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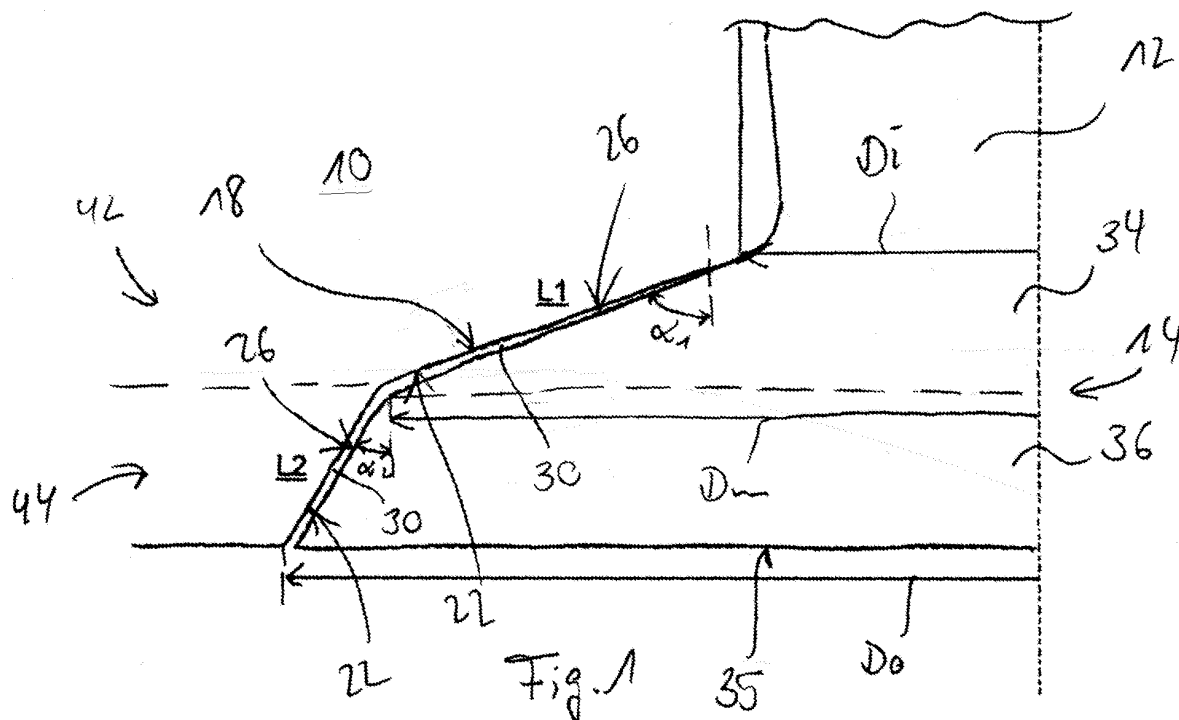
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(54) **Outward opening fuel nozzle**

(57) An outward opening fuel nozzle comprises a nozzle body (10) and a pintle (12), wherein the pintle (12) comprises a closing member (14) receivable on a seat (18) of the nozzle body (10), the seat (18) defines a first sealing surface (22) co-operating with a second sealing surface (26) on a periphery of the closing member (14), and the pintle (12) is slideable so that the clos-

ing member (14) can be lifted from the seat (18) in order to open a fuel passage (30) defined between the first sealing surface (22) and the second sealing surface (26). The first sealing surface (22) and the second sealing surface (26) each comprise at least two conical portions (34, 36, 42, 44) wherein the cone angles (α_1 , α_2) of the conical portions differ.



Description

FIELD OF THE INVENTION

[0001] The present invention relates to an outward opening fuel nozzle for a spray guided injection of fuel into a combustion chamber of an internal combustion engine. Especially, the invention relates to a fuel nozzle for direct-injection gasoline applications.

BACKGROUND OF THE INVENTION

[0002] Direct injection of gasoline (DIG) can reduce the fuel consumption of an internal combustion engine. Among several types of combustion systems for DIG engines, the spray-guided combustion processes appear to be the most efficient one. This DIG type can significantly reduce fuel consumption as well as exhaust emissions. Therefore, recent developments concentrate on the further improvement of spray-guided combustion processes.

[0003] According to the small distance between the injector and the spark plug in a DIG system, the mixture formation of the injected fuel spray is of high relevance. Also, the stability of the injection spray must be ensured during normal operation with high pressures in the combustion chamber. Finally, the injected spray must not hit the spark plug.

[0004] Fig. 5 is a cross-sectional view of a conventional fuel nozzle of a DIG injector. The fuel nozzle is of the outward opening type. It comprises a nozzle body 50 and a pintle 52 with a closing member 54. The closing member 54 is receivable on a seat 56 of the nozzle body 50. This seat 56 defines a first sealing surface which co-operates with a second sealing surface on a periphery of the closing member 54. The first and second sealing surfaces are of conical form. The pintle 52 is slideably arranged in a bore of the nozzle body 50 so that the closing member 54 can be lifted from the seat 56 in order to open a fuel passage 58 defined between the seat 56 and the closing member 54. When the closing member 54 is lifted, the fuel is squeezed under high pressure through the fuel passage 58 and injected into a combustion chamber in the form of a conical fuel spray as defined by the conical shape of the fuel passage 58.

[0005] In order to achieve a stable injection spray, a certain cone angle is required. In actual designs of DIG fuel nozzles, the injected spray has a cone angle of about 80°. In order to achieve such a cone angle, the sealing surface of the seat 56 has a cone angle of 80° and the sealing surface of the closing member 54 has a cone angle of 79°. This ensures a tight closure of the valve, formed by the closing member 54 and the seat 56, along a circular closure line. The closure line is typically upstream of the passage.

[0006] In some applications, a smaller cone angle is required in order to match certain combustion chamber geometries. However, reducing the cone angle of the

injected fuel spray to, for example, 60° leads to an unstable spray, when pressure and temperature in the combustion chamber increase.

[0007] Fig. 4 shows a cross-sectional view of a conventional fuel nozzle of a DIG injector similar to the fuel nozzle of Fig. 5. Fig. 4 shows two different designs of the seat of the nozzle body 56 and 56' and the closing member 54 and 54'. The first design is similar to the design of the nozzle of Fig. 5, but the second design (dotted lines) differs from the first design in the angle of the cone defined by the passage between the seat 56' and the closing member 54'. The cone angle of the second design is 60°. However, the injected spray is unstable due to the small cone angle.

[0008] In order to generate a stable spray with such a small cone angle, it has been found that increasing the diameter of the orifice of the outlet of a fuel injector supports the holding of the hollow cone structure of an injected spray, while reducing the cone angle to 60°. However, such an increase of the orifice diameter leads to a design in which the fuel passage is significantly elongated. This elongated fuel passage has two drawbacks: firstly, the elongation destroys the swirl motion induced to the fuel which stabilizes the spray; secondly, the elongation causes a separation of the spray into fin-gery strings, which stabilize the spray structure, but which are unpredictable and generate undesired strong radial heterogeneity of the spray concentration. Fig. 6 shows a design of a fuel nozzle with such an elongated fuel passage (length L') which is required for achieving a stable spray with a cone angle of about 60°.

OBJECT OF THE INVENTION

[0009] It is an object of the present invention to provide an outward opening fuel nozzle for a spray guided injection of fuel into a combustion chamber of an internal combustion engine, which allows a reduction of the cone angle of the injected fuel spray. This object is achieved by an outward opening fuel nozzle as claimed in claim 1.

SUMMARY OF THE INVENTION

[0010] The present invention relates to an outward opening fuel nozzle comprising a nozzle body and a pintle. The pintle comprises a closing member receivable on a seat of the nozzle body; the seat defines a first sealing surface co-operating with a second sealing surface on a periphery of the closing member; and the pintle is slideable so that the closing member can be lifted from the seat in order to open a fuel passage defined between the first sealing surface and the second sealing surface.

[0011] The basic idea of this invention is to increase the diameter of the orifice of the fuel nozzle while using a small cone angle of the seat and the closing member in order to achieve an injection spray with a small cone angle. According to this idea, the fuel passage is designed so that the fuel firstly travels in a passage portion

which permits to achieve a large diameter of the spray. Then the spray is conducted to a portion of the fuel passage which orientates the spray to a smaller angle that will result in the desired injection spray angle.

[0012] It will be noted that in the nozzle according to the invention, it is possible to keep the diameter of the inlet of the fuel passage at the same value as in a conventional pintle with a single cone angle of about 80°.

[0013] Preferably, conical shapes are used for the first and second sealing surfaces. Hence, the fuel passage is formed so that it firstly generates a fuel spray with a relatively large cone angle in order to achieve a large diameter of the spray. Then, the spray is conducted to a portion of the fuel passage which orientates the spray to a small cone angle that corresponds to the desired injection angle.

[0014] Accordingly, the first sealing surface and the second sealing surface each preferably comprise at least two conical portions. The cone angles of these conical portions differ so that it is possible to design a fuel nozzle with an increased orifice while it is not required to significantly elongate the closing member when an injected spray with a small cone angle should be generated. With at least one conical portion, the fuel fluid can be brought towards a wider radius by use of a large cone angle. At least one subsequent conical portion can then be designed to orientate the fuel fluid to an injection spray with a smaller cone angle. In other words, several conical portions with different cone angles according to the invention allow a flexible design of the fuel nozzle and particularly the formation of the spray injected from the fuel nozzle into a combustion chamber.

[0015] As a result, the present fuel injector allows a stable injection of conical sprays, and is thus particularly well suited to be used in DIG systems, wherein it can be assembled to an actuator to form a fuel injector.

[0016] In a preferred embodiment of the invention, the first conical portion is formed in that it increases the diameter of the closing member and of the seat to a predetermined diameter of the closing member and the seat. The predetermined diameter can be chosen to assure a stable injection spray. Further, a second conical portion is located between the first conical portion and the end face of the closing member and has a cone angle which is smaller than about 80°. This preferred design of the fuel nozzle can have merely two conical portions, which leads to a design that can be simply produced.

[0017] In particular, the first conical portion preferably comprises a cone angle which is larger than 80°. This allows a reduction of the length of the first conical portion compared to the usage of a smaller cone angle. In the latter case, the length of the first conical portion is larger in order to achieve the first predetermined diameter.

[0018] More preferably, the cone angle of the first conical portion is between about 120° and about 160°. It turned out that such an angular range is an optimal compromise between the length of the first conical portion,

required to achieve the predetermined diameter, and the robustness of the shape of the closing member of the pintle. Most preferably, the cone angle of the first conical portion is about 140°.

[0019] In order to achieve a design of the fuel nozzle which is flexibly applicable, the cone angle of the second conical portion is about 60°. Thus, the generated spray which is injected in a combustion chamber also has a cone angle of about 60° and a diameter which is large enough to prevent the instability of the injected spray under high temperature and pressure.

[0020] In a first preferred design of the fuel nozzle, the length of the first conical portion is essentially equal to the length of the second conical portion. The overall length of the closing member according to this design is longer than the length of known closing members but much shorter than the length of a closing member with only one conical portion with a cone angle of about 60° and with the same passage outlet diameter.

[0021] According to a second preferred design of the fuel nozzle, the length of the first conical portion is greater than the length of the second conical portion. This has the advantage of a short overall length of the closing member compared to the overall length of the first preferred design. However, the shape of the closing member might not be robust enough under certain operating conditions.

[0022] The cone angle of the first conical portion of the first sealing surface preferably differs from the cone angle of the first conical portion of the second sealing surface in about 1°. Thus, a circular closure line (the intersection between the seat and the closure member) is located in the first conical portion adjacent to the inlet of the fuel passage. Therefore, minimal pressures are exerted on the pintle due to the pressurized fuel.

[0023] Furthermore, it is preferred that the ratio between the outlet fuel passage area and the inlet fuel passage at the level of the closure line be as small as possible, and in particular in the range of 1 to 3.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG.1: is a section view of a first embodiment of the present invention;

FIG.2: is a section view of a second embodiment of the present invention;

FIG.3: is a sketch showing several sprays with different cone angles and diameters in order to demonstrate the background of the invention;

FIG.4: is a section view of a fuel nozzle known from prior art, wherein the cone angle of the seat and the

closing member of the fuel nozzle is reduced in order to achieve a spray with a small cone angle;

FIG.5: is a section view of the fuel nozzle of Fig. 4 with a cone angle of about 80° as known from prior art; and

FIG.6: is a section view of a fuel nozzle with an elongated fuel passage and cone angle of 60° in order to achieve a small cone angle of the injected spray.

[0025] It will be noted that, for simplicity and symmetry reasons, only half of the nozzle (with regard to the pintle axis) is shown in Figs. 1, 2, 4 and 6.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0026] Preferred embodiments of an outward opening fuel nozzle in accordance with the invention will now be described. In the present embodiments, the fuel nozzle is designed to be used in a direct injection gasoline system.

[0027] In the following description the same and/or equal and/or similar elements can be denoted with the same reference numerals.

[0028] Fig. 1 shows a fuel nozzle of the outward opening type. The nozzle comprises a nozzle body 10 and a pintle 12 which is slideable in a bore of the nozzle body 10. The nozzle body 10 comprises a seat 18 which defines a first sealing surface 22. The first sealing surface 22 co-operates with a second sealing surface 26 on a periphery of a closing member 14 of the pintle 12. During operation of the nozzle, actuation of the pintle 12 permits lifting the closing member 14 from the seat 18 in order to open a fuel passage 30 which is defined between the first sealing surface 22 and the second sealing surface 26.

[0029] As can be seen, the first and the second sealing surfaces 22, 26 each comprise two conical portions 42, 44 and 34, 36, respectively. In detail, the periphery of the closing member 14 as well as the periphery of the seat 18 are formed to comprise two conical portions. A first conical portion 34 of the closing member 14 begins at the inlet of the fuel passage 30. A second conical portion 36 follows the first conical portion 34 and ends with the end face 35 of the closing member 14. Both conical portions 34 and 36 have different cone angles α_1 and α_2 , respectively. The cone angle α_1 is about 140° and the cone angle α_2 about 60° . The length L_1 of fuel passage 30 defined by the first conical portion 34 is larger than the length L_2 of fuel passage 30 defined by the second conical portion 36. The seat 18 is formed similarly to the closing member 14 with a cone angle of its first conical portion 42 differing in about 1° from the cone angle α_1 so as to form a circular closure line when the closing member 14 rests on the seat 18. The circular closure line is located near the inlet of the fuel passage

30 in order to reduce the forces on the closing member 14 caused by pressurized fuel between the pintle 12 and the nozzle body 10 when the closing member 14 is on its seat 18.

[0030] Now, some dimensions shown in Fig. 1 are explained in more detail. D_i is the diameter of the inlet of the fuel passage 30; D_o is the diameter of the outlet of the fuel passage 30 and of the fuel spray when leaving the fuel passage. D_m is a predetermined diameter of the area between the first and second conical portion 34, 36. In order to avoid a fuel spray which has a small cone angle but becomes unstable under certain conditions such as high temperature and pressure, the circular cross-section of the fuel passage 30 is increased from the diameter D_i at the inlet to the diameter D_m . Then, the diameter of the circular cross section of the fuel passage 30 further increases to the diameter D_o of the outlet, the diameter D_o being determined to be large enough to ensure a stable fuel spray under the above mentioned operating conditions. Since the cone angle α_2 of the second conical portions 36 and 44 is about 60° the generated spray has essentially the same cone angle α_2 . Thus, a stable spray with a small cone angle is achieved which does not separate into fingers but is more likely to create an homogenous liquid sheet. It will be noted that when a swirl motion is given to the fuel spray, the spray angle is typically somewhat larger than the cone angle α_2 .

[0031] Due to the two conical portions 34, 42 and 36, 44 with different cone angles, it is possible to reduce the overall length L_1+L_2 of the fuel passage 30 while achieving a stable spray with a small cone angle. For example, the overall length is reduced from 2.2 mm to 1.5 mm (i.e. by about 32%), wherein 2.2 mm is the length of the fuel passage of a fuel nozzle with a cone angle of 60° and a single cone angle as described in connection with Fig. 6. Preferably, the length L_2 is equal to the overall length of the fuel passage of a nozzle with a single cone angle of about 80° . It should also be mentioned that the difference of the cone angles of the second conical portions 36 and 44 can be neglected so that the periphery of the seat 18 and the periphery of the closing member 14 in this area are parallel areas. This results in an increased spray stability.

[0032] In the following a short comparison of a conventional fuel nozzle and of a fuel nozzle according to the invention based on exemplary numerical values is given. The conventional fuel nozzle generates a 80° stable spray. The overall length L of the fuel passage is 0.5 mm. The diameter D_o of the outlet is 2.0 mm. The ratio between the outlet fuel passage area A_o and the inlet fuel passage area A_i at the level of the closure line is 1.7. Compared to these numerical values, the inventive nozzle generates a spray with a cone angle of 60° which remains stable in a range of pressure of about 1-12 bars in the combustion chamber. The overall length L of the fuel passage is 1.5 mm. This is larger than in the conventional design but much smaller than in a design with-

out a stepped fuel passage according to the invention. The length L1 of the first conical portion is 1.0 mm, the length L2 of the second conical portion 0.5 mm. The diameter Do of the outlet passage is 3.6 mm and, therefore, larger than in the conventional design in order to achieve a stable spray. The ratio A_o/A_i is 2.1.

[0033] Fig. 2 shows a fuel nozzle similar to that of Fig. 1. Therefore, in the following only the differences are described. The shown fuel nozzle differs from the fuel nozzle of Fig. 1 in that its seat 28 and its closing member 16 has a different design. Particularly, the closing member 16 and the seat 20, more detailed its sealing surfaces 24 and 28, respectively, comprises a first and a second conical portion 38, 46 and 40, 48, respectively, which have equal lengths L1' and L2'. The cone angles α_3 and α_4 of the first conical portions 38, 46 and the second conical portions 40, 48, respectively, are 140° and 60°, respectively. In contrast to the nozzle of Fig. 1, the overall length L1' + L2' of the closing member 16 of this nozzle is longer than the overall length of the closing member 14, but the pintle valve group is more square. This leads to an increased robustness of the closing member 16 and the pintle 12. Due to the equal lengths L1' and L2' the predetermined diameter Dm' is smaller than the predetermined diameter Dm of the closing member 14 of Fig. 1.

[0034] Fig. 3 shows typical sprays generated by an outward opening fuel nozzle 60. Fig. 3 serves to demonstrate the background of the invention, particularly the connections between the exit (outlet) diameter 62 and the cone angle of the cone-like spray. In order to achieve a stable spray at high temperatures and pressures, a minimum spray width 70 is required. This spray width 70 can be achieved by a spray with a cone angle of 60° or 80°. However, as can be seen from Fig. 3, a spray 64 with a cone angle of 60° requires a larger exit diameter 62 than a spray 66 with a cone angle of 80° in order to achieve the minimum spray width 70. When the spray with cone angle of 60° has the same exit diameter 62 as the spray 66, see the spray 68 in Fig. 3, it does not reach the minimum spray width and, therefore, becomes unstable at high temperatures and pressures.

[0035] It should be noted that the above mentioned numerical values, especially the angle values are only for exemplary purposes and do not restrict the scope of the invention as defined by the attached claims.

List of Reference signs

[0036]

10	Nozzle body
12	Pintle
14, 16	Closing member
18, 20	Seat of the nozzle body
22, 24	First sealing surface
26, 28	Second sealing surface
30, 32	Fuel passage

34, 38	First conical portion of the closing member
35	End face of the closing member
36, 40	Second conical portion of the closing member
5 42, 46	First conical portion of the seat
44, 48	Second conical portion of the seat
α_1, α_3	Cone angle of the first conical portion
α_2, α_4	Cone angle of the second conical portion
L1, L1'	Length of the first conical portion
10 L2, L2'	Length of the second conical portion
Di	Diameter of the inlet of the fuel passage
Dm, Dm'	Predetermined diameter of the closing member
Do	Diameter of the opening of the fuel passage
15 50	Nozzle body
52	Pintle
54, 54'	Closing member
56, 56'	Seat
58, 58'	Fuel passage
20 60	Fuel nozzle
62	Exit diameter
64	Spray with a cone angle of 60°
66	Spray with a cone angle of 80°
68	Spray with a cone angle of 80°
25 70	Minimum spray width
L, L'	Length of the conical portion of the closing member/fuel passage
α, α'	Cone angle of the injected spray
Ai	Area of the inlet of the fuel passage
30 Ao	Area of the outlet of the fuel passage

Claims

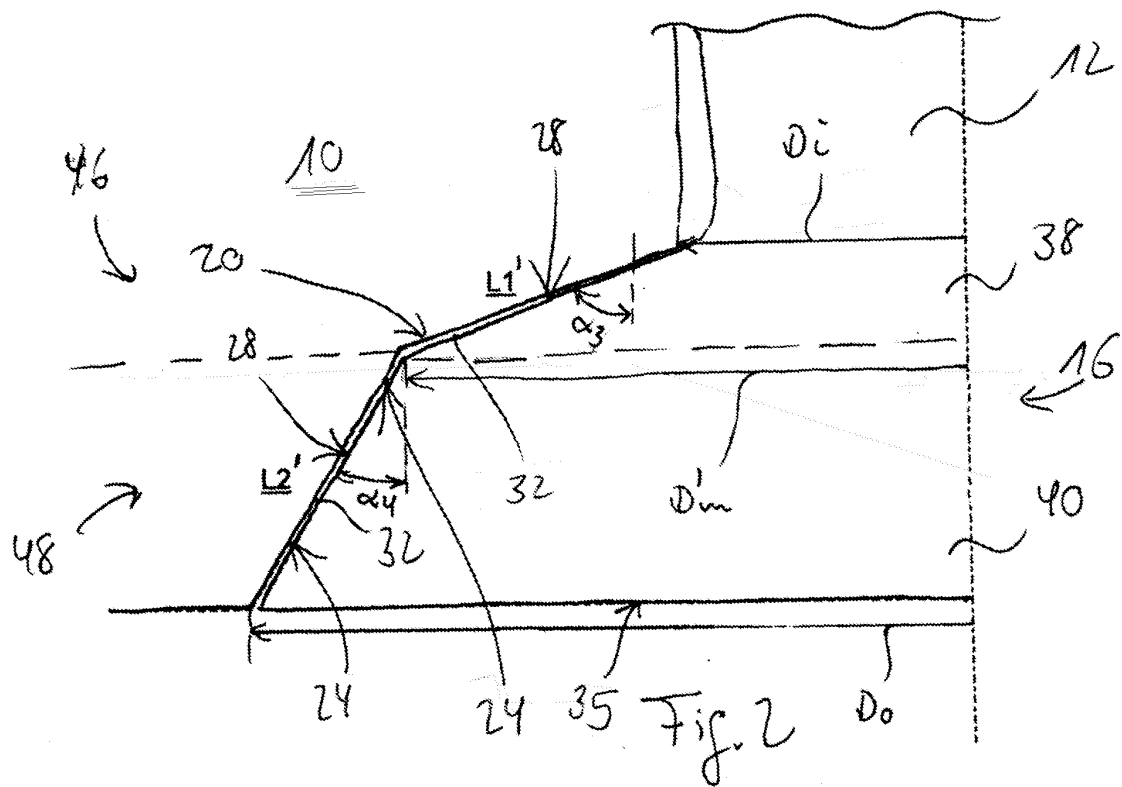
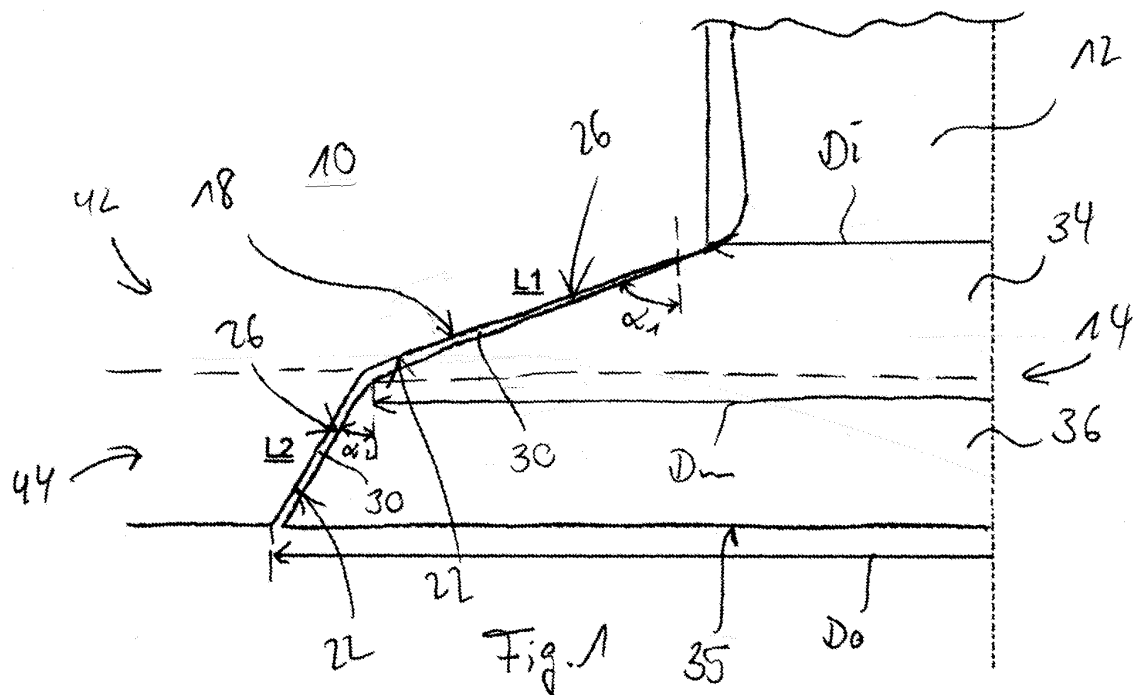
1. An outward opening fuel nozzle comprising a nozzle body (10) and a pintle (12), wherein the pintle (12) comprises a closing member (14; 16) receivable on a seat (18; 20) of the nozzle body (10), the seat (18; 20) defines a first sealing surface (22; 24) co-operating with a second sealing surface (26; 28) on a periphery of the closing member (14; 16), and the pintle (12) is slideable so that the closing member (14; 16) can be lifted from the seat (18; 20) in order to open a fuel passage (30; 32) defined between the first sealing surface (22; 24) and the second sealing surface (26; 28),
characterized in that
the first sealing surface (22; 24) and the second sealing surface (26; 28) are designed in such a way as to define a fuel passage comprising at least two passage portions, wherein said at least two passage portions define different fuel flow directions.
2. The fuel nozzle according to claim 1, **characterized in that** the first sealing surface (22; 24) and the second sealing surface (26; 28) each comprise at least two conical portions (34, 36, 42, 44; 38, 40, 46, 48) wherein the cone angles ($\alpha_1, \alpha_2; \alpha_3, \alpha_4$) of the con-

ical portions differ.

3. The fuel nozzle according to claim 2, **characterized in that** a first conical portion (L1) increases the diameter of the closing member (14; 16), respectively of the seat (18; 20), to a predetermined diameter; and **in that** the fuel passage (30) ends by a conical portion (L2) having a reduced cone angle (α_2 ; α_4) corresponding to the to the desired spray cone angle. 5 10
4. The fuel nozzle according to claim 2 or 3, **characterized in that** the first conical portion (L1) is formed **in that** it increases the diameter of the closing member (14; 16) and of the seat (18; 20) to a predetermined diameter (Dm; Dm') of the closing member (14; 16) and the seat (18; 20), and a second conical portion (L2) is located between the first conical portion (L1) and the end face (34) of the closing member (14; 16) and has a cone angle (α_2 ; α_4) which is smaller than about 80°. 15 20
5. The fuel nozzle according to claim 4, **characterized in that** the first conical portion (34; 38) comprises a cone angle (α_1 ; α_3) which is larger than 80°. 25
6. The fuel nozzle according to claim 5, **characterized in that** the cone angle (α_1 ; α_3) of the first conical portion (34; 38) is between about 120° and about 160°. 30
7. The fuel nozzle according to claim 6, **characterized in that** the cone angle (α_1 ; α_3) of the first conical portion (34; 38) is about 140°. 35
8. The fuel nozzle according to any of claims 4 to 7, **characterized in that** the cone angle (α_2 ; α_4) of the second conical portion (36; 40) is about 60°.
9. The fuel nozzle according to any of the claims 4 to 8, **characterized in that** the length (L1') of the first conical portion (38) is essentially equal to the length (L2') of the second conical portion (40). 40
10. The fuel nozzle according to any of the claims 4 to 8, **characterized in that** the length (L1) of the first conical portion (34) is greater than the length (L2) of the second conical portion (36). 45
11. The fuel nozzle according to any of the claims 4 to 10, **characterized in that** the cone angle of the first conical portion (42; 46) of the first sealing surface (22; 24) differs from the cone angle of the first conical portion (34; 38) of the second sealing surface (26; 28) in about 1°. 50 55
12. The fuel nozzle according to any of the claims 4 to 11, **characterized in that** the cone angle of the first

conical portion (42; 46) of the first sealing surface (22; 24) is essentially equal to the cone angle of the first conical portion (34; 38) of the second sealing surface (26; 28).

13. A fuel injector comprising an outward opening fuel nozzle as claimed in any one of the preceding claims.



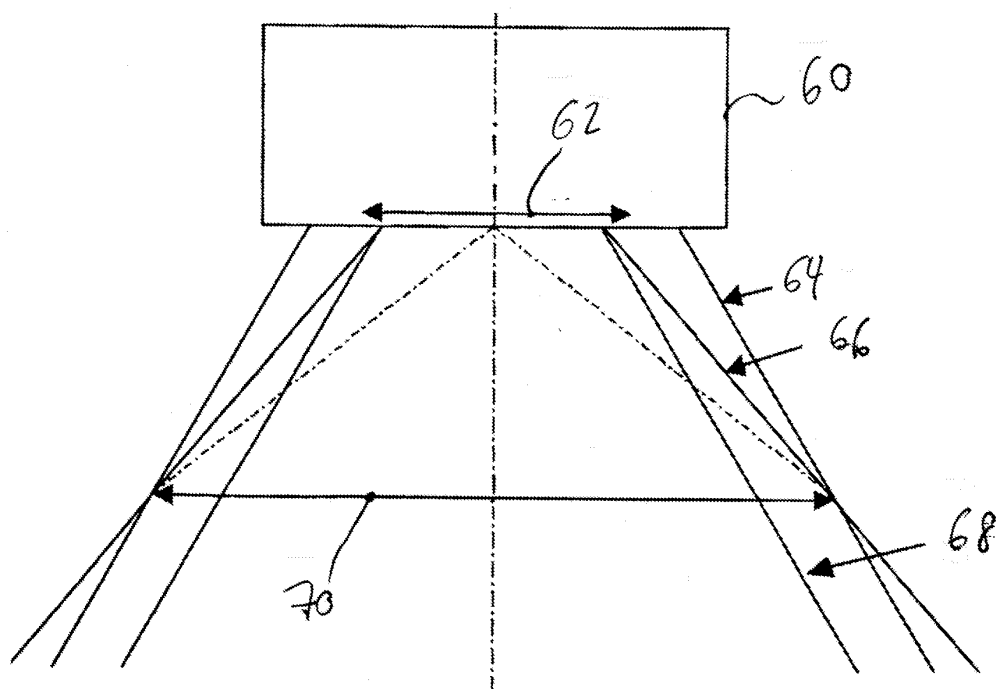


Fig. 3

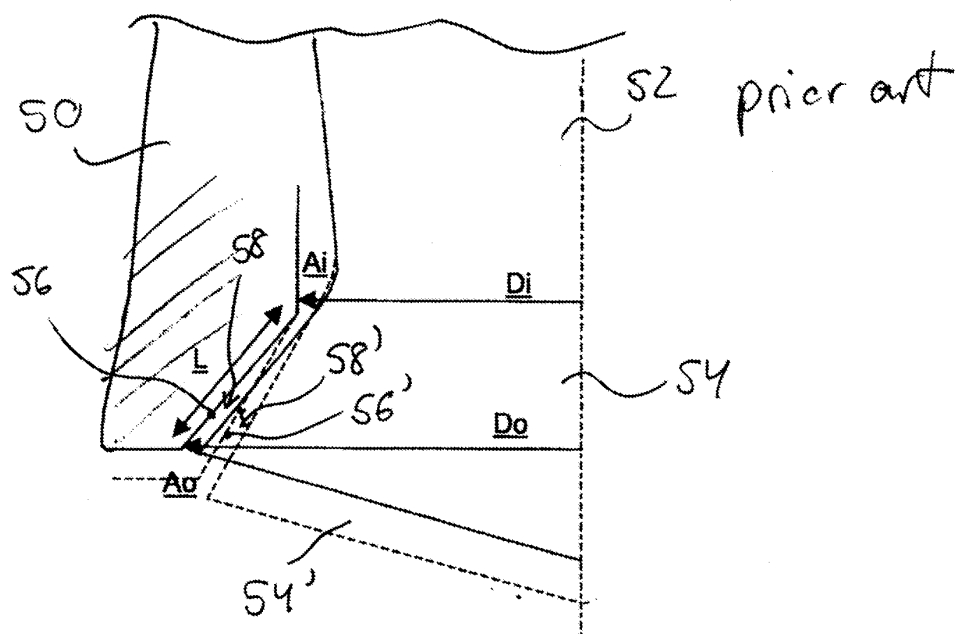
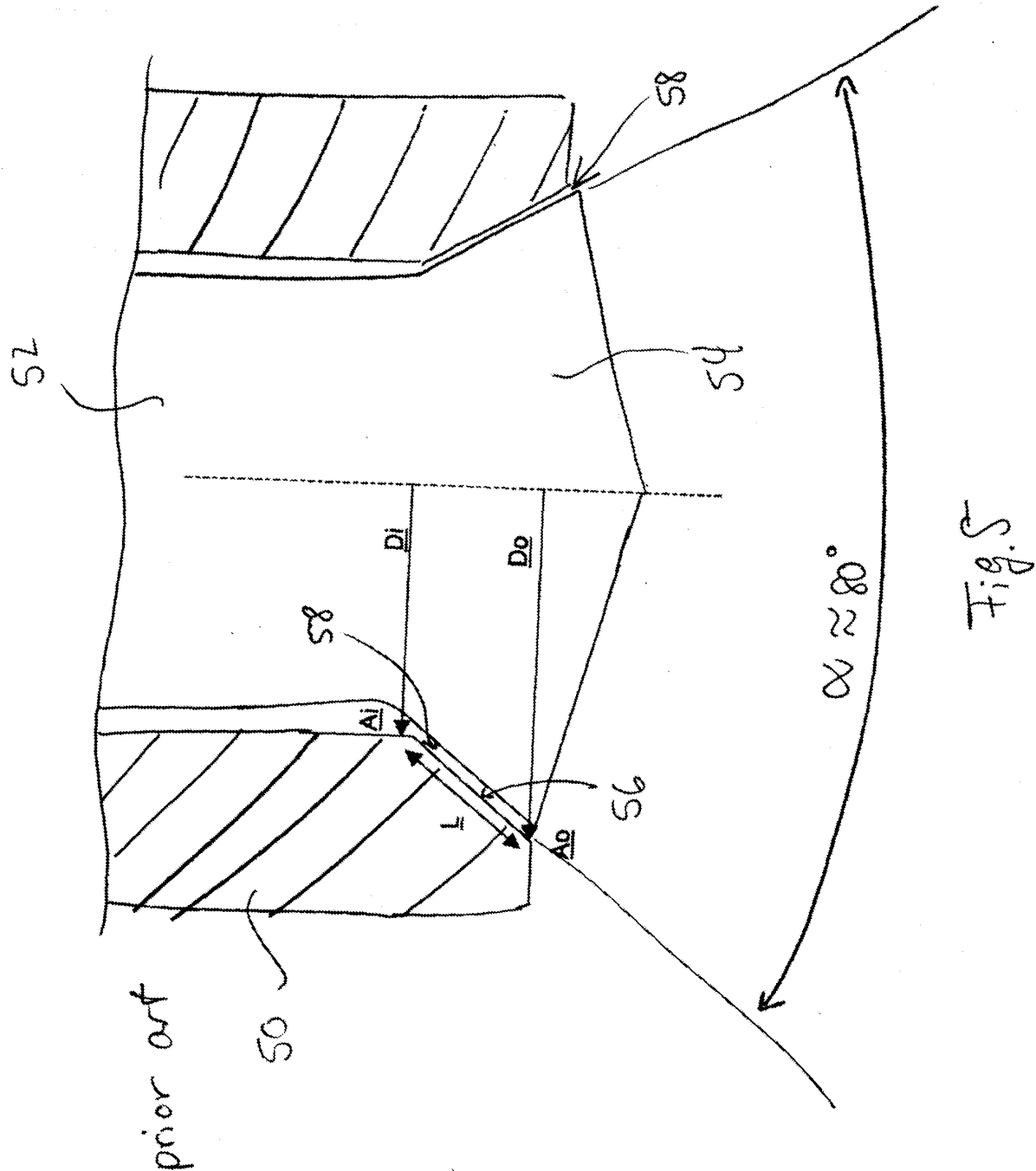
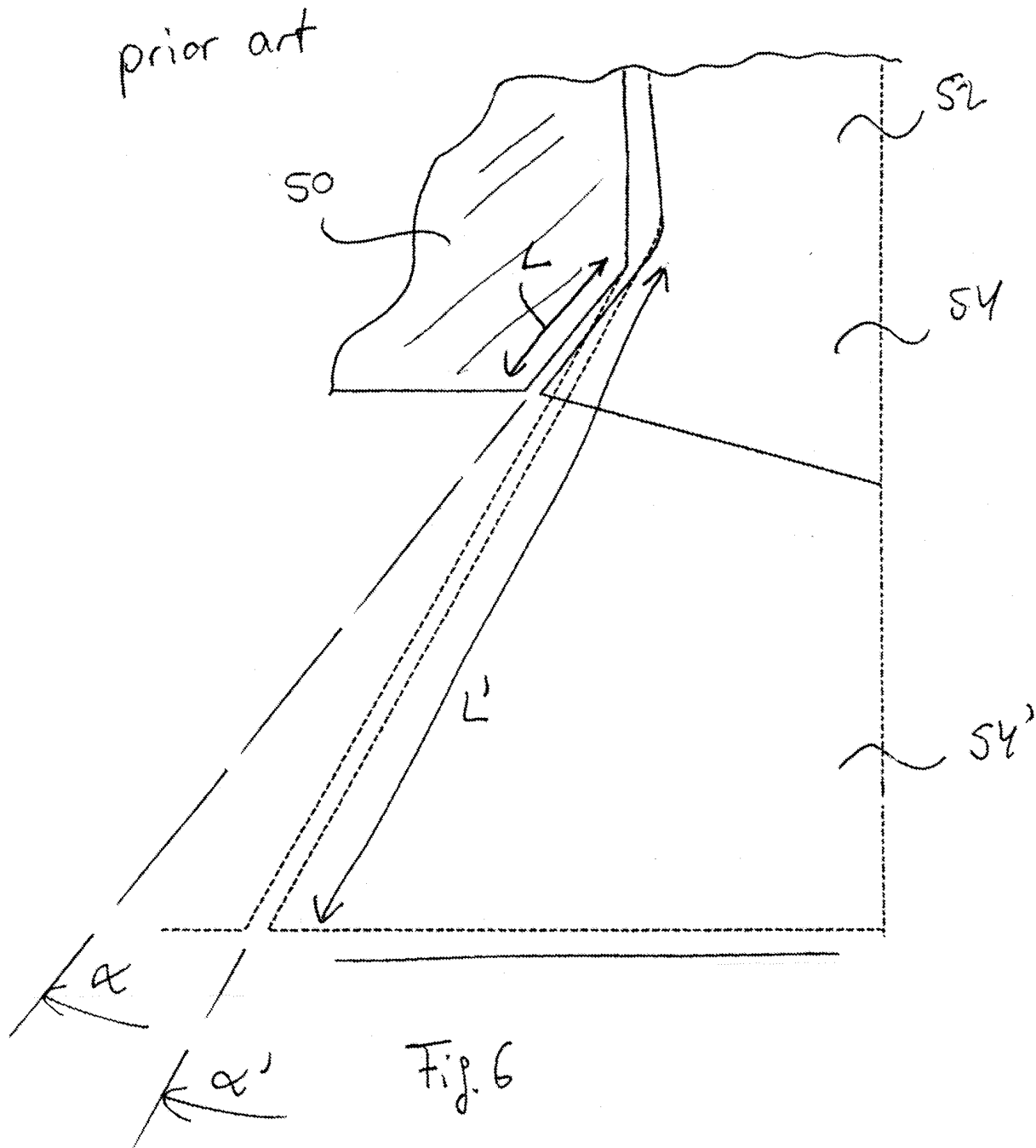


Fig. 4







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Application Number
EP 03 10 2305

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Place of search MUNICH		Date of completion of the search 18 November 2003	Examiner Kolland, U
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EPO FORM 1503 03.82 [P04C01]

**ANNEX TO THE EUROPEAN SEARCH REPORT
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