**6.** Fuel injector (10) provided with a variable orifice nozzle assembly (12) as set in any the preceding claim.


A
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14
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Fig. 1

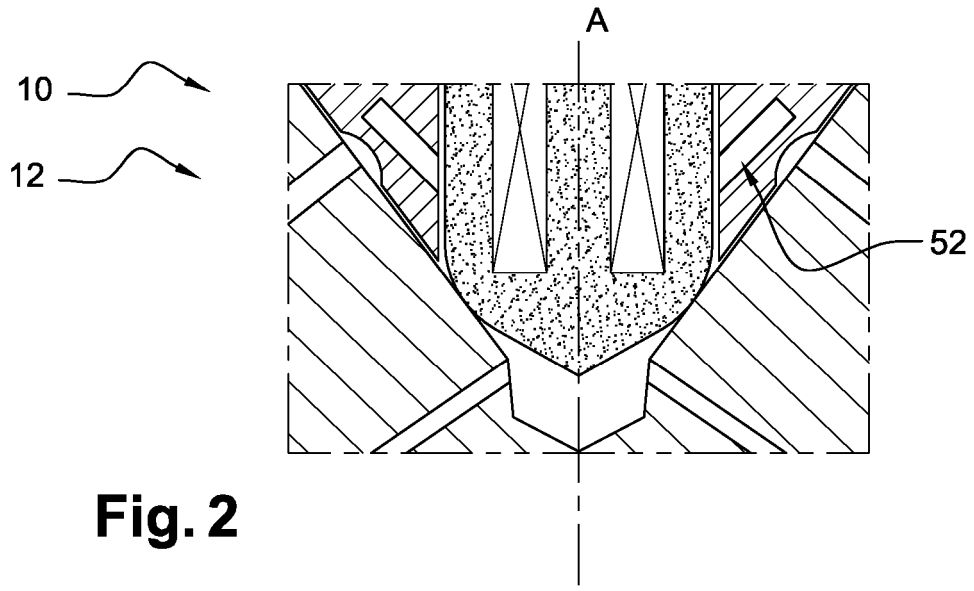
A
10
12
52

Fig. 2

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# EUROPEAN SEARCH REPORT

Application Number
EP 15 15 6616

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 3 July 2015 | Barunovic, Robert |

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# EUROPEAN SEARCH REPORT

Application Number
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