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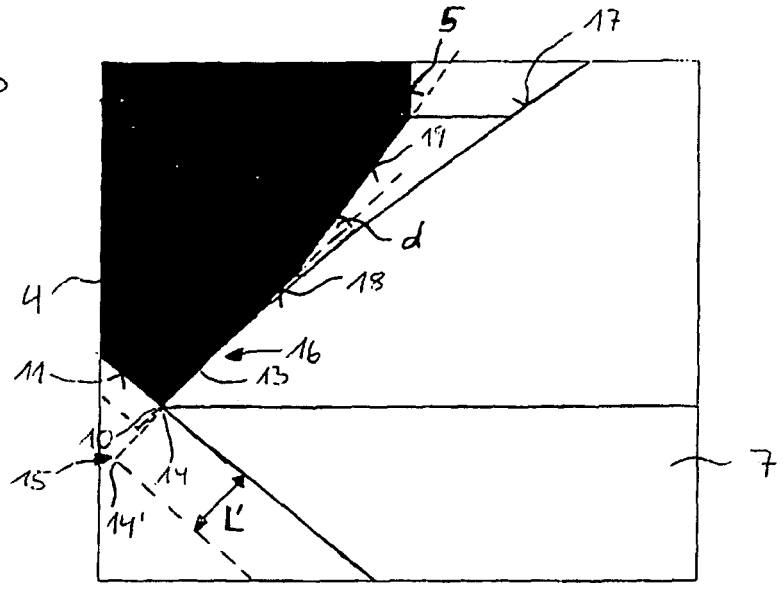
(54) Injector for injecting fluid and method for manufacturing an injector

(57) An injector comprises a valve needle comprising at its downstream end a closing element (7). The closing element (7) extends to an outer edge (14) and has a rounded portion (16) with a contact area (13) upstream of the outer edge (14). The injector further comprises a cartridge (4). The cartridge (4) comprises a seat cone (18) arranged at a seat cone half angle. The seat cone (18) forms a valve seat and extends to a downstream edge (10) at a downstream end of the cartridge (4). The cartridge (4) comprises a recess (5) in which the valve needle is arranged axially moveable and comprises an outer surface (11) directly adjacent to the edge (10) of the cartridge (4). The outer surface (11) is on the same level with the outer edge (14) of the closing element (7) of the valve needle (6) when the closing element (7) is seated with its contact area (13) on the valve seat of the cartridge (4). The cartridge comprises an upstream cone (19) arranged directly upstream of the seat cone (18) and arranged at an upstream cone half angle being smaller than the seat cone half angle and differing less than 15 degrees from the seat cone half angle.

FIG 3



EP 2 246 557 A1

Description

Description

[0001] Injector for injecting fluid and method for manufacturing an injector

[0002] The invention relates to an injector for injecting fluid and to a method for manufacturing an injector and relates particularly to an injector for injecting fuel into an internal combustion engine and a method for manufacturing such injector.

[0003] In a stratified operation mode, spray targeting performance is fundamental for a mixture preparation in a spark plug area. However, cavitation may occur in a nozzle of an injector. This may lead to fluctuations of a spray cone angle and/or a spray front angle. Further, deposits of combustion residues on the injector may distort a spray pattern. Engine misfire and increase of emissions may occur as a consequence.

[0004] The object of the invention is to provide an injector for injecting fluid with a reliable spray pattern. A further object of the invention is to provide a method for manufacturing an injector with a reliable spray pattern.

[0005] These objects are achieved with the features of the independent claims. Preferred embodiments are characterized in the dependent claims.

[0006] According to a first aspect the invention is characterized by an injector for injecting fluid. The injector comprises a valve needle comprising at its downstream end a closing element. The closing element extends to an outer edge and has a rounded portion with respect to a cross-section of the closing element with a contact area upstream of the outer edge.

[0007] The injector further comprises a cartridge comprising a seat cone, a recess, an outer surface and an upstream cone. The seat cone is arranged at a seat cone half angle with respect to a longitudinal axis of the cartridge. The seat cone forms a valve seat and extends to a downstream edge at a downstream end of the cartridge. In the recess the valve needle is arranged axially moveable. The outer surface is arranged directly adjacent to the downstream edge of the cartridge. The outer surface is on the same level with the outer edge of the closing element of the valve needle when the closing element is seated with its contact area on the valve seat of the cartridge. The upstream cone is arranged directly upstream of the seat cone and is arranged at an upstream cone half angle with respect to the longitudinal axis of the cartridge being smaller than the seat cone half angle of the seat cone and differing less than 15 degrees from the seat cone half angle.

[0008] The invention is based on the finding that a smooth acceleration of the fluid while streaming through the nozzle of the injector, which comprises a downstream portion of the cartridge with the seat cone and the upstream cone and the closing element of the valve needle, may reduce a risk of cavitation and by this of an undesirable variation of a spray cone angle and/or a spray front angle of a spray pattern of the injector. The invention is further based on the finding that by shortening a divergent length of the nozzle downstream the contact area of the closing element and the corresponding valve seat of the cartridge the risk of cavitation may be even further reduced. As a consequence, the spray pattern may be stabilized and may show an increased shot to shot repeatability. Further, an axial symmetry of the spray pattern may be improved, particularly in case of very small amounts of fluid injected with each injection. The invention is further based on the finding that with the outer surface of the cartridge at its downstream end being on the same level with the outer edge of the closing element of the valve needle a risk of a build-up of deposits of combustion residues in a fluid path at a fluid outlet of the nozzle may be reduced and by that the spray pattern of the injector may also be stabilized. This particularly allows for a good long term stability of the spray pattern.

[0009] According to a preferred embodiment, a gap between the outer edge of the closing element and the edge of the cartridge has a gap size of less than 2 micrometers when the closing element is seated with its contact area on the valve seat of the cartridge. The advantage is that by this a volume between the closing element and the cartridge at the fluid outlet of the nozzle may be very small and that as a consequence the build-up of deposits of combustion residues may be inhibited or at least reduced such that the spray pattern of the injector essentially is unaffected by deposits of combustion residues. This allows for a particularly good long term stability of the spray pattern.

[0010] According to a further preferred embodiment, the closing element has a cone portion directly upstream the rounded portion arranged at a cone half angle with respect to the longitudinal axis of 50 to 60 degrees. The advantage is that a clear cross-section for the fluid flow may be particularly large and the fluid entering the nozzle from upstream the closing element may thus be even more smoothly accelerated while streaming through the nozzle. This further reduces the risk of cavitation and may thus improve the stability and repeatability of the spray pattern of the injector. Preferably, this cone half angle amounts to 58 degrees.

[0011] According to a further preferred embodiment, the seat cone half angle amounts to 40 to 50 degrees. This allows for a stable spray pattern. Preferably, this seat cone half angle amounts to 47.6 degrees.

[0012] According to a further preferred embodiment, the upstream cone half angle amounts to 28 to 38 degrees. This allows for a low risk of cavitation and by this allows for a stable spray pattern. Preferably, this upstream cone half angle amounts to 35 degrees.

[0013] According to a further preferred embodiment, the recess forms a cylindrical guiding surface for the valve needle. The cylindrical guiding surface is arranged directly upstream the upstream cone. The advantage is that the cartridge and, as a consequence, also the injector may be manufactured with few manufacturing steps and

thus cost effective.

[0014] According to a second aspect the invention is characterized by a method for manufacturing an injector. The method comprises providing a valve needle comprising at its downstream end a closing element. The closing element extends to an outer edge and has a first cone portion directly upstream of the outer edge and has a rounded portion with a contact area directly upstream of the first cone portion. The method further comprises providing a cartridge comprising a valve seat and a recess for arranging the valve needle axially moveable in the recess. The method further comprises determining a first length of the first cone portion between the outer edge and the rounded portion. The method further comprises arranging the valve needle in the recess of the cartridge such that the closing element sits with its contact area on the valve seat of the cartridge. The method further comprises grinding an outer surface of the cartridge and the closing element from its outer edge for a second length in upstream direction to the same level dependent on the first length.

[0015] The invention is based on the finding that by shortening a divergent length of the nozzle downstream the contact area of the closing element and the corresponding valve seat of the cartridge a risk of cavitation may be reduced and by this an undesirable variation of a spray cone angle and/or a spray front angle of a spray pattern of the injector may be reduced. As a consequence, the spray pattern may be stabilized and may show an increased shot to shot repeatability. Further, an axial symmetry of the spray pattern may be improved, particularly in case of very small amounts of fluid injected with each injection. The invention is further based on the finding that with the outer surface of the cartridge at its downstream end being on the same level with the outer edge of the closing element of the valve needle after the grinding a risk of a build-up of deposits of combustion residues in a fluid path at a fluid outlet of the nozzle may be reduced and by that the spray pattern of the injector may also be stabilized. This particularly allows for a good long term stability of the spray pattern.

[0016] According to a preferred embodiment of the second aspect, the second length is equal to the first length. By this, the first cone portion of the closing element may essentially be completely removed and a gap between the outer edge of the closing element and the edge of the cartridge may have a particularly small gap size of preferably less than 2 micrometers when the closing element is seated with its contact area on the valve seat of the cartridge. The advantage is that by this a volume between the closing element and the cartridge at the fluid outlet of the nozzle may be very small and that as a consequence the build-up of deposits of combustion residues may be inhibited or at least reduced such that the spray pattern of the injector essentially is unaffected by deposits of combustion residues. This allows for a particularly good long term stability of the spray pattern.

[0017] According to a further preferred embodiment of the second aspect, the cartridge prior to arranging the valve needle in the recess is manufactured comprises grinding the recess. The method further comprises grinding a seat cone such that the seat cone dilates in downstream direction up to a downstream end of the cartridge and that the seat cone forms the valve seat. The method further comprises grinding an upstream cone directly upstream the seat cone with an upstream cone half angle being smaller with respect to a longitudinal axis of the cartridge than a seat cone half angle of the seat cone. The grinding of the recess, the grinding of the seat cone and the grinding of the upstream cone is performed within the same grinding operation. The advantage is that by this the manufacturing of the cartridge and, as a consequence, the injector is simple, that is, can be performed with few manufacturing steps, and is cost effective.

[0018] In this respect it is advantageous, if the seat cone half angle and the upstream cone half angle differ by a cone half angle difference of less than 15 degrees. This is based on the finding that a smooth acceleration of the fluid while streaming through the nozzle of the injector may reduce a risk of separation and then cavitation and by this of an undesirable variation of a spray cone angle and/or a spray front angle of a spray pattern of the injector. The advantage is that by this the injector may have a particularly stable and repeatable spray pattern.

[0019] According to a further preferred embodiment of the second aspect, the recess is ground to form a cylindrical guiding surface for the valve needle. The cylindrical guiding surface is arranged directly upstream the upstream cone. The advantage is that the cartridge and, as a consequence, also the injector may be manufactured cost effective and with few manufacturing steps.

[0020] In the following, embodiments of the invention are illustrated with reference to the schematic drawings.

[0021] The figures are illustrating:

FIG. 1, an injector,

FIG. 2, a closing element of a valve needle,

FIG. 3, a first view of a downstream portion of a cartridge and the closing element,

FIG. 4, a second view of the downstream portion,

FIG. 5, a flow chart.

[0022] Elements of same construction or function are provided with the same reference signs throughout all figures. Primed reference signs 10', 11' and 14' correspond to features prior to a grinding operation explained below for step S4 in Figure 5 and corresponding reference signs 10, 11 and 14 correspond to features resulting from this grinding operation.

[0023] Figure 1 shows an injector for injecting a fluid. Particularly, the injector is designed for injecting fuel into a cylinder of an internal combustion engine of, for exam-

ple, a vehicle and particularly an automobile. The injector comprises an external tube 1, an internal tube 2 and a valve cap 3. The fluid passes through an annular cavity between the external tube 1 and the internal tube 2 and through the valve cap 3. The injector further comprises a cartridge 4 with a recess 5 in which a valve needle 6 is arranged axially movable. The valve needle 6 comprises a closing element 7 at its downstream end arranged for closing the injector in its closed position inhibiting a fluid flow and for allowing the fluid flow otherwise. The injector further comprises a lifting device with an actuator 8 for moving the valve needle 6 in axial direction for opening and closing the injector. The actuator 8 preferably is a piezo actuator. However, the actuator 8 may alternatively be, for example, a solenoid actuator. In case of the actuator 8 being the piezo actuator, a lift generated by the lifting device depends on an axial elongation of the actuator 8 which is dependent on an electric control signal. The lifting device is mechanically coupled with the valve needle 6 and cooperates with the valve needle 6 such that at least part of the lift generated by the lifting device is transferred to the valve needle 6 moving the closing element 7 in its closed position or in an open position. Further, a closing force is provided to the valve needle 6 by a valve spring 9 which is preloaded during assembly of the injector. However, the injector may be designed differently.

[0024] Figure 2 shows the closing element 7 at the downstream end of the valve needle 6 and Figures 3 and 4 show a first and second view of a downstream portion of the cartridge 4 and the closing element 7, respectively. Figure 3 essentially shows part of a nozzle of the injector comprising the downstream portion of the cartridge 4 and the closing element 7.

[0025] The recess 5 of the cartridge 4 widens conically in the downstream portion of the cartridge 4 up to an edge 10, 10' of the cartridge 4 which represents a downstream end of the cartridge 4. A conical inner surface directly upstream the edge 10, 10' of the cartridge 4 forms a seat cone 18 of the cartridge 4 comprising a valve seat. The closing element 7 comprises a contact area 13 at a rounded portion 16 of the closing element 7. In the closed position of the closing element 7 the contact area 13 is sealingly seated on the valve seat inhibiting the fluid flow. The contact area 13 at the rounded portion 16 allows for a ring-shaped contact line on the valve seat in the closed position of the closing element 7.

[0026] The closing element 7 widens downstream the contact area 13 up to an outer edge 14, 14' of the closing element 7. Prior to a grinding step for bringing an outer surface 11, 11' of the cartridge 4 and the outer edge 14, 14' of the closing element 7 to the same level, which is explained below, the closing element 7 comprises a first cone portion 15 directly upstream the outer edge 14, 14' and directly downstream the rounded portion 16 of the closing element 7. A seat cone half angle b1 of the seat cone 18 of the cartridge 4 with respect to a longitudinal axis A of the cartridge 4, see step S1 in Figure 5, preferably is slightly larger than a first cone half angle a1 of the first cone portion 15 of the closing element 7. By this, the seat cone 18 of the cartridge 4 and the first cone portion 15 of the closing element 7 diverge from the valve seat and contact area 13 in a direction of the fluid flow, that is, in downstream direction. Preferably, the angles differ by less than ten degrees and differ even more preferably by less than five degrees. The first cone half angle a1 of the first cone portion 15 of the closing element 7 preferably amounts to about 46 degrees.

[0027] The closing element 7 preferably further comprises a second cone portion 17 directly upstream the rounded portion 16 with a second cone half angle a2 with respect to the longitudinal axis A of the cartridge 4. The second cone half angle a2 preferably is greater than the first cone half angle a1 and preferably amounts to 58 degrees. Due to this large second cone half angle a2 the second cone portion 17 can be large and a clear cross-section for the fluid flow at an entrance of the nozzle can be large. By this, a risk of cavitation can be particularly low.

[0028] The cartridge 4 comprises directly upstream of the seat cone 18 an upstream cone 19 with an upstream cone half angle b2 with respect to the longitudinal axis A of the cartridge 4, see step S1 in Figure 5. The upstream cone half angle b2 is smaller than the seat cone half angle b1. The upstream cone half angle b2 and the seat cone half angle b1 preferably differ by a cone half angle difference d of less than fifteen degrees. By this, a smooth transition is formed between the upstream cone 19 and the seat cone 18 allowing for a smooth change of the clear cross-section and thus for a smooth acceleration of the fluid while streaming through the nozzle. By this, the risk of cavitation can be particularly low.

[0029] Depending on a requested spray cone angle, the seat cone half angle b1 may preferably range from 40 to 50 degrees. In this case, a nominal value of the first cone half angle a1 is preferably about 1.5 degrees smaller than the seat cone half angle b1. The upstream cone half angle b2 preferably is 12.6 degrees smaller than the seat cone half angle b1 and the second cone half angle a2 preferably is 10.4 degrees greater than the seat cone half angle b1. The seat cone half angle b1 preferably amounts to 47.6 degrees and the upstream cone half angle b2 preferably amounts to 35 degrees. These mentioned angle differences preferably are kept constant over the mentioned range of the seat cone half angle b1 of 40 to 50 degrees. The first cone half angle a1, the second cone half angle a2 and the upstream cone half angle b2 thus preferably are determined dependent on the choice of the seat cone half angle b1 and the mentioned angle differences.

[0030] The recess 5 preferably forms a cylindrical guiding surface for the valve needle 6 and preferably is arranged directly upstream of the upstream cone 19. The recess 5, particularly at its downstream end, therefore preferably does not represent a wall of a fluid chamber with a diameter different from that of a guiding surface

that may be arranged upstream of the fluid chamber. This has the advantage that the cylindrical guiding surface, the seat cone 18 and the upstream cone 19 can be manufactured in the same process step. By this, these can be manufactured very precise and a further step for manufacturing the fluid chamber is not necessary. The manufacturing can thus be efficient and cost effective.

[0031] Figure 5 shows a flow chart showing part of the manufacturing of the injector. The step S1 comprises providing the cartridge 4. The manufacturing of the cartridge 4 comprises grinding the recess 5, grinding the seat cone 18 with the seat cone half angle b1 such that the seat cone 18 dilates in downstream direction up to the downstream end of the cartridge 4 and grinding the upstream cone 19 directly upstream the seat cone 18 with the upstream cone half angle b2 being smaller with respect to the longitudinal axis A of the cartridge 4 than the seat cone half angle b1 of the seat cone 18. The grinding of the recess 5, the seat cone 18 and the upstream cone 19 is preferably performed within the same grinding operation. The seat cone half angle b1 and the upstream cone half angle b2 differ by the cone half angle difference d of preferably less than 15 degrees. The recess 5 preferably is ground to form the cylindrical guiding surface for the valve needle 6 such that the cylindrical guiding surface begins directly upstream the upstream cone 19 and extends in upstream direction far enough to allow for a precise and reliable guiding of the valve needle 6.

[0032] A step S2 comprises providing the valve needle 6 with the closing element 7. The closing element 7 comprises the first cone portion 15, the rounded portion 16 with the contact area 13 and preferably comprises also the second cone portion 17, the first cone portion 15 being arranged at the first cone half angle a1 and the second cone portion 17 being arranged at the second cone half angle a2, see also Figure 2 for details. Step S2 further comprises determining a first length L of the first cone portion 15 between the outer edge 14' and the rounded portion 16.

[0033] A step S3 comprises arranging the valve needle 6 in the recess 5 of the cartridge 4 such that the closing element 7 sits with its contact area 13 on the valve seat of the cartridge 4. Generally, the outer surface 11' of the cartridge 4 directly adjacent to the edge 10' of the cartridge 4 at the downstream end of the cartridge 4 and the outer edge 14' of the closing element 7 are not yet on the same level in this step. A step S4 therefore comprises grinding the outer surface 11' of the cartridge 4 and the closing element 7 from its outer edge 14' for a second length L' in upstream direction to the same level dependent on the first length L. Preferably, the second length L' equals the first length L. As a consequence, the first cone portion 15 essentially is completely ground away and the rounded portion 16 is arranged directly upstream the resulting outer edge 14 of the closing element 7. After grinding, the resulting outer edge 14 of the closing element 7 and the resulting outer surface 11 of the cartridge 4 preferably are on the same level. The result is shown in a step S5 and, in more detail, in Figures 3 and 4. The second length L' may alternatively be different from the first length L. However, limiting the grinding to the second length L' being smaller than or equal to the first length L has the advantage that the sealing between the valve seat of the cartridge 4 and the contact area 13 of the closing element 7 in its closed position is not affected by the grinding. With the second length L' being greater than the first length L there is a risk of destroying this sealing. However, dependent on the dimensions of the rounded portion 16 and the location of the contact area 13 the second length L' may also be selected to be greater than the first length L without the risk of destroying the sealing.

[0034] Due to the grinding in step S4 a volume of a gap between the seat cone 18 of the cartridge 4 and the rounded portion 16 downstream the contact area 13 and the corresponding valve seat can be very low, when the closing element 7 is seated with its contact area 13 on the valve seat of the cartridge 4. Preferably, a gap size G of the gap between the outer edge 14 of the closing element 7 and the edge 10 of the cartridge 4 amounts to about or preferably less than two micrometers.

Claims

1. Injector for injecting fluid, comprising

- a valve needle (6) comprising at its downstream end a closing element (7), the closing element (7) extending to an outer edge (14) and having a rounded portion (16) with respect to a cross-section of the closing element (7) with a contact area (13) upstream of the outer edge (14),
- a cartridge (4) comprising

-- a seat cone (18) arranged at a seat cone half angle (b1) with respect to a longitudinal axis (A) of the cartridge (4), the seat cone (18) forming a valve seat and extending to a downstream edge (10) at a downstream end of the cartridge (4),
-- a recess (5) in which the valve needle (6) is arranged axially moveable,
-- an outer surface (11) directly adjacent to the edge (10) of the cartridge (4), the outer surface (11) being on the same level with the outer edge (14) of the closing element (7) of the valve needle (6) when the closing element (7) is seated with its contact area (13) on the valve seat of the cartridge (4) and
-- an upstream cone (19) arranged directly upstream of the seat cone (18) and arranged at an upstream cone half angle (b2) with respect to the longitudinal axis (A) of the cartridge (4) being smaller than the seat cone half angle (b1) of the seat cone (18)

and differing less than 15 degrees from the seat cone half angle (b1).

2. Injector according to claim 1, wherein a gap between the outer edge (14) of the closing element (7) and the edge (10) of the cartridge (4) has a gap size (G) of less than 2 micrometers when the closing element (7) is seated with its contact area (13) on the valve seat of the cartridge (4).

3. Injector according to any one of claims 1 or 2, wherein the closing element (7) has a cone portion directly upstream the rounded portion (16) arranged at a cone half angle with respect to the longitudinal axis (A) of 50 to 60 degrees.

4. Injector according to any one of the preceding claims, wherein the seat cone half angle (b1) amounts to 40 to 50 degrees.

5. Injector according to any one of the preceding claims, wherein the upstream cone half angle (b2) amounts to 28 to 38 degrees.

6. Injector according to any one of the preceding claims, wherein the recess (5) forms a cylindrical guiding surface for the valve needle (6), the cylindrical guiding surface being arranged directly upstream the upstream cone (19).

7. Method for manufacturing an injector comprising

- providing a valve needle (6) comprising at its downstream end a closing element (7), the closing element (7) extending to an outer edge (14') and having a first cone portion (15) directly upstream of the outer edge (14') and having a rounded portion (16) with a contact area (13) directly upstream of the first cone portion (15),
- providing a cartridge (4) comprising a valve seat and a recess (5) for arranging the valve needle (6) axially moveable in the recess (5),
- determining a first length (L) of the first cone portion (15) between the outer edge (14') and the rounded portion (16),
- arranging the valve needle (6) in the recess (5) of the cartridge (4) such that the closing element (7) sits with its contact area (13) on the valve seat of the cartridge (4) and
- grinding an outer surface (11) of the cartridge (4) and the closing element (7) from its outer edge (14') for a second length (L') in upstream direction to the same level dependent on the first length (L).

8. Method according to claim 7, wherein the second length (L') is equal to the first length (L).

9. Method according to any one of claims 7 or 8, wherein the cartridge (4) prior to arranging the valve needle (6) in the recess (5) is manufactured comprising

- grinding the recess (5),
- grinding a seat cone (18) such that the seat cone (18) dilates in downstream direction up to a downstream end of the cartridge (4) and that the seat cone (18) forms the valve seat and
- grinding an upstream cone (19) directly upstream the seat cone (18) with an upstream cone half angle (b2) being smaller with respect to a longitudinal axis (A) of the cartridge (4) than a seat cone half angle (b1) of the seat cone (18) and wherein the grinding of the recess (5), the seat cone (18) and the upstream cone (19) is performed within the same grinding operation.

10. Method according to claim 9, wherein the seat cone half angle (b1) and the upstream cone half angle (b2) differ by a cone half angle difference (d) of less than 15 degrees.

11. Method according to any one of claims 9 or 10, wherein the recess (5) is ground to form a cylindrical guiding surface for the valve needle (6), the cylindrical guiding surface being arranged directly upstream the upstream cone (19).

FIG 1.

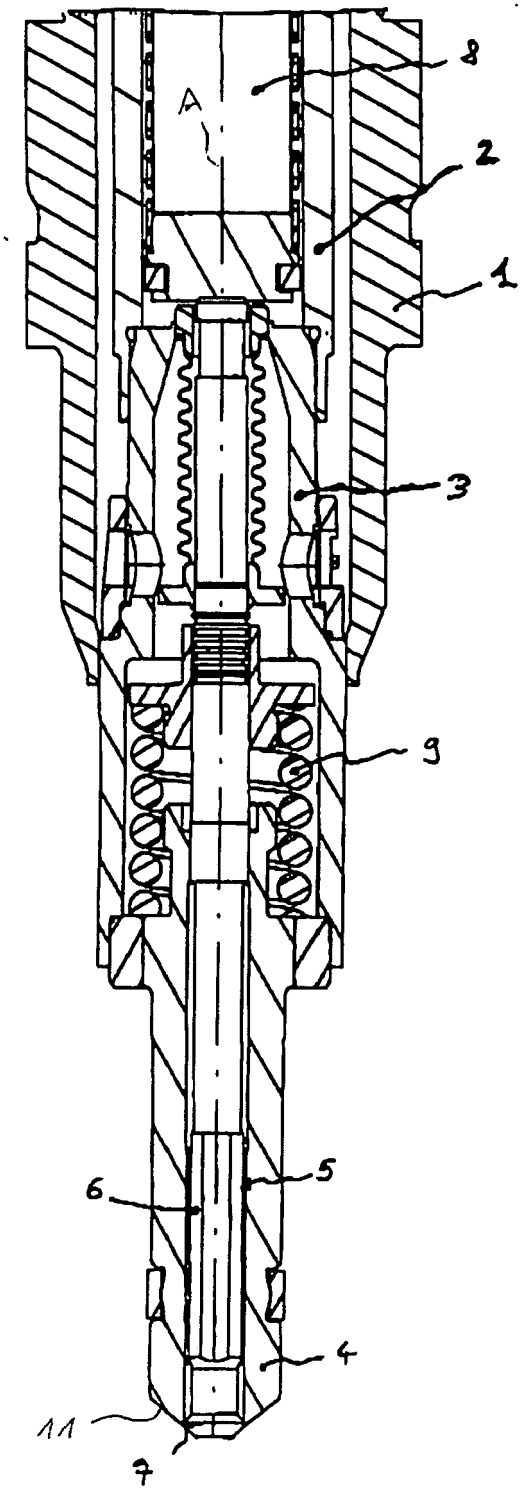


FIG 2

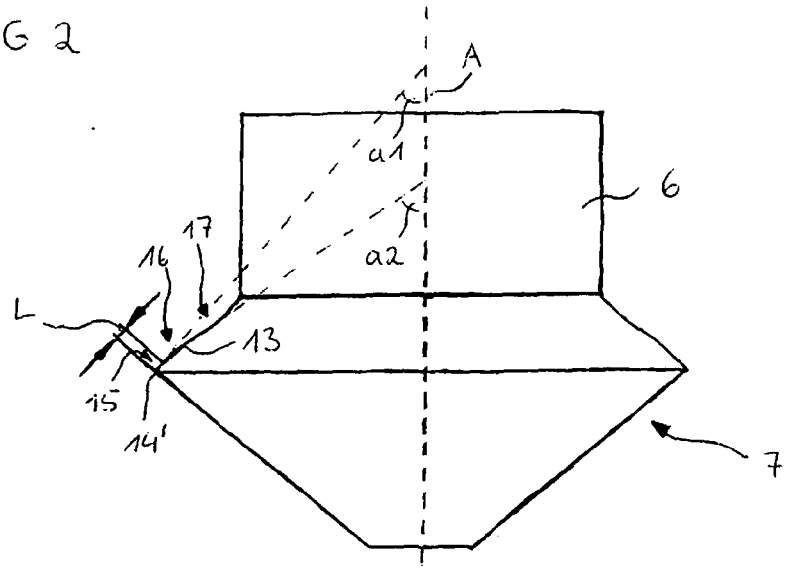


FIG 3

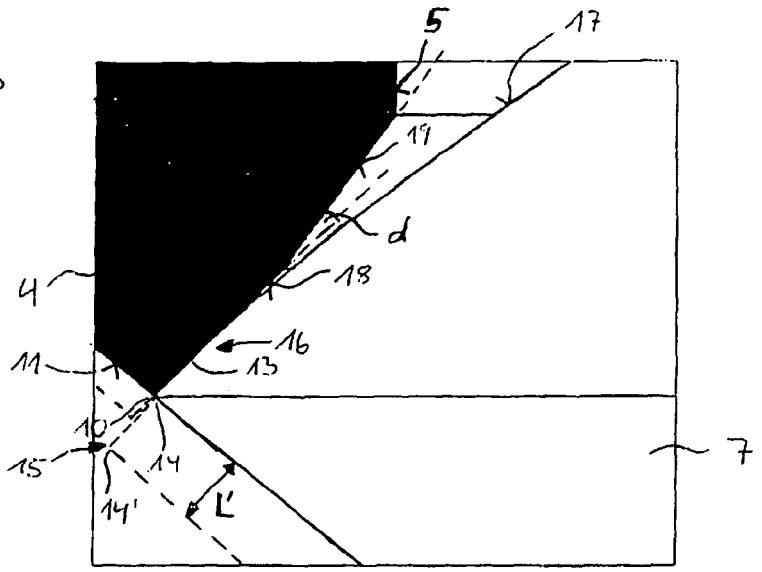


FIG 4

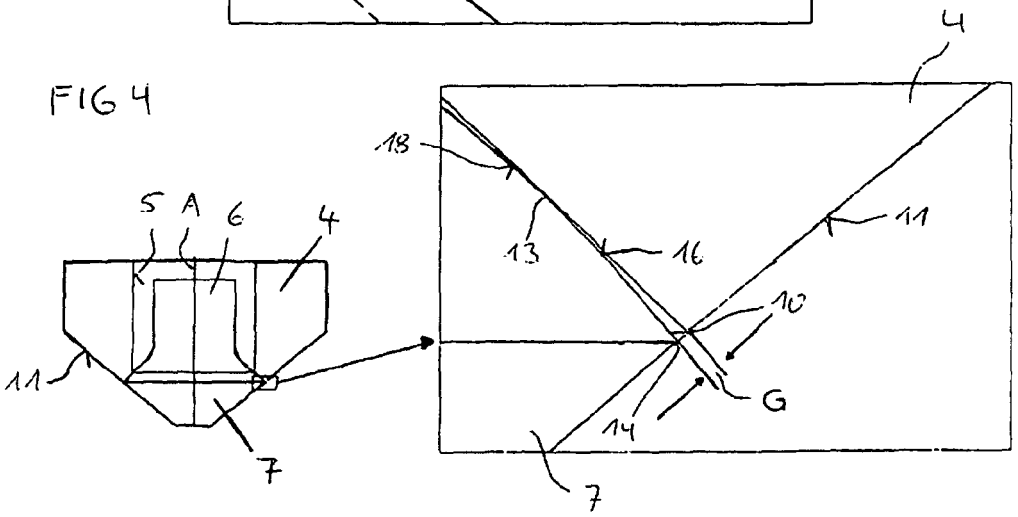
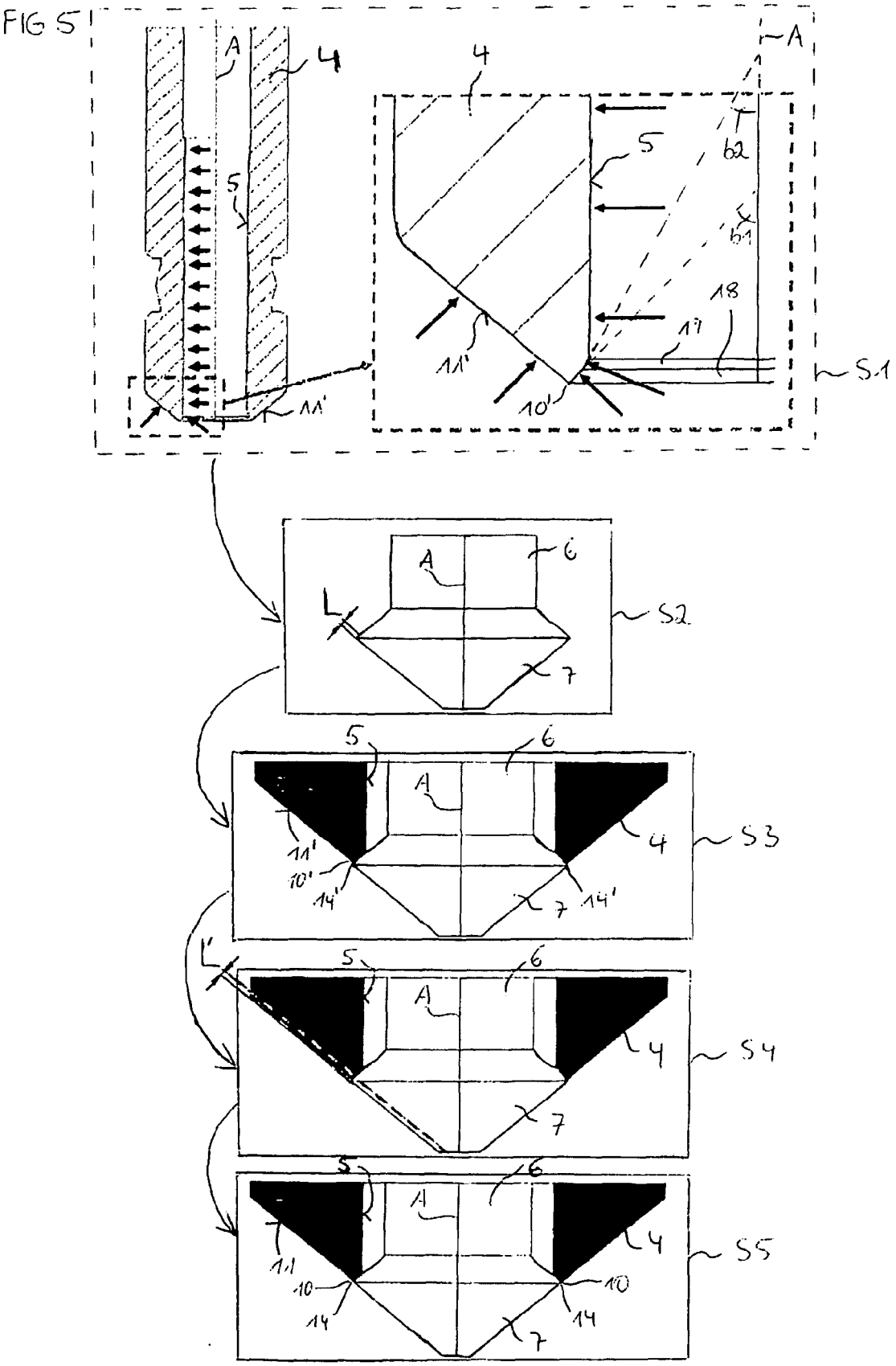


FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 09 00 5548

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* paragraph [0021]; figure 4 *	1	F02M63/00
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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	3 November 2009	Landriscina, V

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 00 5548

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