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(54) **Fuel injection valve for an internal combustion engine**

(57) A fuel injection valve for an internal combustion engine is disclosed. A valve needle (3) with a needle axis (4) is movably positioned in a recess (6) of a first housing portion (5) of a housing (2) of the fuel injection valve. A first guide portion (17) of the valve needle (3) has radial protrusions (39) defining a first radial gap (22) between an inner surface (21) of the recess (6) and the protrusions (39). Between the inner surface (21) and the shaft (16) of the needle (3) a second radial gap (30) exists. The valve needle (3) comprises a resistance portion (32) for orientating the fuel stream between the first guide portion (17) and the needle tip (8) wherein a third radial gap (31) between the inner surface (21) and the resistance portion (32) is formed which is bigger than the first gap (22) and smaller than the second gap (30).

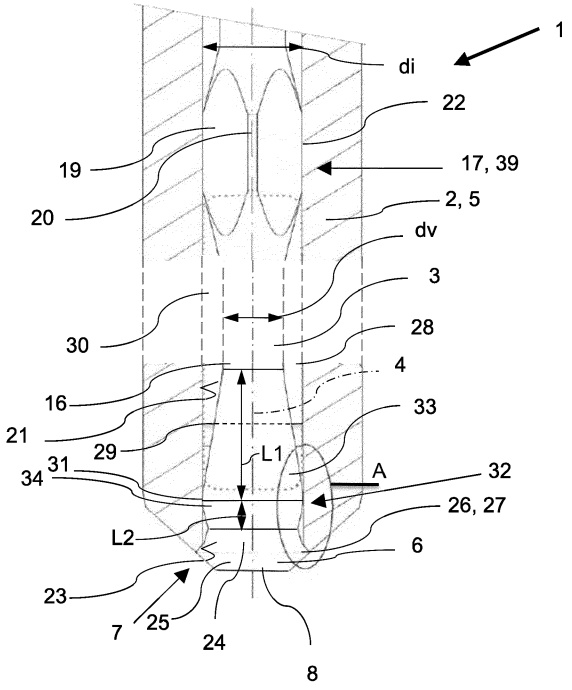


Fig. 3

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Description

[0001] The disclosure relates to a fuel injection valve for an internal combustion engine.

[0002] Fuel injection valves which operate electromagnetically are well known. With the aid of a magnetic coil which is chargeable by electricity to generate a magnetic field, a magnetisable armature which may be combined with a valve needle, will be stimulated for movement. Normally, the movement is an axial movement along a valve needle axis of the valve needle.

[0003] Fuel injection valves may have different nozzle orifices producing different injection sprays. In other words, the pattern of the injection spray depends on the nozzle orifice. The most well known injection spray is a conical spray pattern which may be generated for example by an inward opening injector. Inward opening injectors have a valve needle which moves in upstream direction with respect to the fuel stream for opening the nozzle orifice so that the valve needle has to be opened against a fuel force produced by the fuel.

[0004] Another pattern of an injection spray is a holed cone spray pattern which may be realized e.g. by an outward opening injector. The valve needle of an outward opening injector moves in the direction of the fuel stream for opening the nozzle orifice. In this case, a needle tip of the valve needle may project beyond a housing of the fuel injection valve. The needle tip may be shaped analogously to that of a charge-cycle valve of the combustion engine. This needle tip shape is particularly well suited for producing a holed cone spray distribution.

[0005] The needle has to be guided in the housing by guide means. These guide means reduce a flow cross section of the fuel which is formed between the valve needle and an inner surface of the tubular housing. To avoid tilting of the valve needle, one of the guide means has to be positioned close to the needle tip.

[0006] The guide means is designed to support the mechanism of movement in a stable condition, i.e. few microns of tolerance exists between the housing and the valve needle in the guided area. On the other side, the guide means has to guarantee that a sufficient amount of fuel may pass the guide means; therefore, a fluid channel has to be created.

[0007] When the valve needle starts to move for a few microns of lift, a pressure drop distribution of the fuel is mainly responsible for the spray formation. Because of the channels and stays of the guide means, a degradation of the axial-symmetrical spray momentum can occur so that the spray cone deviates from a desired balanced and rotationally invariant shape.

[0008] It is an object of the invention to specify a fuel injection valve which has an improved spray behaviour.

[0009] This object is achieved by a fuel injection valve for an internal combustion engine with the features of the independent claim. Advantageous embodiments of the invention are given in the sub-claims.

[0010] A fuel injection valve for an internal combustion engine is specified. The fuel injection valve may be provided for a fuel injection device of the internal combustion engine. The fuel injection valve comprises a housing and a valve needle.

[0011] The housing has a first housing portion with a recess having an inner surface. A nozzle orifice is provided in first housing portion being positioned at a downstream end of the recess.

[0012] The valve needle has a needle axis and is movably positioned in the recess. The valve needle comprises a shaft and a needle tip which is positioned at a first end of the shaft. In one embodiment, the needle tip of the valve needle is in the shape of a truncated double cone with the base areas of the two truncated cone sections facing towards each other and in particular coinciding.

[0013] The nozzle orifice and the needle tip together form an injection nozzle of the fuel injection valve. The needle tip is operable to prevent fuel from passing through the nozzle orifice in a closing position and is movable in downstream direction to allow a stream of fuel passing the nozzle orifice in an opening position of the valve needle.

[0014] A first guide portion of the valve needle has a plurality of protrusions for guiding the valve needle. Preferably, a fluid channel - through which fuel can pass the first guide portion in axial direction - is formed between in each case two protrusions which directly follow one another in angular direction around the needle axis. This may be realized by a guide means with stays - representing the protrusions - and flats, the stays and flats alternating in angular direction around the needle axis so that channels between the inner surface and each of the flats are realized and at the same time the stays enable the guiding of the valve needle in the housing.

[0015] The valve needle comprises a resistance portion between the first guide portion and the needle tip for orientating the fuel stream. The resistance portion in particular protrudes radially from the shaft of the valve needle. The resistance portion is in particular operable to effect a flow resistance for fuel flowing along the needle shaft from the first guide portion towards the needle tip by means of protruding radially from the shaft. The flow resistance may also be denoted as flow resistivity or as drag.

[0016] A first radial gap between the inner surface and the protrusions is formed. In other words, the protrusions are radially spaced apart from the inner surface of the recess by a first distance. The first distance is in particular the smallest distance between any one of the protrusions and the inner surface when the valve needle is centered in the recess.

[0017] Between the shaft and the inner surface, a second radial gap is formed. In other words, the shaft of the valve needle - in particular in an axial region between the first guide portion and the resistance portion - is spaced apart from the inner surface by a second distance.

[0018] The resistance portion shapes a third radial gap

between the inner surface and the resistance portion. In other words, the resistance portion is spaced apart from the inner surface by a third distance.

[0019] The third radial gap is bigger than the first radial gap and smaller than the second radial gap. In other words, the third distance is larger than the first distance and smaller than the second distance.

[0020] Due to flow resistance effected by the third gap, an improved and stabilized pressure drop distribution and fuel velocity in transient operating mode as well as in full opening position is achievable for the fuel stream between the first guide portion and the nozzle orifice. Thus, a particular good rotational symmetry of the spray distribution is achievable.

[0021] Preferably, the resistance portion has a rotationally invariant shape with respect to rotation around the needle axis. Preferably, by means of the rotationally invariant resistance portion, the third gap is annularly shaped, i.e. it is in particular rotationally invariant with respect to the needle axis. Such shapes may be particularly advantageous for achieving a rotationally symmetric spray distribution.

[0022] In one embodiment, the resistance portion comprises a first section and a second section. They are both in the shape of truncated cones wherein the base of the first section corresponds to the base of the second section. In particular, the - imaginary - bases are congruent and flush. Preferably, they are parallel to one another and preferably perpendicular to the needle axis. In one development, they are positioned in a common plane. The advantage of this design is the particularly small risk for a stall of the fluid stream, in particular when the first portion has an axial extension which is larger than the axial extension of the second portion.

[0023] In a further embodiment, a segue between the first portion and the second portion is formed having a third axial extension and in particular a maximum diameter, wherein the third gap is defined by the segue and the inner surface. In other words, the resistance portion has its largest cross-sectional dimension -represented by the maximum diameter - in the region of the segue. The minimum spacing defining the third diameter is, thus, located between the segue of resistance portion and the inner surface. Because of the third axial extension of the third gap the fuel stream distribution becomes more stabilized.

[0024] In another embodiment, the resistance portion has a curved shape. In particular, a surface of the resistance portion has a smooth shape - i.e. without kinks, steps or dips. This is advantageous for preventing stall.

[0025] In another embodiment, a hydraulic diameter of the recess in the region of the first guide section is at least ten times bigger than a hydraulic diameter in the region of the resistance portion. The hydraulic diameter is in particular defined by the cross-sectional area of the recess in the respective region which is not occupied by the valve needle. Such proportions of the hydraulic diameter are advantageous for achieving an improved pressure drop distribution.

[0026] In one embodiment, the valve needle comprises a second guide portion upstream of the first guide portion. The second guide portion comprises one or more protrusions for guiding the valve needle. The second guide portion is in particular arranged adjacent to an upstream end of the valve needle. By means of the first and second guide portions, tilting of the needle axis relative to the housing can be largely avoided.

[0027] Further advantages, features and details of the invention may be derived from the following description of preferred exemplary embodiments as well as from the drawings. The features and feature combinations as previously mentioned in the description as well as the features and feature combinations which will be mentioned in the following description of the figures and/or which are solely illustrated in the figures are not only applicable in the respective indicated combination but also in other combinations or isolated, without departing from the scope of the invention. For the sake of clarity, only those features are identified by reference numerals in the figures, which are useful for the corresponding description of the figures. Thus, the items need not be identified by their reference numerals throughout all figures, without losing their assignments.

[0028] In the figures:

Figure 1 is a longitudinal sectional view of an fuel injection valve according to an unclaimed configuration,

Figure 2 is a longitudinal sectional view of a cut-out of the fuel injection valve according to figure 1,

Figure 3 is a longitudinal sectional view of a cut-out of an exemplary embodiment of a fuel injection valve,

Figure 4 is a longitudinal sectional view of a detail A of the exemplary embodiment.

[0029] Figure 1 shows an exemplary embodiment of a fuel injection valve 1 with an outward opening injector for an internal combustion engine according to an unclaimed configuration. The fuel injection valve 1 comprises a housing 2, in which a valve needle 3 with a needle axis 4 is movably arranged. The valve needle axis 4 is also a central longitudinal axis of the housing 2.

[0030] The valve needle 3 is movably arranged in a first housing portion 5 of the housing 2, in particular it is received in a recess 6 of the first housing portion 5. The valve needle 3 is operable to open and close a nozzle orifice 7 of the recess 6, the nozzle orifice 7 being positioned at a downstream end of the recess 6.

[0031] The valve needle 3 has a shaft 16 which is generally cylindrically shaped and has a first guide portion 17 and a second guide portion 18. Each of the guide portions 17, 18 has a four radial protrusion 39, specifically four stays 20, and four flat areas 19. Each flat area 19 is

positioned between two circumferentially adjacent stays 20. The stays 20 are spaced apart from the inner surface 21 of the recess 6 by a first distance so that a first gap 22 is defined between the stays 20 and the inner surface 21. This first gap 22 is just so small that the moving of the valve needle 3 is not hindered and a guidance is realized. A friction between the shaft 16 and the inner surface 21 is largely avoided by the fuel which also functions as a lubricant.

[0032] By means of the flat areas 19, fluid channels between the inner surface 21 and the flat areas 19 are formed so that the fuel may pass the guide sections 17, 18 in axial direction.

[0033] The valve needle 3 further has needle tip 8 disposed at a downstream end of the shaft 16. The needle tip 6, together with the nozzle orifice 7, shapes an injection nozzle of the fuel injection valve 1. In a closing position of the valve needle 3, the needle tip 8 abuts a valve seat 23 which is comprised by the housing 2 to prevent fuel from passing through the nozzle orifice 7. The valve needle 3 is axially displaceable away from the closing position in downstream direction - i.e. in axial direction from the guide portions 17, 18 towards the needle tip 6 - to allow a stream of fuel passing the nozzle orifice 7 in an opening position of the valve needle 3. Preferably, the valve seat 23 is comprised by a conical surface adjoining and surrounding the nozzle orifice 7.

[0034] The needle tip 8 has a first truncated cone shaped section 24 and a second truncated cone shaped section 25. The first truncated cone 24 and the second truncated cone 25 are positioned in such way that a base area 26 of the first truncated cone 24 coincides with a base area 27 of the second truncated cone 26. The seconf cone shaped section 25 is positioned subsequent to the first cone shaped section 24 in axial direction away from the shaft 16. The first truncated cone shaped section 24 interacts with the valve seat 23 for sealing of the nozzle orifice 7.

[0035] The design of the nozzle orifice 7 in combination with the needle tip 8 generates a hollow spray cone of the fuel when the valve needle 3 opens the nozzle orifice 7. A shape of the valve seat 23 and a shape of the needle tip 8 have to be very accurate produced to guarantee a sealing during a closing position of the fuel injection valve 1 and also the spray pattern and therefore the spray quality during an opening position of the fuel injection valve 1.

[0036] A second housing portion 9 of the housing 2 is fixed to the first housing portion 5 or in one piece with the first housing portion 5. Together, the first and second housing portions 5, 9 in particular represent a valve body of the fuel injection valve.

[0037] The second housing portion 9 comprises a valve spring 10. This valve spring 10 is circumferentially surrounding a portion of the valve needle 3. The valve spring 10 is preloaded to press the needle tip 8 against the valve seat 23.

[0038] Further, the fuel injection valve comprises an electromagnetic actuator 11 with a magnetic coil 12 and a movable armature. The magnetic coil 12 is positioned in a coil housing 13 which laterally surrounds a third housing portion 14 of the housing 2. The third housing portion 14 precedes the second housing portion 9 in axial direction towards the nozzle orifice 7, so that the second housing portion 9 is arranged between the first housing portion 5 and the third housing portion 14.

[0039] The third housing portion 14 comprises the armature and a calibration spring 15. The armature is mechanically coupled to the valve needle by a piston which is fixed to the armature and axially projects beyond the armature to an upstream end of the shaft 16 of the valve needle 3. The piston is pressed against the upstream end of the shaft 16 by the calibration spring 15 so that a spring force is transferred to the valve needle 3 in opposite axial direction of the spring force of the valve spring 10 for calibrating the fuel injection valve 1.

[0040] Figure 2 represents a longitudinal sectional view of a cut-out of the fuel injection valve 1 as seen in figure 1. The needle tip 8 is designed like a typically cylinder valve of an inlet or an outlet valve of an internal combustion engine. With exception of the nozzle orifice 7 and an upstream portion of the recess 6 where the valve spring 10 is positioned, an inner diameter di of the recess 6 may be constant. Also, with exception of the guide portions 17, 18 a first diameter dv of the shaft 16 is constant, so that an annular passage 28 with a constant flow cross-section 29 having a second gap 30 is created. Due to the protrusions 39, in this exemplary embodiment in form of stays 20, alternating in circumferential direction with the flat areas 19, the rotational symmetry of fuel pressure and the fuel distribution with respect to the needle axis are modified downstream of the first guide portion 17 so that an undesirable non homogenous spray momentum of the spray cone is created.

[0041] Figure 3 shows a longitudinal sectional view of a cut-out of an exemplary embodiment of fuel injection valve. The fuel injection valve of the present exemplary embodiment is, in general, of the same construction as the fuel injection valve discussed in connection with figures 1 and 2 above.

[0042] However, according the present embodiment, the valve needle 3 has a resistance portion 32. The resistance portion 32 is arranged between the first guide portion 17 and the needle tip 8, upstream of the first truncated cone 25. The resistance portion 32 is a rotationally symmetric protrusion of the shaft 16.

[0043] An annular third gap 31 between the valve needle 3 and the inner surface 21 is shaped by the resistance portion 32 of the valve needle 3. For realizing a homogeneous spray momentum, the third gap 31 is bigger than the first gap 22 but smaller than the second gap 30. It is currently believed that due to the resistance portion 32 protruding radially outward from the shaft 16 and reducing the hydraulic diameter, the resistance portion 32 generates a constriction of in the fuel path through the recess 6 in this or any other embodiment of the invention. In the region of the constriction, the fuel path has in par-

ticular a rotationally invariant shape with respect to rotation around the needle axis. In this way, the resistance portion 32 effects a flow resistance for the fuel flowing through the fluid channels of the first guide portion 17 and further along the shaft 16 which smoothes angular differences in fuel flow and improves the homogeneity of the angular flow distribution.

[0044] In a preferred embodiment a ratio between the smallest flow cross section of the first guide portion 17 and the smallest flow cross section of the resistance portion 32 has a value of 10 or more, in particular of 20 or more. In other words, the hydraulic diameter of the recess 6 in the region of the first guide portion 17 is at least 10 times larger, in particular at least 20 times larger, than in the region of the resistance portion 32. The hydraulic diameter is in particular defined by the cross-sectional area of the fluid channels shaped by the stays 20 and flats 19. The value is set in dependence on a stabilization pressure level which is desired for an application of the combustion engine.

[0045] In this exemplary embodiment the resistance portion 32 has a first section 33 and a second section 34 both formed as a truncated cone. The truncated cones are orientated to each other in this way that their base areas correspond.

[0046] The second section 34 is positioned between the first section 33 and the first truncated cone 24 of the needle tip 8. The second axial extension L2 of the second section 34 is smaller than a first axial extension L1 of the first section 33. This relates to a preferred flow cross section upstream of the third gap 31.

[0047] A segue 35 between the first section 33 and the second section 34 is designed, see Figure 4. The segue 35 has a constant maximum diameter dmax over a third axial extension L3, so that the third gap 31 is realized between the segue 35 and the inner surface 21.

[0048] With other words, the resistance portion 32 and the needle tip 6 together have a shape 38 formed like a "S", respectively a curved shape 38.

Claims

1. A fuel injection valve for an internal combustion engine, comprising

   - a housing (2) with a first housing portion (5) having a recess(6) with an inner surface (21),
   - a nozzle orifice (7) of the first housing portion (5) being positioned at a downstream end of the recess (6),
   - a valve needle (3) with a needle axis (4) being movably positioned in the recess (6), comprising a shaft (16) and a needle tip (8) positioned at a first end of the shaft (16), forming together with the nozzle orifice (7) an injection nozzle of the fuel injection valve (1) and preventing fuel from passing through the nozzle orifice (7) in a closing position of the fuel injection valve (1) and being movable in downstream direction for allowing a fuel stream to pass the nozzle orifice (7) in an opening position of the valve needle (3),
   - a first guide portion (17) of the valve needle (3) with a plurality of radial protrusions (39) for guiding the valve needle (3),
   - a first radial gap (22) between the inner surface (21) and the protrusions (39)
   - a second radial gap (30) between the inner surface (21) and the shaft (16), wherein
   - the valve needle (3) comprises a resistance portion (32) for orientating the fuel stream between the first guide portion (17) and the needle tip (8) wherein a third radial gap (31) between the inner surface (21) and the resistance portion (32) is formed which is bigger than the first gap (22) and smaller than the second gap (30).

2. The fuel injection valve according to claim 1, **characterized in that** the resistance portion (32) protrudes radially from the shaft (16) in such fashion that the third radial gap (31) is annularly shaped.

3. The fuel injection valve according to claim 1 or 2, **characterized in that** the resistance portion (32) comprises a first section (33) and a second section (34) both shaped as truncated cones wherein the base of the first section (33) corresponds to the base of the second section (34).

4. The fuel injection valve according to claim 3, **characterized in that** a first axial extension (L1) of the first portion is greater than a second axial extension (L2) of the second portion.

5. The fuel injection valve according to claim 3 or 4, **characterized in that** the resistance portion (32) has a segue (35) between the first portion (33) and the second portion (34), the segue (35) having a third axial extension (L3)and a maximum diameter (dmax), wherein the third gap (31) is formed between the segue (35) and the inner surface (21).

6. The fuel injection valve according to one of the preceding claims, **characterized in that** the resistance portion (32) has a curved shape (38).

7. The fuel injection valve according to one of the preceding claims, **characterized in that** a hydraulic diameter of the recess (6) in the region of the first guide section (17) is at least ten times bigger than in the region of the resistance portion

(32).

8. The fuel injection valve according to one of the preceding claims,
characterized in that
the valve needle (3) comprises a second guide portion (18) upstream of the first guide portion (17).

9. The fuel injection valve according to claim 8,
characterized in that
the second guide portion (18) comprises at least one radial protrusion (39).

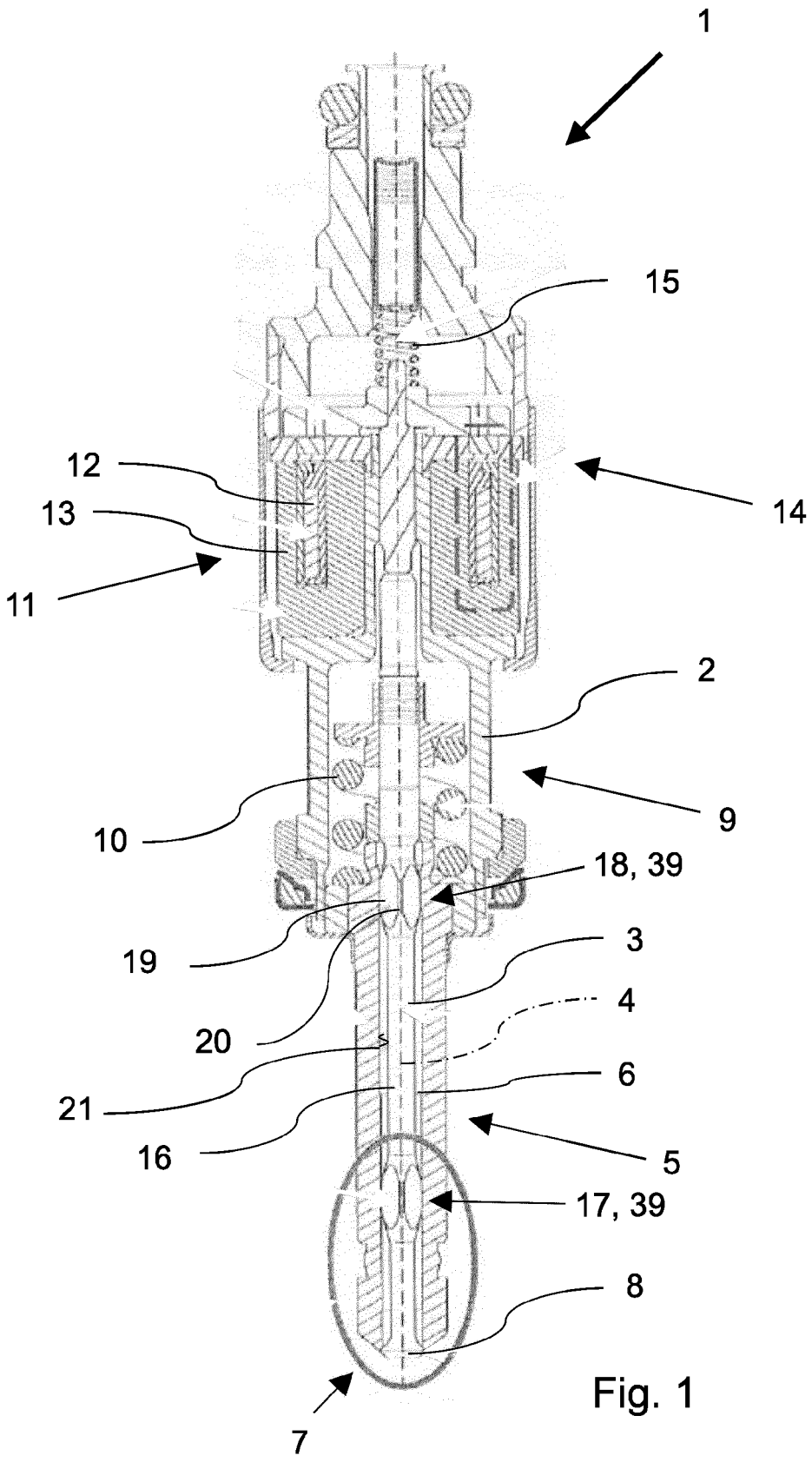


Fig. 1

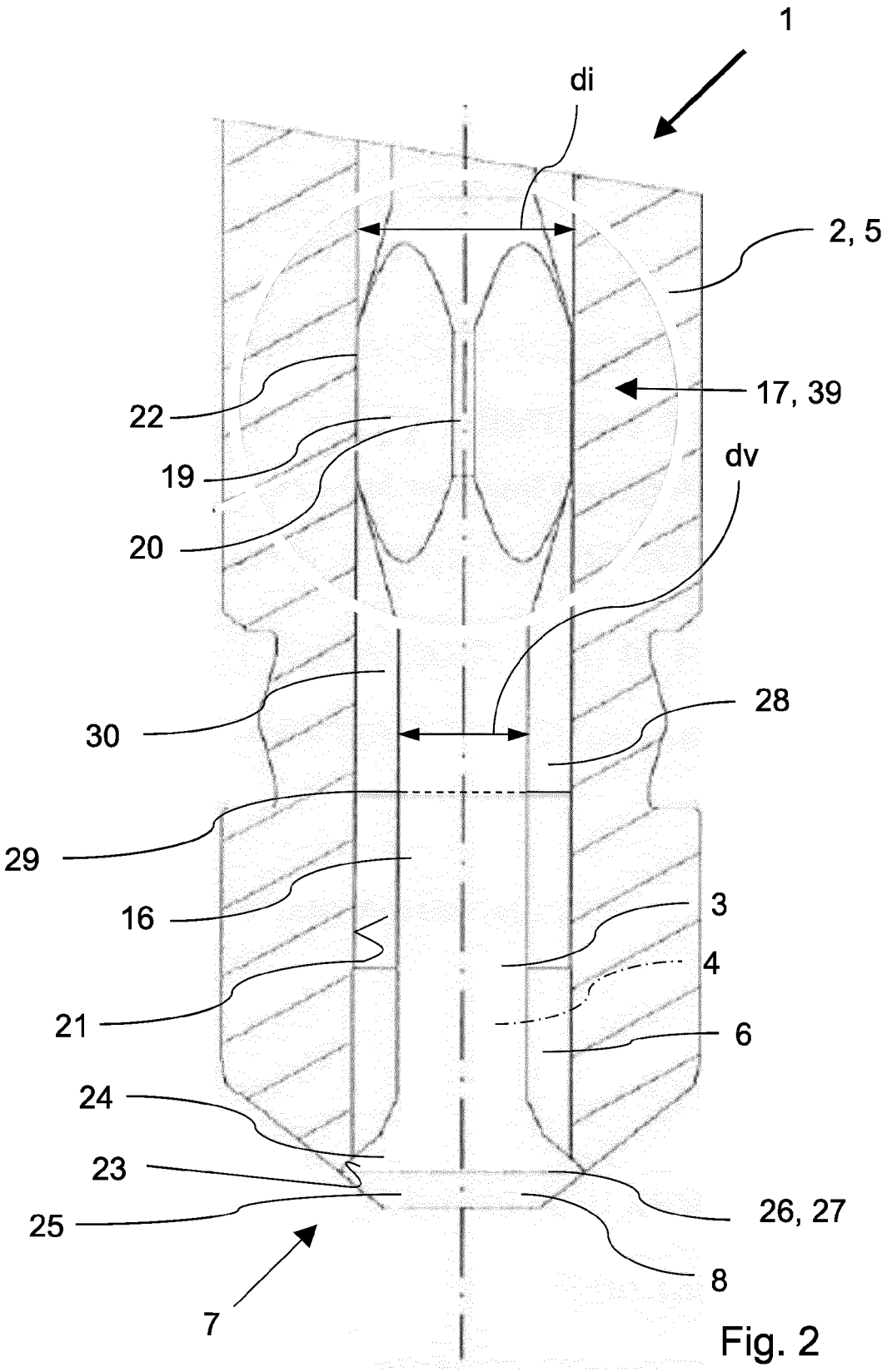


Fig. 2

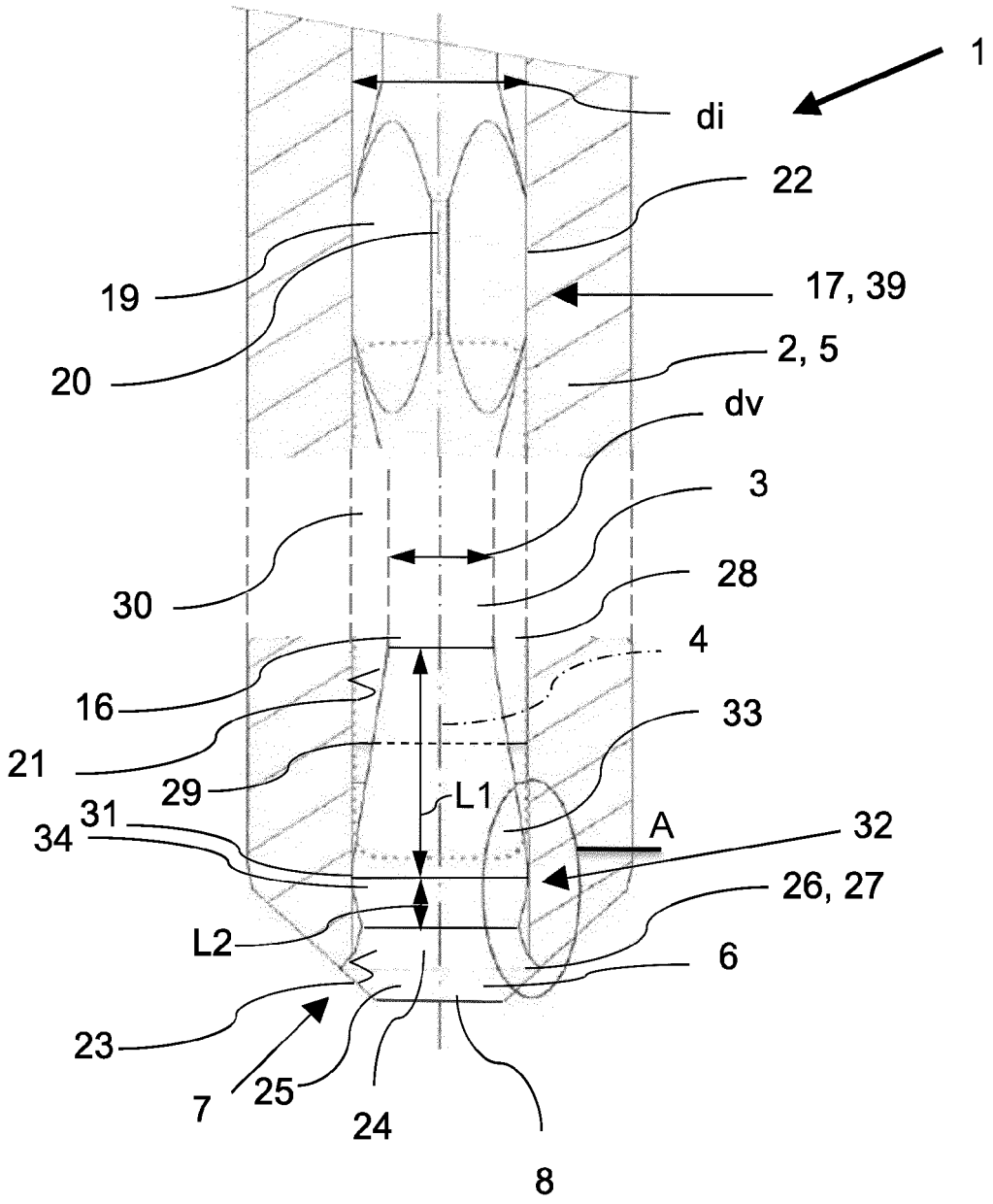

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Fig. 3

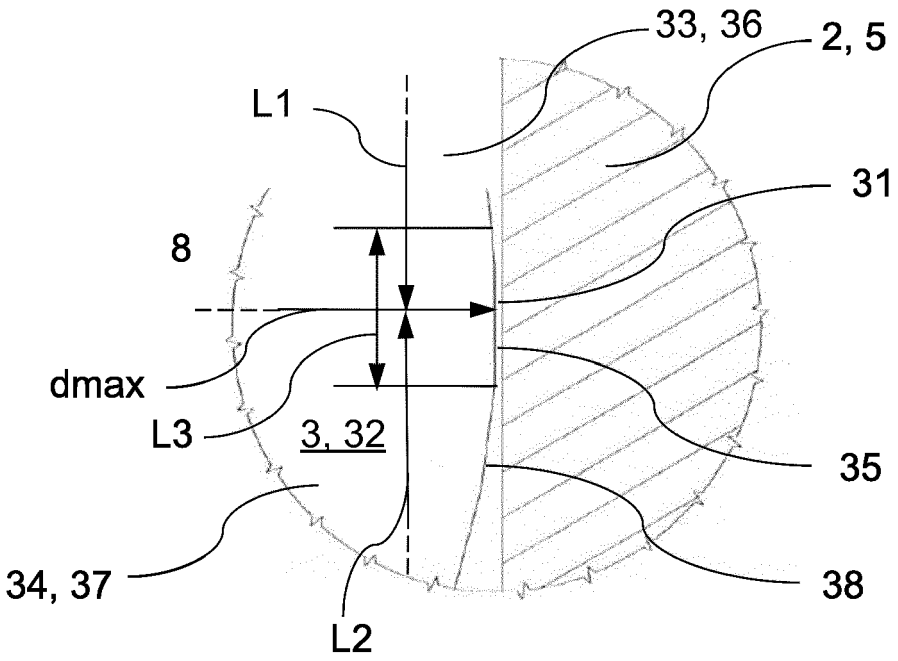


Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 3463

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 September 2014	Landriscina, V

CATEGORY OF CITED DOCUMENTS

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