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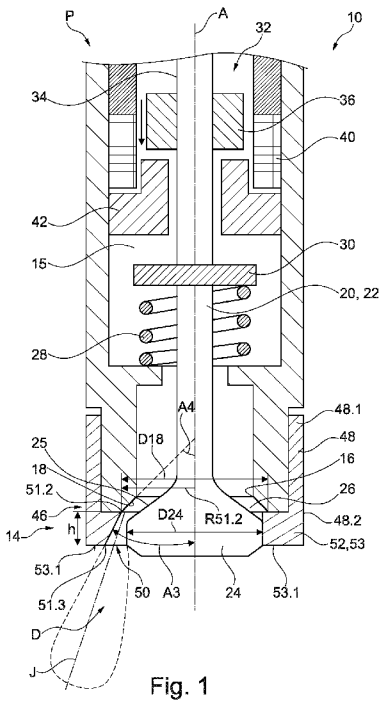


Fig. 1

(57) Abstract: The invention relates to a gas injector (10) for injection of gaseous fuel. The gas injector extends along an injector axis (A) from a proximal side (P) to a distal side (D) and comprises: an injector body (12) defining a fuel passage (15) and having a distally disposed end portion (14) that defines a valve seat (18) surrounding an outlet opening (16); an outwardly opening closure element (20) axially movable between a proximal position, in which it engages the valve seat (18) to close the outlet opening (16), and a distal position, in which it releases the outlet opening (16); a flow-guiding element (46) situated downstream of the valve seat (18) in flow direction of the gas injector (10) and configured to shape a gas jet to be injected into an engine combustion chamber; wherein the flow-guiding element (46) comprises an annular guide wall (53) surrounding the valve seat (18) and extending distally beyond the latter up to a distal end (53.1), thereby defining an axial aperture (54) of the flow-guiding element (46); and wherein at least one notch (50) is formed in said annular guide wall (53) to generate a side jet, the notch (50) extending over a fraction of the circumference of the annular guide wall (53); and wherein the notches (50) define a flared-out deflection surface (51) having a base section (51.1) adjacent to the valve seat (18).

GAS INJECTOR FOR HYDROGEN ICE

Technical field

The present invention generally relates to gaseous fueled internal combustion engines, in particular hydrogen ICE. The invention more specifically relates to an injector for injection of gaseous fuel into a combustion chamber of such engine, in particular direct injection.

Background Art

Recently, in an effort to reduce emissions, gaseous fuels such as natural gas or hydrogen have been used in internal combustion engines as alternatives to liquid fuels.

In the case of injectors for liquid fuels, inwardly-opening valve closure elements are typically used. These inwardly-opening valve closure elements may have various sealing seat geometries, such as a ball pressing against a cone or the like. In this case, a sac volume with holes provide access for the liquid fuel to enter the combustion chamber and allow a control over both the quantity and direction of the flow.

A less common approach to liquid fuel injection is to use an outwardly opening valve. Outwardly opening valve closure elements have the property that the direction of movement for opening is towards the combustion chamber of the internal combustion engine. In this case the seat angle on the cone defines the angle of the jet introduced in the combustion chamber and thus the mixture formation. If a customer desires another injection jet shape, it is usually necessary to modify the seat angle. In the case of liquid fuels, care must be taken to manage the spray breakup process into droplets. If the droplets are too large they will not evaporate and mix properly with the air. Furthermore, if the external surfaces of the injector which are exposed to the hot burnt gases of the combustion chamber are wet with fuel, then this will result in the formation of deposits on the injector tip. These deposits prevent proper spray formation and result in the formation of unwanted particulate emissions and toxic exhaust gas. As a result, the conical seat area is normally the primary spray forming surface for liquid injection.

For gas injection, the wetting of the external surface is not as critical and it is known that to shape the gas jet, an external jet-guiding element downstream of the valve seat may be used. Indeed, jet-guiding elements may be designed individually for customers to provide them with the required injection jet configuration, independently of valve seat or other geometrical conditions.

Technical problem

It is an object of the present invention to provide a gas injector that has a flow-guiding element of improved design.

General Description of the Invention

To achieve this object, the present invention proposes a gas injector for injection of gaseous fuel as claimed in claim 1; the gaseous fuel may in particular be natural gas or hydrogen. The present gas injector design is adapted for direct injection but could be used for injection upstream of the cylinder.

The present gas injector extends along an injector axis from a proximal side to a distal side and comprises:

an injector body defining a fuel passage and having a distally disposed end portion that defines a valve seat surrounding an outlet opening;

an outwardly opening closure element axially movable between a proximal pintle position, in which it engages the valve seat to close the outlet opening, and a distal pintle position, in which it releases the outlet opening; and

a flow-guiding element situated downstream of the valve seat in flow direction of the gas injector and configured to shape a gas jet to be injected into an engine combustion chamber.

The flow-guiding element comprises an annular guide wall surrounding the valve seat and extending distally beyond the latter up to a distal end, thereby defining an axial aperture of the flow-guiding element.

At least one notch, typically a plurality, is formed in the annular guide wall to generate a side jet, the notch extending over a fraction of the circumference of the annular guide wall.

Such design of the flow-guiding element contrasts with the conventional annular jets and promotes a better mixing of the flow of gaseous fuel with air, by forming several side jets of gas that are distributed across the combustion chamber.

The flow-guiding element comprises an axial aperture, i.e. it is open-ended in the opening direction of the closure element. That is the flow-guiding element does not cover the closure element. This normally implies that the flow-guiding element defines a generally through cylindrical passage of which the diameter is greater than the maximum diameter of the closure element.

An additional benefit of this design is thus that the flow-guiding element forms a kind of open-ended cap, which unlike some traditional cap designs does not form a plenum chamber downstream of the valve seat. This avoids occurrence of localized pressure variations on the pintle that affect the forces on the closure element and hence its motion. This can lead to unwanted variations in the time taken to either open or to close the closure element and the velocity of the closure element. These variations will make the injector less controllable and/or less durable.

In the context of the invention, side jets are jets of gaseous fuel that project from a given notch according to a jet direction that forms an acute angle relative to the injector axis, the angular spread depending on the angle of the notch. Typically, the notches are configured such that the side jets form an angle of at least 30° with respect to the injector axis.

The number of notches may depend on the application. A number of two, three or four notches is considered desirable, in particular to keep distinct, separate side jets that do not merge/coalesce with one another. These notches may be distributed evenly in the circumferential direction or asymmetrically.

Typically, each notch extends over a predetermined angular range, and two neighboring notches are separated (in circumferential direction along the annular guide wall) by a predetermined separation angle.

The notches are preferably formed in the distal end of the annular guide wall, i.e. in the front portion of the flow-guiding element. They are arranged to extend from the distal end of the annular guide wall in axial direction, or in axial and radial direction.

The notches define a deflection surface having a base section adjacent to the valve seat. The deflection surface is “flared out” in the sense that it extends radially outward and generally follows an acute angle relative to the injector axis.

The base section forms a kind of continuation of the valve seat and hence has its inner edge contiguous or adjacent the outer edge (portion) of the valve seat.

Different shapes can be envisaged for the base section, to generate a side jet as described. Possible shapes that align with the valve seat and then diverge outwardly are e.g. conical or spherical forms.

In embodiments the base section is a conical surface. The conical seat surface may be defined by an aperture half angle between 30 and 60°.

Preferably, the aperture angle of the base section is equal or smaller than an aperture angle of the conical seat surface.

Depending on the design, in particular of the angle/orientation of the base section, the notch may open in the distal end (end face) or in the lateral side of the flow-guiding element.

In embodiments, the annular guide wall extends axially over a distance ranging from a ratio of x2 through x4 the closing member lift beyond the valve seat.

A controlled clearance exists between an inner diameter of the annular guide wall and an outer diameter of the closure member downstream of the valve seat. In embodiments, this clearance may be controlled to form a narrow gap, e.g. less than 0.15 mm (on the radius) or less than 0.3 times the closing member lift. In such cases, essentially all of the gas stream discharged through the valve seat flows through the notches.

In other embodiments, there is a predetermined gap, comparatively larger, that is configured to create an axial jet component, since gas may then flow through this gap along the portions of the annular guide that separate the notches. The gap may for example vary from 0.25 to 0.5 mm (on the radius), or from 0.5 to 1.0 times the closing member lift.

When said predetermined gap is equal to or greater than 0.15 mm, the notches are preferably separated by a separation angle of at least 30°. Conversely, when said

gap is lower than 0.15 mm, the notches are preferably separated by a separation angle between 10 and 30°.

In embodiments, the flow-guiding element comprises a cylindrical member comprising a distal annular wall portion with an inwardly protruding annular lip, the latter forming said annular guide wall.

The flow-guiding element may be fitted over said injector end portion. In particular, the cylindrical member may comprise a proximal annular wall portion surrounding said injector tip portion and fixed thereto.

In embodiments, the closing member is a pintle having a shaft received in the injector body to be axially movable therein a pintle head outside said body and cooperating with said valve seat.

According to another aspect, the invention concerns an internal combustion engine, in particular a hydrogen ICE, comprising at least one combustion chamber associated with a gas injector as disclosed herein.

The above and other embodiments are recited in the appended dependent claims.

Brief Description of the Drawings

Further details and advantages of the present invention will be apparent from the following detailed description of several not limiting embodiments with reference to the attached drawings, wherein:

Fig. 1 is a cross sectional view through an embodiment of the present gas injector with the flow-guiding element attached;

Fig. 2 shows (A) a perspective view of the tip of the injector of Fig.1 as well as (B) a bottom view thereof;

Fig. 3 is a perspective view of an embodiment of the present flow-guiding element;

Fig. 4 is a cross sectional view through the flow-guiding element of Fig.3;

Fig. 5 is a bottom view of the flow-guiding element of Fig.4;

Figs.6 is a photograph of a hydrogen jet obtained with a conventional gas injector having a conical fuel jet;

Fig. 7 is a photograph of hydrogen jets obtained with a gas injector according to the present disclosure;

Figs.8 to 12 are schematic views of alternative embodiments of the flow-guiding element, where (a) is a bottom view and (b) a perspective view.

Description of Preferred Embodiments

Figs. 1 and 2 relate to a first embodiment of the fuel injector 10 according to the present invention. The fuel injector 10 is adapted to inject a gaseous fuel, in particular hydrogen (H_2) or natural gas (CH_4), into a combustion chamber of an internal combustion engine (not shown). The fuel injector is here only described briefly for the sake of exemplification; the design of the injector per se is not the focus of the invention. The fuel injector 10 is mostly symmetrical about an injector axis A and comprises an injector body 12. When installed to the engine, at least an end portion 14, or tip, of the injector body 12 is inserted into an opening of the cylinder head. The injector body 12 defines a fuel passage 15, which extends axially from a proximal side P towards a distal side D, where it communicates with an outlet opening 16. Reference sign 18 designates a valve seat that surrounds the outlet opening 16. The valve seat 18 typically defines a conical surface. A closure element, here a pintle 20, is axially movable between closed and open positions to control the outlet opening 16. The pintle 20 comprises a shaft 22 moveably received inside the injector body 12 and a head 24, which radially protrudes from the shaft 22 at the distal end thereof. Pintle head 24 forms a valve member that is adapted to cooperate with the valve seat 18. The pintle head 24 has a diameter D24, i.e. maximum diameter, and hence a Radius R24 (=D24/2).

The injector body 12 and pintle 20 are typically made of metallic material, in particular steel or stainless steel; however, this should not be construed as limiting and other appropriate materials may be employed.

In the open position, which is shown in Fig. 1, the pintle head 24 is spaced from the valve seat 18, thereby forming an annular flow passage 26 downstream of the outlet opening 16. The outlet opening 16 is thus released by the pintle 24; gaseous fuel can flow through opening 16 and passage 26, whereby a jet of gas is expelled from the nozzle tip 14. In the closed position (not shown), the pintle head 24 –more precisely an annular sealing surface 25 thereof facing valve seat 18– engages the

valve seat 18 that is formed at tip 14 around the outlet opening 16. The pintle 20 closes and seals the outlet opening 16 and the flow of gaseous fuel downstream of opening 16 is prevented. A spring 28 biases the pintle 20 towards the proximal pintle position, i.e. the closed position. Spring 28 engages a radial collar 30 that protrudes from the pintle shaft 22.

Proximally of the pintle 10, an armature member 32 is disposed inside the injector body 12. The armature member 32 is here biased by an armature spring (not shown) towards the distal side (may alternatively be biased proximally). It comprises an elongate, roughly cylindrical armature shaft 34 and an annular armature collar 36 that circumferentially surrounds the armature shaft 34 and is connected thereto, e.g. by welding. The armature collar 36 is axially movable within a cylinder portion of the injector body 12. To facilitate the movement of the armature 32, the armature shaft 34 is generally received in guide bearings.

A solenoid 40, which generates a magnetic field when energized, surrounds the armature element 32. The solenoid 40 is here shown inside the injector body 12 but could also be arranged outside. Distally of the armature collar 36 is a body portion 42 which is magnetizable by solenoid 40 and assists in shaping the magnetic field. In this embodiment, the distal body portion 42 functions as a pole piece. Body portion 42 can be integral with the body 12 or a separate part (as shown). The magnetic field created by energizing the solenoid 40 allows pulling the armature collar 36 and the entire armature 32 towards the distal side D in a distal movement. In doing so, the armature shaft 34 pushes the pintle shaft 22, wherefore the armature 32 is forced into the distal direction and moved in an open position, as e.g. shown in Fig.1. The gas injector 10 is hence referred to as ‘outwardly opening’. Again, this design and actuation mode with springs and solenoid is only exemplary. Those skilled in the art may devise other injector geometries and actuation principles, e.g. hydraulic.

Reference sign 46 indicates a flow-guiding element extending downstream of the sealing seat 18 in flow direction of the gas injector and configured to shape the gas jet to be injected into the engine combustion chamber.

The flow-guiding element 46 comprises an annular guide wall 53 surrounding the valve seat 18 and extending distally beyond the latter up to a distal end 53.1, thereby defining an axial aperture 54 of the flow-guiding element. A plurality of notches 50,

namely three, are formed in the annular guide wall 53 to generate separate/individual side jets, each notch extending over a fraction (i.e. a portion) of the circumference of the annular guide wall.

In general, the notches are formed as recesses or cut-outs extending from the distal end 53.1 into the annular guide wall 53.

In the shown embodiments, the flow-guiding element 46 is a cylindrical member that is fitted over the injector tip. It may be made from stainless steel or other appropriate material. As can be seen from the drawings, this cylindrical member defines an annular wall 48 that comprises, at the distal end, an inwardly protruding annular lip 52. The proximal wall portion 48.1 of the cylindrical member acts as mounting portion and surrounds the nozzle end/ tip 14. At the distal end, the annular wall portion 48.2 provided with the inwardly protruding annular lip 52 forms the annular guide wall 53, which extends beyond the valve seat 18 up to distal end 53.1 (hence end face). The annular lip 52 has proximal and distal surfaces 52.1, 52.2 and an inner side surface 52.3. In this variant, the annular lip 52 has a rectangular cross-section, whereby surfaces 52.1 and 52.2 extend perpendicular to axis A whereas inner side surface 52.3 extends parallel to axis A.

The distal aperture 54 is defined by the annular guide wall 53 and specifically its inner side surface 52.3. It may be noted that the flow-guiding element 46 is open-ended, i.e. there is no closing wall beyond the annular guide wall 53. The annular guide wall 53 does not contain any feature extending inwardly beyond D54 or defining a diameter lower than D54.

The flow-guiding element 46 hence forms an open cap, that is fitted over the injector tip, and can hence be easily adapted depending on the application (i.e. onto which engine model the injector is fitted). As visible in Fig.2, due to the notches 50 provided in the annular guide wall 53, the flow-guiding element 46 appears as a ring or sleeve with a crenelated front edge surrounding the pintle head 24.

The annular wall 48 has an inner diameter D48 which is greater than the diameter D54 of the aperture 54 defined by lip 52.

The notches 50 are configured to generate side jets, i.e. jets projecting distally and radially with a predetermined angle relative to injector axis A. The center axes J of the side jets are represented by dashed lines in the figures. In general, the shape

and angle of the jets J is controlled by the shape of the respective notches 50. The angle of the notch 50 required to produce a particular jet angle can be determined by CFD simulation.

Further to be noted in Fig.2B is the gap g that is defined between the periphery of the pintle head 24 and the diameter D54 of aperture 54 in flow-guiding element 46. In the embodiment of Figs.1 and 2 the gap g is narrow such that it essentially prevents axial gas flow. As a result, this first embodiment of flow-guiding element 46 produces three side jets. For example, a narrow gap g may be less than 0.15 mm on the radius.

In other embodiments, the gap g can be larger, to produce an axial jet, in addition to the side jets. Such axial jets are oriented by the inner surface 52.3 which may be parallel to axis A (as in Fig.10). For example, a large gap may vary from 0.25 to 0.5 mm in radius.

An (second) embodiment of a flow-guiding element 46 similar to that of Fig.2 is now presented in Figs. 3 to 5. One will recognize the annular wall 48 with its distal inwardly protruding lip 52, forming the annular guide wall 53. Three notches 50 are formed from the distal end 53.1 of the annular guide wall 53, i.e. from the bottom end in Fig.5. In the shown embodiment the notches 50 are formed mainly in the lip 52. The notches 50 hence extend both axially and radially in the lip 52, respectively in annular guide wall 53.

Two adjacent notches 50 are separated by a separating wall portion 55 extending over an angle A1. Two cases may be considered when determining the preferable value of A1.

In embodiments, the angle A1 can be selected as follows. When the clearance g between D24 and D54 is < 0.15 mm the angle A1 is preferably at least 10° to provide sufficient separation to avoid merging of the side jets, but no more than 30° to avoid excessive restriction of the mass flow through the injector tip. When the clearance g is > 0.15 mm then an axial jet is formed and angle A1 is preferably greater than 30° with no upper limit.

In this second embodiment, the flow-guiding element 46 includes three notches 50 that are evenly distributed in circumferential direction. Each notch 50 extends over an angle A2 between two separating wall portions 55.

The orientation of the side jets depends on the configuration of the notches. The notches 50 define a deflection surface 51 that is outwardly flared. That is the deflection surface 51 generally forms an acute angle relative to the injector axis A to control the side jets.

As can be seen from Fig.1, a section 51.1 of the deflection surface 51, referred to as base section, is adjacent to the valve seat 18. That is, the inner edge 51.2 of the base section 51.1 is contiguous to the outer portion of the valve seat 18. The outer edge 51.3 of base section 51.1 is farther away both radially and axially (distal direction).

The base section 51.1 thus forms a surface that extends beyond the valve seat downstream thereof, and will define the orientation of the side jet J.

In particular, as shown on Fig.1, the radius R51.2 of inner edge 51.2 may be equal to the maximum radius of the valve seat 18 (i.e. D18/2).

It may also be noted from the figures that the lip 52 extends inwardly beyond the outer portion of the valve seat 18, i.e. D54 < D18.

In this embodiment, the base section 51.1 is a conical surface defined by an aperture half angle A3. Angle A3 is by design equal to or smaller than the half angle A4 of the conical valve seat surface 18. This is the case for the first and second embodiments.

The base section 51.1 forms the bottom of the notch 50 and is arranged between two arcuate transition surfaces 51.4 that progressively connect with the side surface 52.3 and distal surface 52.2. The notches 50 are typically formed by milling but could also be easily formed by grinding, electro-discharge machining or other typical metal forming processes.

The annular wall 53 has a height indicated h; h represents the length of the annular guide wall 53 projecting beyond valve seat 18, along axis A. This height determines the axial length of the guiding surface for the jet.

For proper control of the gas jets, it is desirable that the height h is greater than the stroke of the pintle. As a result, in the fully open position of the pintle (maximum outward stroke) the pintle is still mostly surrounded by the annular guide wall 53, as represented in Fig.1. It is also desirable that the flow-guiding device does not extend deeply into the combustion chamber.

Depending on embodiments, the height h preferably lies in the following range:

$$2xL \leq h \leq 4xL$$

where L is the full lift of the pintle (i.e. axial distance from closed pintle position to fully open pintle position).

Fig.7 is a photograph from the spray chamber illustrating the hydrogen jet shape obtained with a fuel injector according to the present disclosure, with a design similar to Figs.1-5 (i.e. 4 notches and small gap g). It can be observed that the hydrogen stream is well distributed into the combustion chamber, as a plurality of 4 jets (there are 2 overlapping jets in the center).

By contrast, Fig.6 is a photograph from the spray chamber illustrating the hydrogen jet shape obtained with a conventional outwardly opening injector where the nozzle tip is configured to create an annular gas jet by means of conical deflecting walls. The gas jet is very dense and only centrally located.

As it will be understood by those skilled in the art, the number of notches and their configurations can be adapted to shape the jets. Different alternate designs of the flow-guiding element are presented below in reference to Figs 8 to 12.

In all four embodiment the flow-guiding element is a cylindrical member with an inwardly protruding annular lip at the distal end.

Figures 8 show an embodiment wherein the flow guiding element 46 comprises a lobular structure with four notches 50 evenly distributed in the circumferential direction, with a narrow gap g. It will thus produce essentially four side jets J that are equally spaced in circumferential direction. As can be seen, there is a minimal separation angle A1 between the notches. For such a narrow gap g, the separation angle A1 is at least 10°.The base section 51.1 of the notches 50 has an angle A3 steeper than the valve seat angle A4.

In the embodiment of Fig. 9, the flow guiding element 46 comprises two notches 50 asymmetrically distributed in the circumferential direction, to produce two side jets. Furthermore, there is a large gap g, which generates an axial jet. For such a large gap g, the separation angle A1 is at least 30°. The base section 51.1 of the notches 50 is conical with a broader half cone angle A3 compared to the design of Fig.1.

Fig. 10 shows an embodiment with a regularly spaced three-notch 50 configuration with narrow gap, similar to that of Fig. 1. However, the angle A3 of the base section 51.1 of each notch 50 is wider than in Fig.1. The angle A3 substantially matches that of the valve seat 18, thereby allowing for the maximum jet angle to be produced. It may be noted that here the notches 50 radially traverse the whole thickness of the annular guide wall 53 and open in the lateral side 48.3. Figures 11 presents an embodiment similar to Fig.1, with three lobular notches 50 evenly distributed in the circumferential direction and with a narrow gap g. However, the separation angle A1 is minimal, i.e. 10°, and the notches 50 are thus wider.

Finally, Fig.12 presents a four-lobe concept with small gap g. Compared to Fig.8, the notches 50 do not comprise a conical base section 51.1 (i.e. straight), but curve (the diameter progressively increasing in the distal direction, i.e. without discontinuity). For example, the base section 51.1 may be formed as a spherical section. The transition sections 51.4 may be formed with a certain radius with a grinding wheel. It may be noted that the curved shape of the base section 51.1 is such that its end radius is inferior to the outer radius of the annular guide wall, such that the notches 50 open in the distal end 53.1.

Claims

1. A gas injector (10) for injection of gaseous fuel, extending along an injector axis (A) from a proximal side (P) to a distal side (D) and comprising:

   an injector body (12) defining a fuel passage (15) and having a distally disposed end portion (14) that defines a valve seat (18) surrounding an outlet opening (16);

   an outwardly opening closure element (20) axially movable between a proximal position, in which it engages the valve seat (18) to close the outlet opening (16), and a distal position, in which it releases the outlet opening (16);

   a flow-guiding element (46) situated downstream of the valve seat (18) in flow direction of the gas injector (10) and configured to shape a gas jet to be injected into an engine combustion chamber;

   wherein the flow-guiding element (46) comprises an annular guide wall (53) surrounding the valve seat (18) and extending distally beyond the latter up to a distal end (53.1), thereby defining an axial aperture (54) of the flow-guiding element (46);

   wherein at least one notch (50) is formed in said annular guide wall (53) to generate a side jet, the notch (50) extending over a fraction of the circumference of the annular guide wall (53); and

   wherein the notches (50) define a flared-out deflection surface (51) having a base section (51.1) adjacent to the valve seat (18).

2. The gas injector (10) according to any one of the preceding claims, wherein the flow-guiding element (46) includes 2 to 4 notches (50).

3. The gas injector (10) according to claim 1, wherein the flow-guiding element (46) includes 3 or 4 notches (50).

4. The gas injector (10) according to claim 2 or 3, wherein the notches (50) are evenly distributed in circumferential direction.

5. The gas injector (10) according to claim 2 or 3, wherein the notch distribution is asymmetrical.

6. The gas injector (10) according to any one of the preceding claims, wherein the notches (50) extend from the distal end (53.1) of the annular guide wall (53) in an axial direction.

7. The gas injector (10) according to any one of the preceding claims, wherein the base section (51.1) is a conical surface defined by an aperture half angle A3 between 30 and 60°.

8. The gas injector (10) according to any one of the preceding claims, wherein the valve seat (18) defines a conical seat surface and the aperture half angle A3 is equal to or smaller than an aperture half angle of said conical seat surface.

9. The gas injector (10) according to any one of the preceding claims, wherein the annular guide wall (53) extends over a distance (h) ranging from a ratio of x2 through x4 the closing member (20) lift beyond the valve seat (18).

10. The gas injector (10) according to any one of the preceding claims, wherein a narrow gap (g) exists between an inner diameter D54 of said annular guide wall (53) and an outer diameter D24 of said closing member (20).

11. The gas injector (10) according to claim 10, wherein (D54-D24)/2 is less than 0.15 mm,

12. The gas injector (10) according to claim 10, wherein (D54-D24)/2 is less than 0.3 times the closing member (20) lift.

13. The gas injector (10) according to claim 10 to 12, wherein the notches (50) are separated by a separation angle A1 between 10 and 30°.

14. The gas injector (10) according to any one of claims 1 to 9, wherein a predetermined gap exists (g) between an inner diameter D54 of said annular wall (53) and an outer diameter D24 of said closing member (20) so as to create axial jet component(s).

15. The gas injector (10) according to claim 14, wherein (D54-D24)/2 is between 0.25 to 0.5 mm.

16. The gas injector (10) according to claim 14, wherein is between 0.5 and 1.0 times the closing member (20) lift.

17. The gas injector (10) according to claim 14 to 16, wherein the notches (50) are separated by a separation angle A1 of at least 30°.

18. The gas injector (10) according to any one of the preceding claims, wherein the flow-guiding element (46) comprises a cylindrical member (48) comprising a distal annular wall portion (48.2) with an inwardly protruding annular lip (52), the latter forming said annular guide wall (53).

19. The gas injector (10) according to claim 18, wherein said flow-guiding element (46) is fitted over said injector end portion (14), preferably wherein said cylindrical member (48) comprises a proximal annular wall portion (48.1) surrounding said injector end portion (14) and fixed thereto.

20. The gas injector (10) according to any one of the preceding claims, wherein the closing member (20) is a pintle (20) having a shaft (22) received in the injector body (12) to be axially movable therein and a pintle head (24) outside said body (12) and cooperating with said valve seat (18).

21. An internal combustion engine comprising at least one combustion chamber associated with a gas injector (10) according to any one of the preceding claims.

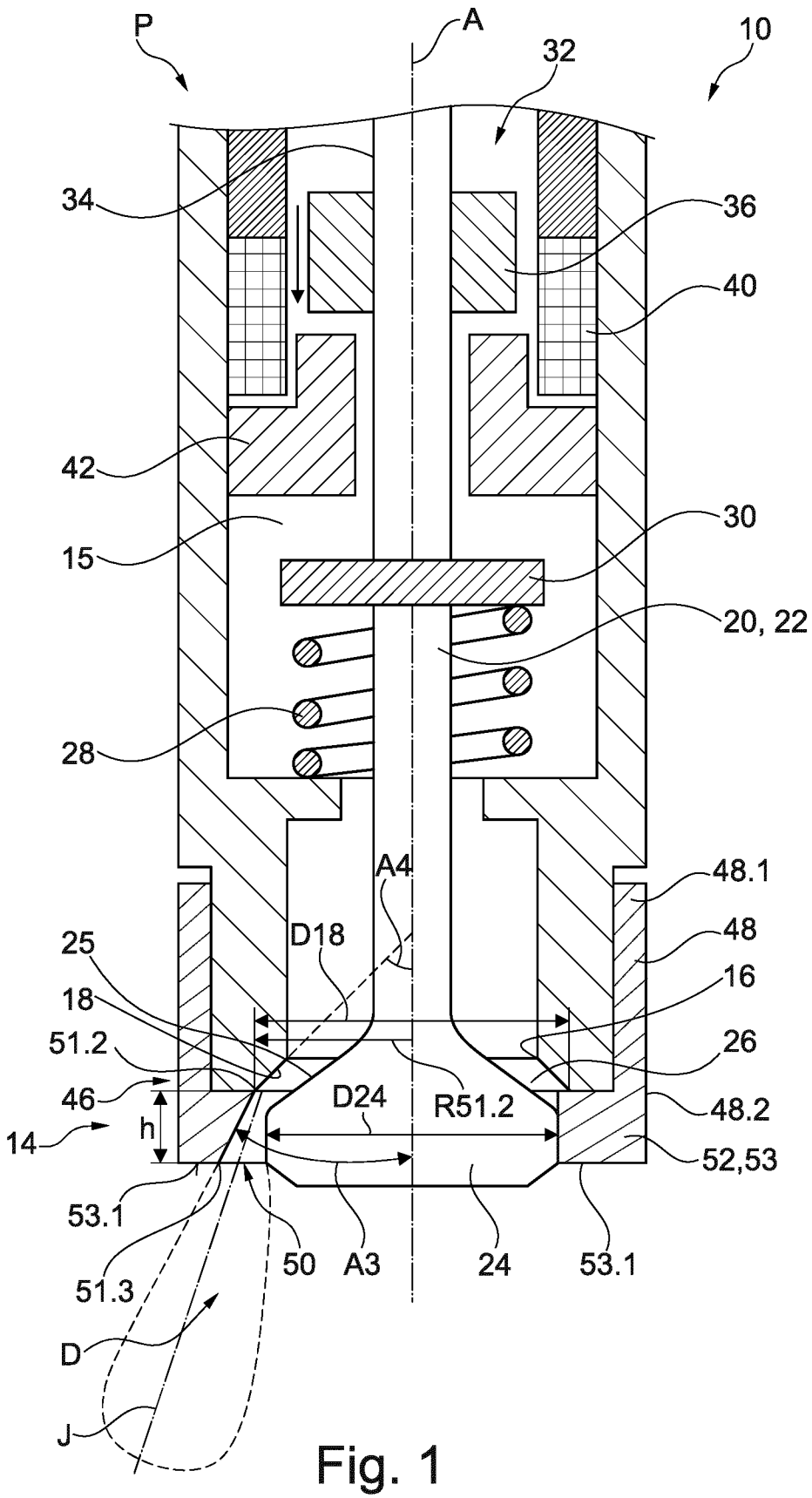

P
A
10
32
34
36
40
42
30
15
20, 22
28
A4
48.1
D18
48
25
16
18
51.2
26
46
D24
R51.2
48.2
14
h
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53.1
50
A3
24
53.1
51.3
D
J

Fig. 1

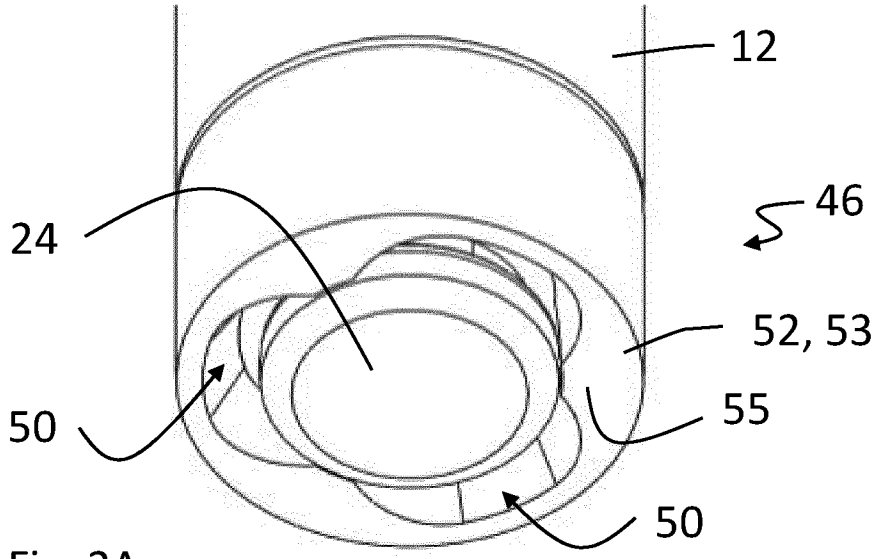

12
46
24
52, 53
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Fig. 2A

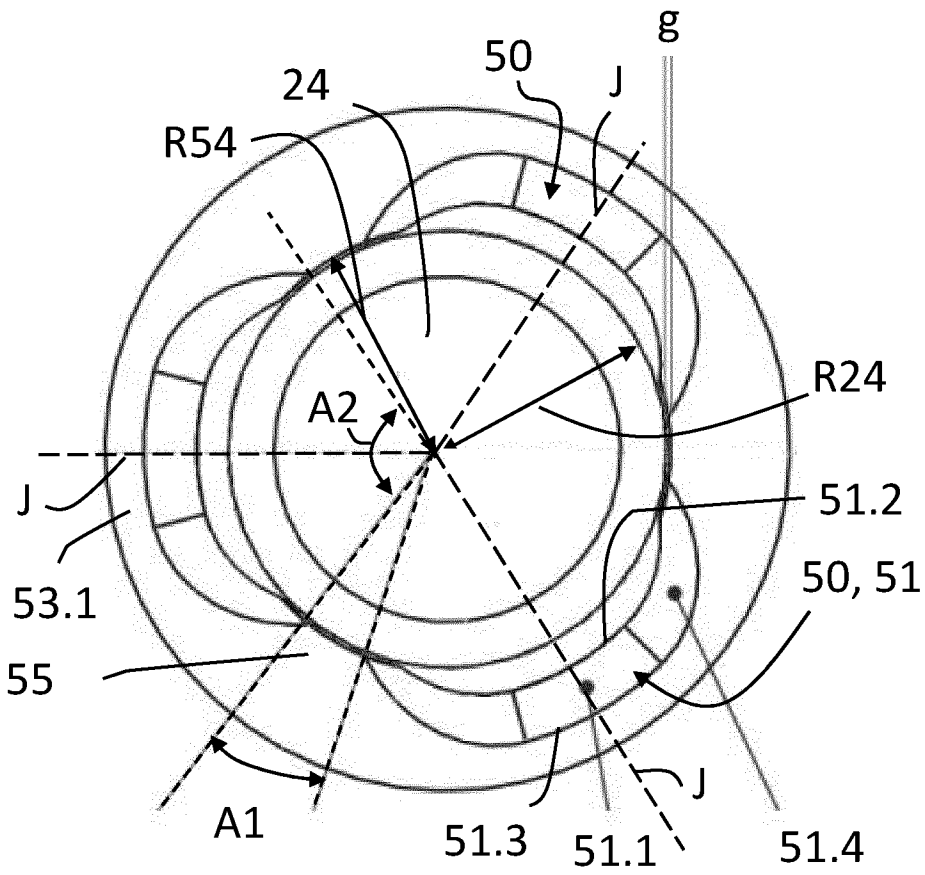

g
50
24
J
R54
R24
A2
J
51.2
53.1
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55
J
A1
51.3
51.1
51.4

Fig. 2B

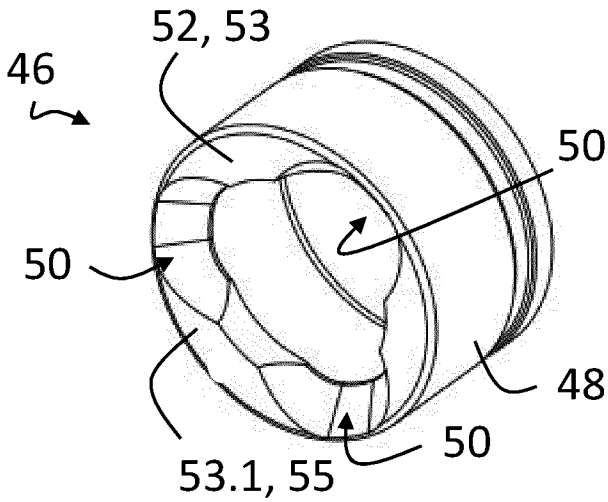


Fig. 3

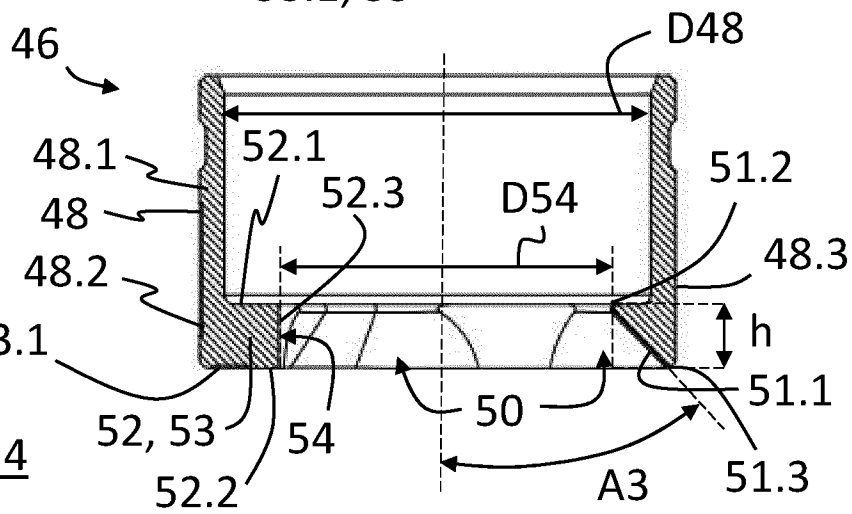


Fig. 4

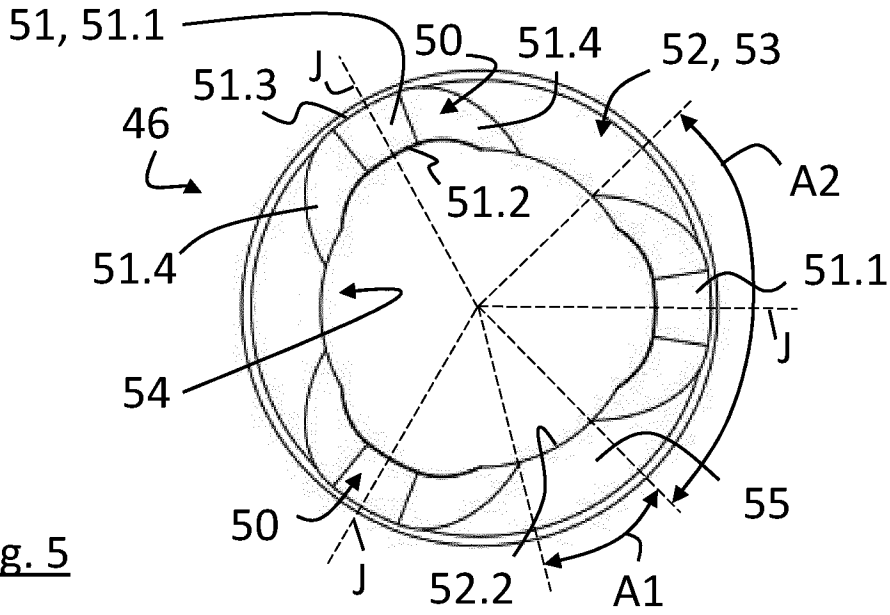


Fig. 5

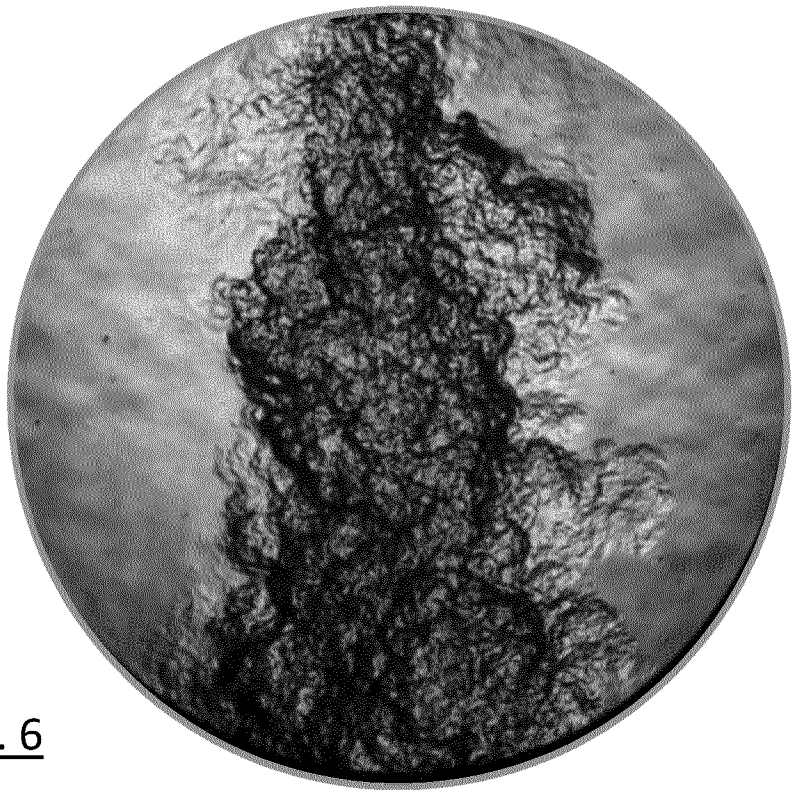


Fig. 6

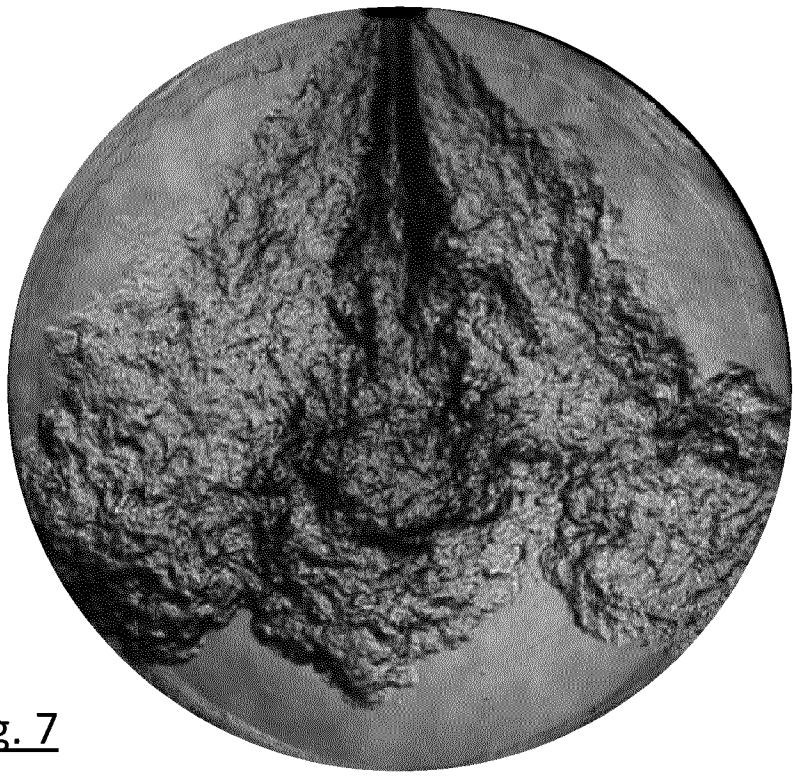


Fig. 7

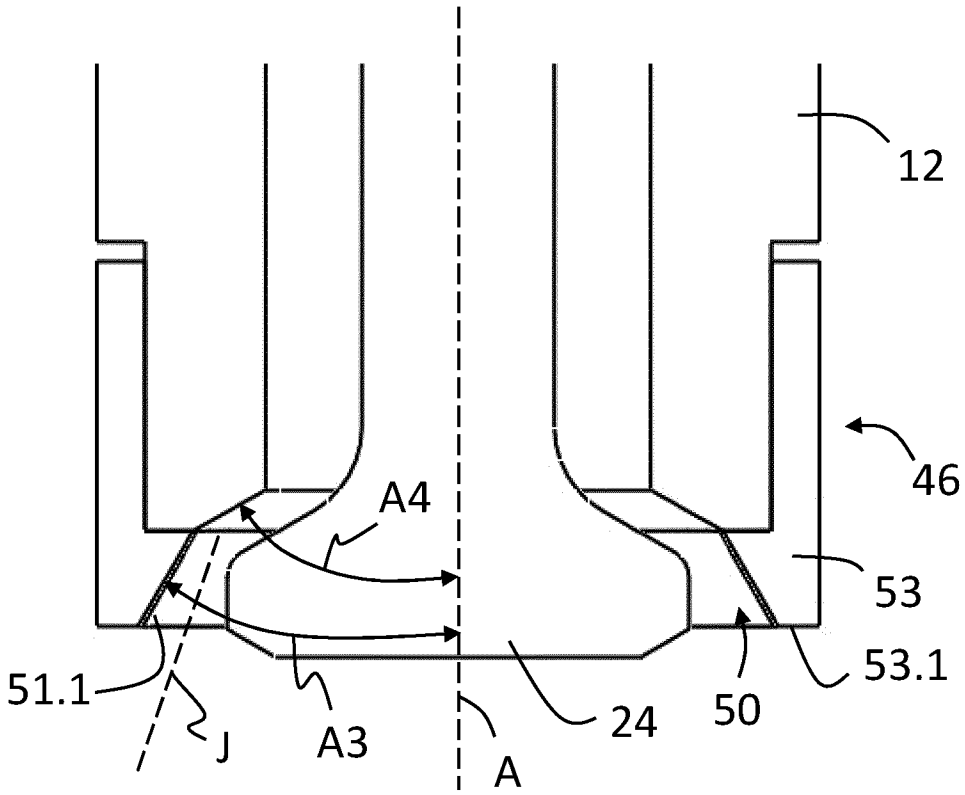


Fig. 8a

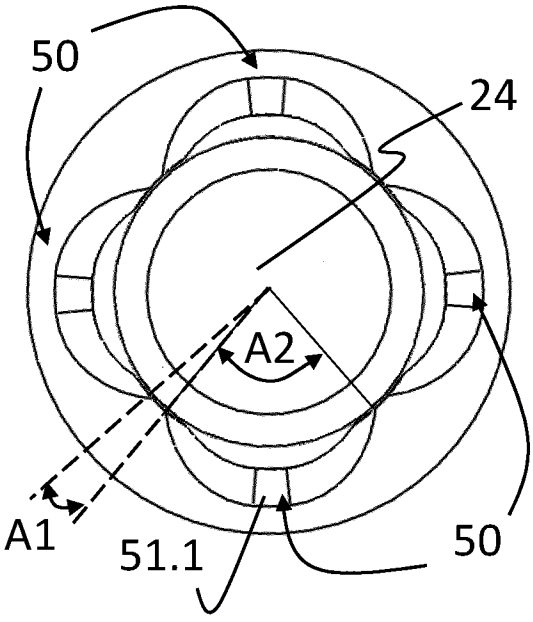


Fig. 8b

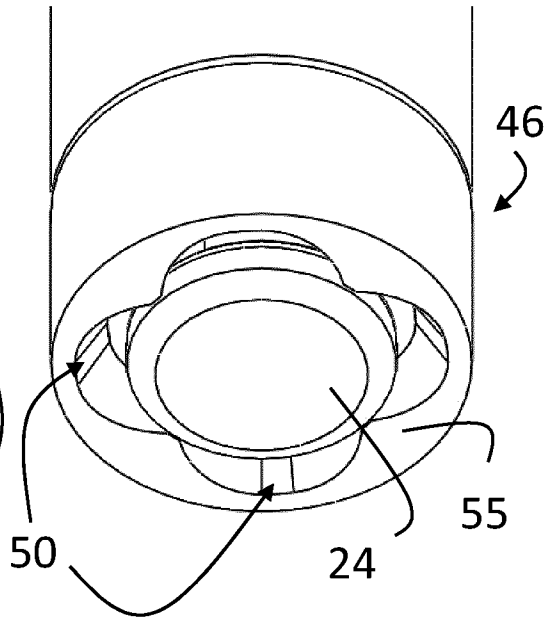


Fig. 8c

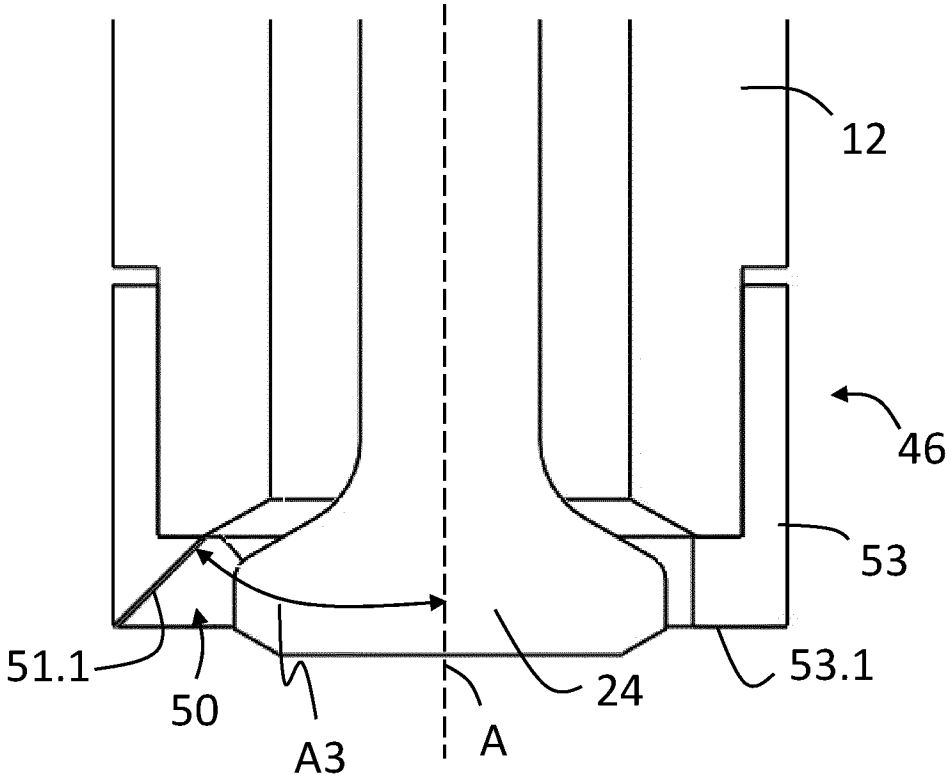


Fig. 9a

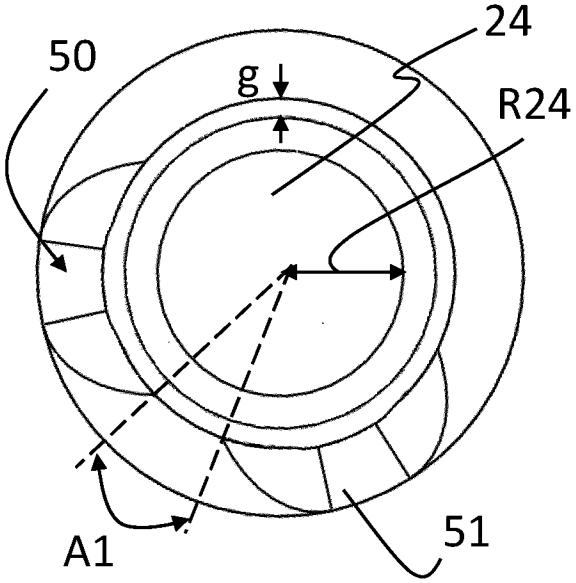


Fig. 9b

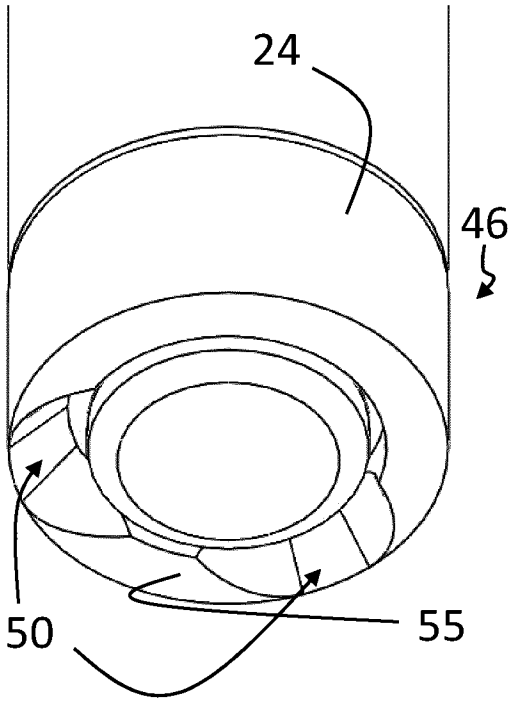


Fig. 9c

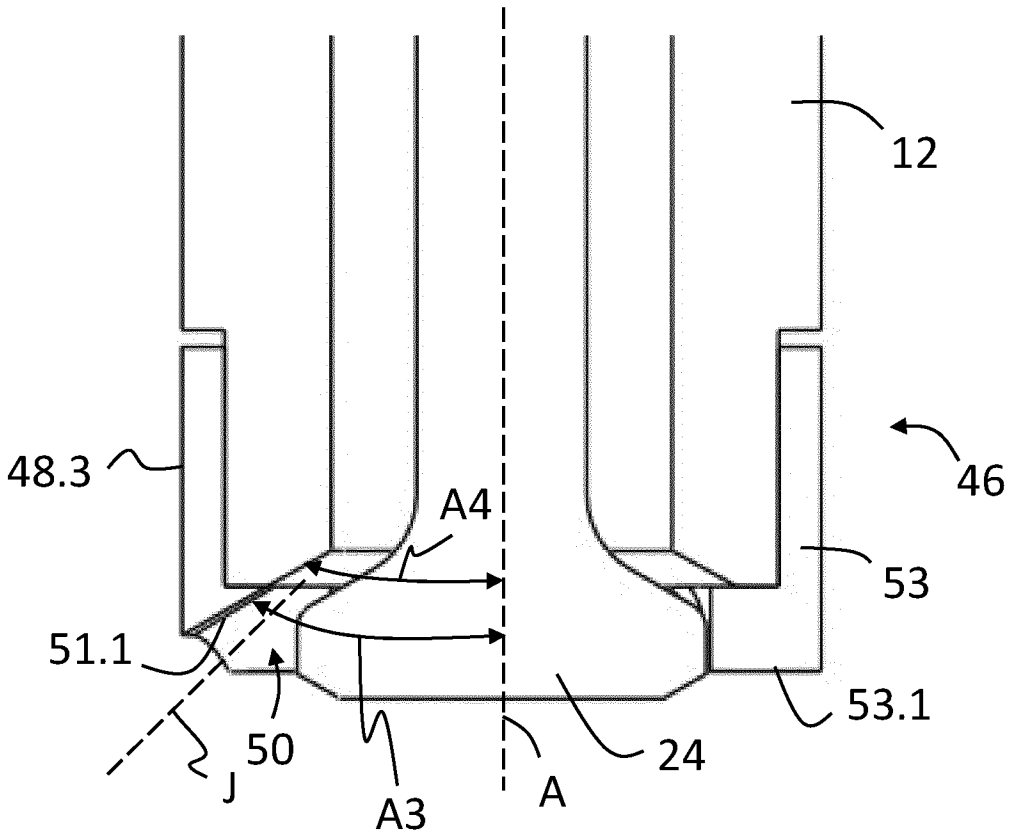


Fig. 10a

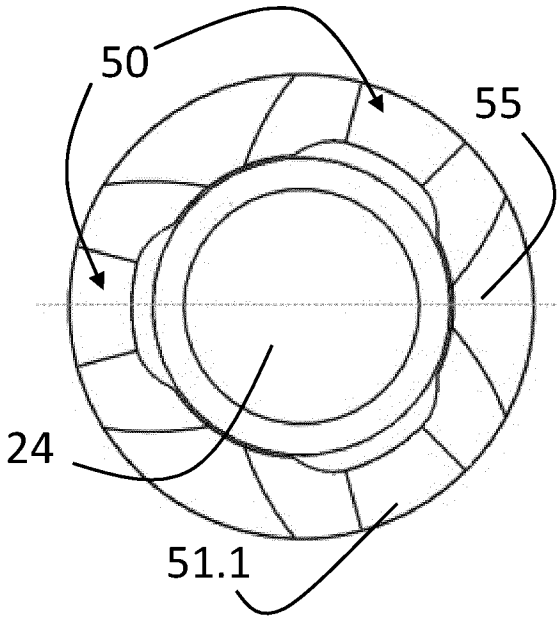


Fig. 10b

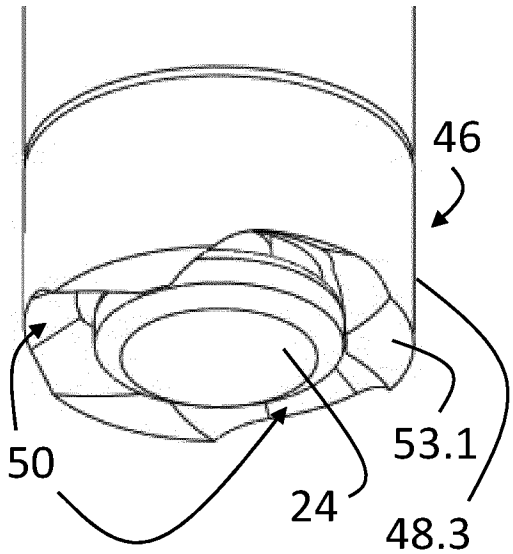


Fig. 10c

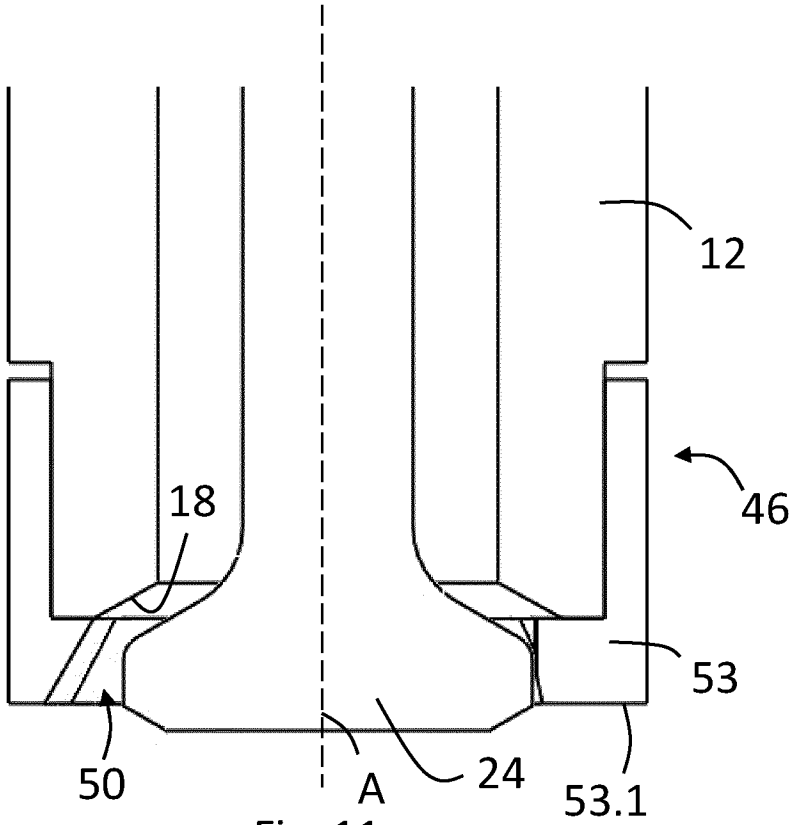


Fig. 11a

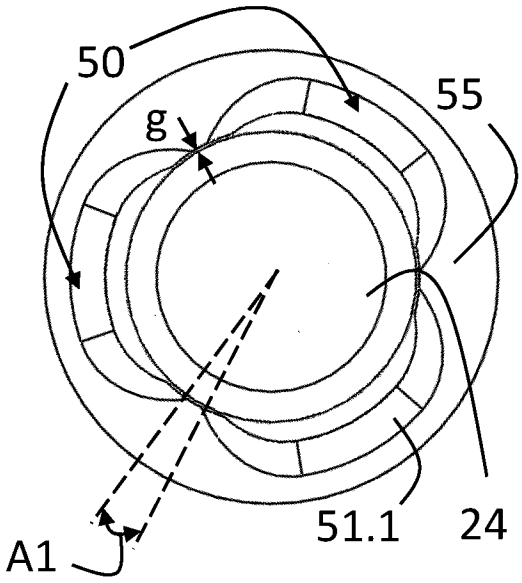


Fig. 11b

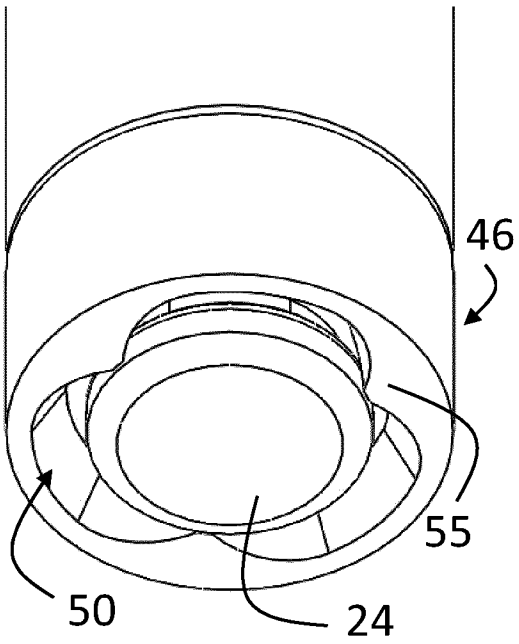


Fig. 11c

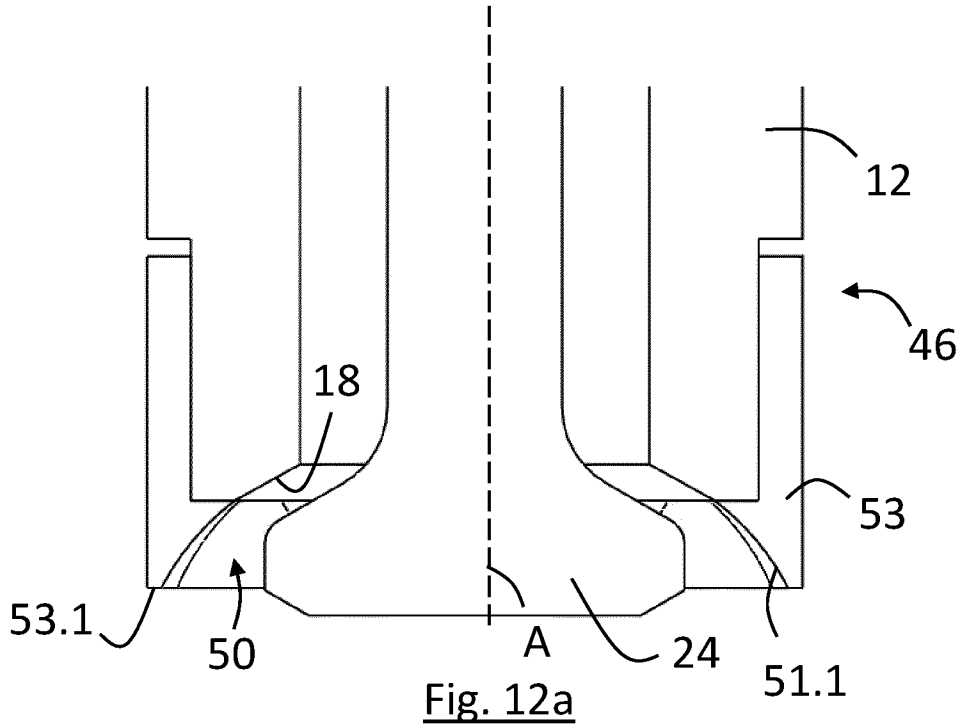


Fig. 12a

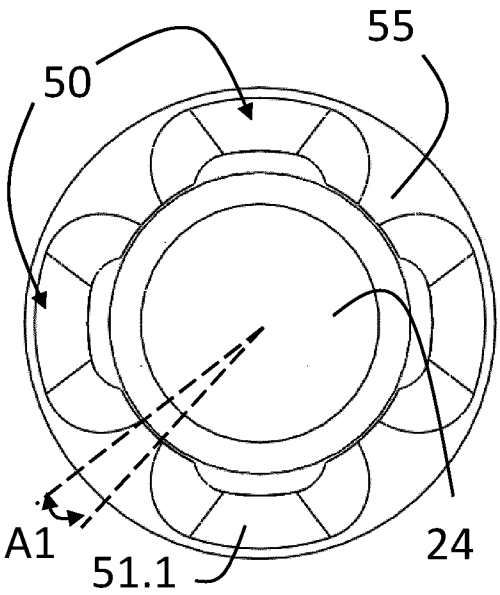


Fig. 12b

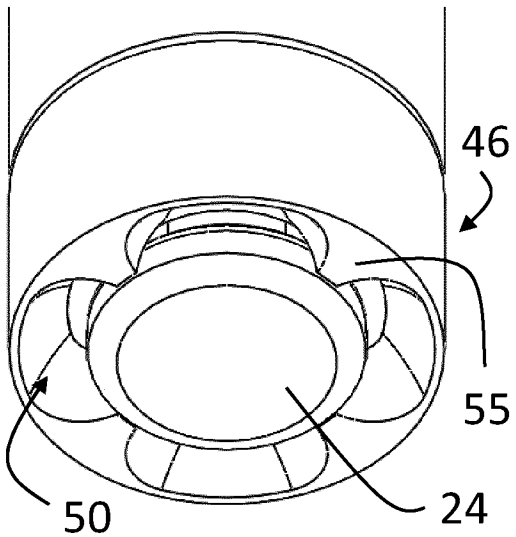


Fig. 12c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/057242

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M21/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2004 044820 A1 (BOSCH GMBH ROBERT [DE]) 30 March 2006 (2006-03-30) figures 1, 2	1-4,6-21
X	EP 0 234 642 A1 (SPICA SPA [IT]) 2 September 1987 (1987-09-02) title; figures 3-10	1-4, 6-17,20, 21
X	US 5 577 473 A (LINDER ERNST [DE]) 26 November 1996 (1996-11-26) claim 1; figures 2-5	1,5, 7-17,20, 21
A,P	WO 2023/110127 A1 (VOLVO TRUCK CORP [SE]) 22 June 2023 (2023-06-22) the whole document	1-21

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☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2024	03/05/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kolodziejczyk, Piotr

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/057242

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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WO 2023110127 A1	22-06-2023	NONE	