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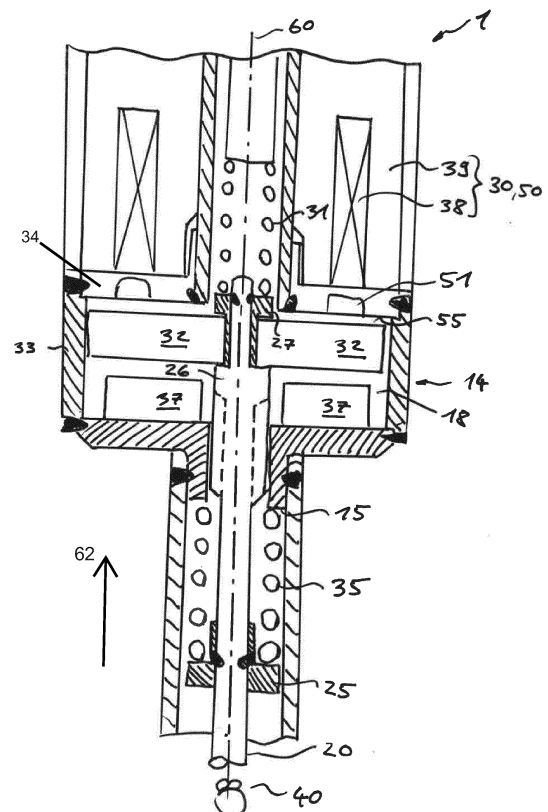
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(54) **Injection valve**

(57) Injection valve (1) for an automotive engine comprising:

- a valve body (14) comprising a cavity (18) and a fluid outlet portion (40),
- a valve needle (20) axially movable in the cavity (18), the valve needle (20) preventing a fluid flow through the fluid outlet portion (40) in a closing position and displaceable in an opening direction (62) along a longitudinal axis (60) to other positions for releasing the fluid flow through the fluid outlet portion (40),
- an electro-magnetic actuator unit (30) being configured to actuate the valve needle (20), wherein the actuator unit (30) comprises
 - an armature (32) which is arranged in the cavity (18) and being axially moveable relative to the valve needle (20), the armature (32) being operable to move the valve needle (20),
 - an acceleration device (50) comprising a pole piece (34) which is arranged in the cavity (18) subsequent to the armature (32) in the opening direction (62), the acceleration device (50) being fixed to the cavity (18) and being operable to move the armature (32) by applying a magnetic force,
 - a deceleration device (35) being arranged in the cavity (18), the deceleration device (35) being configured to dampen or to avoid an impact of the armature (32) onto the pole piece (34).

FIG 5



Description

[0001] The invention relates to an injection valve.

[0002] An object of the invention is to create an injection valve which facilitates a reliable and precise functioning of the injection valve.

[0003] This object is achieved inter alia by the features of the independent claim. Advantageous embodiments of the invention are given in the dependent claims.

[0004] According to at least one embodiment, the injection valve comprises a valve body. The valve body is preferably the mechanically stabilizing part of the injection valve. The valve body comprises a cavity and a fluid outlet portion. In particular, the valve body hydraulically couples a fluid inlet portion to the fluid outlet portion via the cavity.

[0005] According to at least one embodiment, the injection valve comprises a valve needle. The valve needle is axially movable in the cavity. In a closing position, the valve needle prevents a fluid flow through the fluid outlet portion. In other positions, the valve needle allows the release of the fluid flow through the fluid outlet portion. The valve needle is in particular displaceable in an opening direction along a longitudinal axis to the other positions for releasing the fluid flow through the fluid outlet portion.

[0006] According to at least one embodiment, the injection valve comprises an electro-magnetic actuator unit being configured to actuate the valve needle. Preferably, by means of the actuator unit the valve needle can be moved reversibly, i.e. in reciprocating fashion.

[0007] The injection valve may be an inward opening injection valve in one embodiment. In this case, the opening direction is in particular directed from the fluid outlet portion towards the fluid inlet portion, i.e. against the direction of the fluid flow. In an alternative embodiment, the injection valve is an outward opening injection valve. In this case, the opening direction is in particular directed from the fluid inlet portion towards the fluid outlet portion, i.e. in the same direction as the direction of the fluid flow.

[0008] According to at least one embodiment, the actuator unit comprises an armature which is arranged in the cavity. The armature is axially moveable relative to the valve body and also relative to the valve needle. The armature is designed to move the valve needle. The armature is at least temporarily in direct contact with the valve needle. The valve needle in particular has a top part which may also be denoted as an armature retainer. The armature is preferably operable to engage the top part for moving the valve needle. In particular, the armature is formed like a disk with a central hole, the valve needle being fed through said hole. The armature retainer may expediently overlap with the armature in top view along the longitudinal axis.

[0009] According to at least one embodiment, the actuator unit comprises an acceleration device. The acceleration device may comprise a pole piece. The pole piece is preferably arranged in the cavity subsequent to the

armature in the opening direction. For example and in particular in case of an inward opening valve, the acceleration device, in particular at least its pole piece, may be arranged in the cavity on a side of the armature remote from the fluid outlet portion. Preferably, the acceleration device is fixed to the valve body so that there is no relative movement between the valve body and the acceleration device. The acceleration device can be free of moving parts. By way of example, the acceleration device comprises or is composed of an electro-magnet. The acceleration device is operable to move the armature by applying a magnetic force to the armature.

[0010] That the pole piece is arranged in the cavity also encompasses a configuration in which the pole piece is comprised by the valve body and contributes to hydraulically sealing the cavity of the valve body against the surrounding of the injection valve or against other components of the injection valve. In this case, the pole piece is in particular inserted into another part of the valve body. In any case, the acceleration device preferably has at least one surface which faces towards the armature and towards which the armature is attracted when the electromagnetic-actuator unit is energized. This surface is briefly denoted as stop face in the following. The stop face may expediently be arranged in the cavity or constitute a surface region of the cavity.

[0011] According to at least one embodiment, the actuator unit comprises a deceleration device which is preferably arranged in the cavity. The deceleration device is configured to dampen or to avoid an impact of the armature onto the acceleration device, in particular onto the pole piece, for example onto the stop face. In other words, the deceleration device is designed to prevent a so-called hard stop of the armature. According to at least one embodiment, the deceleration device comprises a spring. The spring may be located on a side of the armature remote from the pole piece. For example and in particular in case of an inward opening injection valve, the spring is preferably located between the armature and the fluid outlet portion. By way of example, the spring has a spring constant of at least 50 N/mm or 100 N/mm and/or at most 200 N/mm or 400 N/mm.

[0012] According to at least one embodiment, the spring is fixed between a body rest and a needle rest. In this case, the body rest is a part of the valve body which is located between the armature and the spring. In particular, the body rest completely surrounds the spring. The needle rest is fixed onto the needle or is a part of the needle. The needle rest may be fixed on a side of the spring remote from the body rest. For example and in particular in case of an inward opening injection valve, the needle rest is preferably located between the spring and the fluid outlet portion.

[0013] According to at least one embodiment, in the closing position the spring of the deceleration device has a pre-stressing of at least 7.5 N or 10 N and/or of at most 20 N or 15 N. The pre-stressing can be tensile or compressive. The injection valve has, in one embodiment,

an additional calibration spring for forcing biasing the valve needle towards the closing position and to retain the valve needle in the closing position when the actuator unit is de-energized.

[0014] According to at least one embodiment, a speed of the armature at the acceleration device - in particular at that longitudinal position where the armature comes into contact with the stop face - is reduced to at most 50% or preferably to at most 20% or more preferably to at most 10% of a maximum speed of the armature by means of the deceleration device. In a preferred embodiment however, the deceleration device is designed to prevent a direct contact between the armature and the acceleration device in the intended use of the injection valve. In particular the deceleration device is operable to prevent a direct contact between the armature and the pole piece throughout the operation of the injection valve. In other words, the injection valve is configured in such fashion by means of the deceleration device that the armature remains spaced apart from the stop face in a fully open configuration of the injection valve.

[0015] According to at least one embodiment, the actuator unit comprises at least one permanent magnet which is preferably arranged between the armature and the deceleration device in an axial direction along the valve needle. The permanent magnet is in particular operable to bias the armature in a direction away from the armature retainer of the valve needle. In this way, the permanent magnet may advantageously contribute to set a predefined idle stroke of the armature before engaging with the armature retainer for moving the valve needle away from the closing position.

[0016] According to at least one embodiment, the armature is or comprises a permanent magnet. In one development, the acceleration actuator unit comprises the permanent magnet and the armature is or comprises a further permanent magnet.

[0017] According to at least one embodiment, the acceleration device comprises at least one electro-magnet with a coil and a core. The coil and the core may be arranged on a side of the pole piece remote from the armature, wherein the pole piece may be an individual part adjacent to the core and in particular adjoining the core or the pole piece may be an axial end portion of the core which is in one piece with the core. For example and in particular in the case of an inward opening valve, the coil and the core are preferably arranged on a side of the armature remote from the fluid outlet. Moreover, the coil and/or the core are preferably formed symmetric to an axis along which the valve needle can be moved.

[0018] According to at least one embodiment, the core comprises or consists of at least one soft magnetic composite. The soft magnetic composite is preferably composed of metal powder particles with an electrically isolating surface.

[0019] According to at least one embodiment, the core is of a U-shape or of a double U-shape when seen in a cross-sectional view. The legs of the at least one U are

preferably oriented parallel with the valve needle and in particular the longitudinal axis. An open end of the U can face the armature. In this way, each of the legs may, for example, correspond to one magnetic pole so that a particular efficient force transfer to the armature is achievable.

[0020] According to at least one embodiment, the valve body comprises a non-magnetic shell which is arranged around the armature when seen in a radial direction. In other words, the non-magnetic shell extends circumferentially around the armature. In this way, parasitic magnetic flux may be particularly small.

[0021] According to at least one embodiment, in the closing position the armature rests on a supporting part of the valve needle. The supporting part is preferably located on a side of the armature facing away from the pole piece. For example and in particular in case of an inward opening injection valve, the supporting part is located on a side of the armature facing the fluid outlet portion. In the closing position, the armature is preferably distant from a top part of the valve needle. The armature is in particular operable to engage the top part in order to move the valve needle in the opening direction for opening the injection valve. For example and in particular in case of an inward opening injection valve, the top part is on a side of the armature remote from the fluid outlet portion.

[0022] According to at least one embodiment, the acceleration device is designed to accelerate the armature from the supporting part to the top part in order to move the valve needle and in order to open the injection valve.

[0023] According to at least one embodiment, the injection valve is designed for high-pressure applications with a fluid pressure between 350 bar and 500 bar, inclusive.

[0024] According to at least one embodiment, the acceleration device and/or the armature is/are free of a chrome plating.

[0025] Exemplary embodiments of the invention are explained in the following with the aid of schematic drawings. Elements of the same design and function that appear in different illustrations are identified by the same reference character.

[0026] In the Figures:

Figure 1 shows a sectional view of an injection valve according to the prior art,

Figure 2 shows a flow sensitivity curve of an injection valve according to the invention,

Figure 3 shows a flow rate curve and an associated Timapping of an injection valve according to the invention,

Figure 4 shows a dependency of a current versus the time and a lift sensitivity curve of an injection valve according to the invention, and

Figure 5 shows a sectional view of an injection valve according to the invention.

[0027] Currently, the injector design as shown in Figure 1 uses the so-called free lift concept to improve the capability to activate at very high pressure. The free lift concept uses the momentum of an armature 32 to generate a hammering opening of a valve needle 20 (also referred to as kick effect) to overcome a hydraulic load on a seat especially at high pressures of e.g. 350 bar to 500 bar. The initial needle speed, based on this concept, is relatively high and this is very important for a fuel spray preparation at an initial opening transient of the valve 1.

[0028] Due the fact that an electro-magnet 36, also referred to as a solenoid, is active during the opening transient after the armature needle kick event, a magnetic force sustains the motion of the armature 32 and consequently the travelling of the needle 20 with an additional acceleration up to a kind of hard stop for stroke. The presence of the hard stop at a stop face 55 that limits the armature 32 travelling (the so-called lift) creates a bounce that affects the linearity behavior of a Ti mapping (flow rate versus activation time Ti) as an s-shaped region occurs.

[0029] However, due to increasingly stringent requirements the solenoid injector must be controllable with or without the mechatronic approach in order to deliver very small fuel quantities.

[0030] In addition, the hard stop creates a hydraulic sticking force after a bounce between the armature 32 and the stop faces 55 of a pole piece 34 with an additional delay in a closing event with respect to an electrical switch-off signal. This behavior can change during the lifetime of the valve 1 because wearing of the surfaces involved in the hard stop concept, so that a significant deviation of the flow rate versus time, is expected.

[0031] To get a traditional hard stop in that design, both armature 32 and pole faces 55 have to be chromed to increase the hardness and minimize the wearing. Actual actuators use standard magnetic stainless steels (e.g. 430SS, i.e. in particular stainless steel having the SAE grade 430) as magnetic materials with a relatively high eddy current effect because of a bulk electrical conductivity. For this reason it is not easy to accurately control the magnetic force versus the needle position by the electronics in real time and, as a consequence, the flow mass for very low quantities especially into the ballistic operating range.

[0032] Thus, the multiple injection strategy suffers from the relatively long demagnetization transient time related to the presence of an eddy current, too. This can limit separation time among activations and, hence, also a number of multiple injections for each engine cycle.

[0033] In the design in Figure 1, the armature 32 is located between a hydro disc 26 (also referred to as supporting part) and an upper guide 27 (also referred to as top part or armature retainer). The hydro disc 26 and the upper guide 27 are welded onto the needle 20 so all these

bodies 20, 26, 27 can move together. The armature 32 has a free space between the hydro disc 26 and the upper guide 27 to generate the momentum and the kick effect on the needle 20 when the solenoid 36 is activated. The armature 32 starts to move from a lower position (in contact with the hydro disc 26) because of the presence of a permanent magnet 37 located at a bottom side of the armature 32. This permanent magnet 37 generates a continuous pulling force to maintain a stable position of the armature 32 without any solenoid activation.

[0034] The armature's overall force $F_{tot}(t)$ into the free lift space in dependence on the time t provides the momentum to support the hammering effect applying a solenoid current as the following dynamic equation:

$$\int_0^{T@kick} F_{tot}(t) dt = m_A v_{T@kick}$$

[0035] Here, m_A is the armature mass and $v_{T@kick}$ is its speed at the contact event. This momentum generates an initial speed to the needle 20 to overcome the pressure of the fuel and to improve a spray preparation at an initial opening transient. For example, the injection valve of Figure 1 uses a common stainless steel as a core material in the electro-magnet 36. However, this does not support a fast demagnetization process and multiple injection applications are difficult to realize.

[0036] The injector design of Figure 1 supports a final damping and, thus, a speed reduction of the armature 32 before the contact (hard stop) because of a squish effect between the flat surfaces of the pole piece 34 and the armature 32. The larger the surfaces, the higher the damping effect, in particular in the last 5 to 10 μm before contact. However, this approach cannot guarantee a good stability over population because of the complexity involved in fixing the parallelism of the stop faces 55 to gain the best damping effect and a complete elimination of the armature bounce. Another problem of this approach is related to the sticking hydraulic effect in the closing behavior with a delay to close the valve 1 and, thus, an increase of the mass flow associated to a specific activation time. Other approaches provide special armature geometries with dynamic pressure drop fixtures to get the damping (holes, slots and so on); these fixtures increase the cost of the product.

[0037] The present invention proposes to solve the above-mentioned problems in particular with the following design factors, that can be combined, see also Figure 5:

- using an improved flow sensitivity curve of a generic multi-holes inward injector,
- using a core material for the electro-magnet 30 with an improved magnetic characteristic,

- using a deceleration device 35, e. g. in the form of a secondary spring with high stiffness, in order to eliminate the hard stop concept,
- using a permanent magnet 37 to support the free lift concept, and/or
- using a non-magnetic shell 33 around the armature 32 to support the injector mechanical structural resistance at high pressures.

[0038] More specifically, the injection valve 1 has a valve body 14 defining a cavity 18. A valve needle 20 is arranged in the cavity 18 extending along the longitudinal axis 60 from a needle ball at the fluid outlet portion 40 of the fluid injection valve 1 to an armature retainer 27 at an opposite longitudinal end. An armature 32 is shifted over the valve needle 20 so that it is movable along the longitudinal axis 60 with respect to the valve needle 20 between the armature retainer 27 and a supporting part 26. Expediently, the armature 32 is also axially displaceable with respect to the valve body 14.

[0039] The injection valve 1 has an electromagnetic actuator unit 30 which comprises the armature 32 and an acceleration device 15 comprising a coil 38, a core 39 and a pole piece 34. The pole piece 34 is comprised by the valve body 14 in the present embodiment. More specifically, it is inserted into the non-magnetic shell 33 of the valve body 14 and welded thereto in a fluid tight manner so that it hydraulically separates the armature 32 from the coil 38 and the core 39, both of which are arranged adjacent to the pole piece 34 on a side of the pole piece 34 facing away from the armature 32 outside of and surrounding the valve body 14.

[0040] A permanent magnet 37 is arranged in the cavity 18 on the side of the armature 32 facing away from the pole piece 34. Also the permanent magnet 37 may be laterally surrounded by the non-magnetic shell 33.

[0041] The pole piece 34 has a non-magnetic inlay 51 laterally overlapping the coil 38. Radially inward and radially outward of the non-magnetic inlay 51, the pole piece 34 comprises a magnetic material such as ferritic steel and in particular overlaps the core 39 laterally. For example, opposite magnetic poles may be achievable radially inward and radially outward of the non-magnetic inlay 51, respectively, in this way.

[0042] When the electromagnetic actuator unit 30 is energized, the coil 38 generates a magnetic field which is shaped by the core 39 and the pole piece 34 and attracts the armature 32 towards the pole piece 34, in particular towards a stop face 55 of the pole piece 34. By means of interaction via the armature retainer 727, the armature 32 is operable to take the valve needle 20 with it in direction towards the pole piece 34, which in the present embodiment is the opening direction 62 that is directed from the fuel outlet portion 40 towards a fuel inlet and of the injection valve 1 opposite of the fuel outlet portion 14 with respect to the longitudinal axis 60. Before coming into engagement with the armature retainer 27, the armature 32 travels - with respect to the valve body

14 and the valve needle 20 - for an idle stroke in the opening direction 62 from a position in which it abuts on the supporting part 26 towards which it is biased by means of the permanent magnet 37.

[0043] The injection valve 1 according to the present embodiment has two springs, a calibration spring 31 and a further spring acting as deceleration device 35. The calibration spring 31 bears on the armature retainer 27 at one axial end whereas the second axial end of the calibration spring 31 bears on a spring seat which is fixed with respect to the valve body on the side of the valve needle 20 remote from the fuel outlet portion 40. The deceleration device 35 abuts a body rest 15 which is positionally fixed to the valve body 14 on the side of the armature 32 remote from the armature retainer 27 and on a needle rest 25 which is fixed to the needle 20 on the side of the body rest 15 remote from the armature 32. The armature 32 is operable to move the valve needle 20 out of its closing position and in the opening direction 62 against the bias of the calibration spring 31 and of the deceleration device 35.

[0044] The flow sensitivity curve of a multi-holes injector (see Figure 2) can be used to reduce or to eliminate the dependence of the flow with respect to the needle/ball stroke also without the presence of a hard stop. The needle lift, depending to the injector application, can be chosen in the range of 90 μm to 100 μm or higher to minimize the sensitivity of the multi-holes flow rate with respect to the effective needle lift.

[0045] Using the free lift concept and the hammering effect to support the high pressure opening capability in combination with the deceleration device 35 consisting of a spring with a high stiffness i.e. between 100 N/mm and 200 N/mm, it is possible to guarantee the best time evolution of the instantaneous flow rate and the Ti-mapping without the S-shape formation. A gradient of that curve also into the ballistic area can be smoothed for better electronic control. Final needle stroke (and related flow rate across the multi-holes) is determined, due to the Hooke law, by the following equation:

$$Needle_{STROKE} = \frac{F_{tot}(I_{hold}, P, F_0)}{K_{springVB}}$$

[0046] In this equation, F_{tot} is the net force over the armature, supporting the needle position depending to the electrical current I_{hold} , the pressure P of the fluid, and the calibration condition of the static two springs 31, 35 force, compare Figure 2. A typical flow instantaneous flow rate curve and associated Ti-mapping in this condition can be represented with a lot of benefit in terms of linearity behaviors and Q_{dmin} control, see Figure 3.

[0047] In the schematic representation of Figure 3, left side, OPP1 is the opening valve event, OPP2 is the maximum needle stroke, OPP3 is the starting point of the

back motion, and OPP4 is the closing valve event.

[0048] For the core 39 of the electro-magnet 30 of the acceleration device 50, so-called Somaloy is preferably used. Somaloy is an SMC (soft magnetic composite) that can be used in dry conditions to avoid chemical attack of aggressive liquids, the base powdered is pure iron with nano-coating obtained by oxidation that drastically increases the macro electrical resistivity with limitation of eddy current effect. The housing can be formed by pressing to get a three-dimensional body, in particular with a lubricant to minimize friction. A post-annealing at 500°C can normalize the three-dimensional magnetic properties and can minimize internal residual postpress stresses. Thus, very good magnetic properties with low demagnetization times can be achieved.

[0049] By the use of these Somaloy materials in particular in combination with a U-shaped core 39 (when seen in a cross-sectional view, see Figure 5), a good phasing of a peak of a current during boost phase and the hammering effect of the armature 32 to open the valve 1 at maximum speed of the armature 32 for better spray preparation can be achieved, see Figure 4A. An initial distance between the armature 32 and the stop face 55 of the pole piece 34, including the free lift, can be set for example at 200 μm +/- 100 μm or +/- 50 μm .

[0050] The free lift can be set, for example, at 50 μm +/- 25 μm or +/- 10 μm . The permanent magnet 37 can be used to support the initial armature position (static magnetic force on the armature 32). After the armature-needle contact event, the electrical current can be free-wheeled to hold a level to balance the net force over the armature 32. The valve spring 35 increases its contrast with the maximum value at the final armature position that can be designed into the non-sensitive area of the flow curve with respect to the needle position, see Figure 4B. In this way, the flow rate after the opening transient can be stabilized for the rest of the activation time with a minimum sensitivity with respect to the current profile level, magnetic path and valve spring tolerances, for example if the needle stroke is in the range of 100 μm in accordance with Figure 4B. A calibration spring 31 can be used to minimize the piece-to-piece flow variation in the population as a normal way to calibrate the solenoid injector.

[0051] The elimination of the hard stop in this design, preferably in combination with the Somaloy material in the electro-magnet 30, provides a fast closing because there is no sticking between the armature 32 and the pole piece 34. Preferably, the design avoids any contact between the pole piece 34 and the armature 32, also at fully opened valve 1. In particular, the armature 32 is spaced apart from the stop face 55 throughout the operation of the injection valve. A fast demagnetization process for better supporting the multiple injection capability and the reliability of the product over its lifetime, because of the elimination of wear between the armature 32 and the pole piece 51 due to the contact degradation (that is present also with chrome layer deposition over the pole faces),

can be achieved.

[0052] The lifetime of this injection valve 1 is improved also because all magnetic forces (in particular from the coil 38 and from the permanent 37 magnet) can act on the armature 32 only in an axial direction along an axis 60 without radial effect because the external shell 33 is made from a non-magnetic material like stainless steel 316SS, i.e. in particular stainless steel having the SAE steel grade 316. So a reduced friction on the moving parts is also achieved.

[0053] In this design with the proposed Somaloy U-shaped core 39 in combination with the free lift concept supported by the permanent magnet 37, a relatively high pulling force (i.e. 5 N to 7 N), to maintain a stable original position of the armature 32 without solenoid activation and better support of the repeatability of the actuations under work conditions, can be realized. This relatively high force, derived from the permanent magnet 37, also improves the "no bounce" at closing event OPP4. The elimination of the hard stop concept and associated chrome plating also reduces environmental pollution.

[0054] Thus, the combination of the above-mentioned design parameters can improve the performances of the multi-streaming (multi-holes) injector 1 of Figure 2 with benefits in terms of $Q_{d_{\min}}$ reduction, spray formation at opening transient, linearity behaviors and degradation over a lifetime for high pressure direct injector applications.

[0055] Hence, an actuator for a multi-holes inward opening application of the present invention is able to control a flow without a traditional hard stop with chrome plating for high pressure injector application (i.e. at 350 to 500 bar) with reduced degradation performances over the product lifetime.

[0056] An actuator to control the flow rate is realized in particular with the combination of a high performance magnetic material (i.e. from the Somaloy family) with a U-shape design and a double spring system with one spring (i.e. the spring of the deceleration device 35) with a high stiffness of preferably > 100 N/mm) used to stop the motion at final stroke. The flow sensitivity characteristic curve of the multi-holes benefits from the dismissal of the hard stop concept for high pressure applications.

[0057] The combination of the free lift concept realized with the support of a permanent magnet 37 and the high spring stiffness to support the instantaneous flow rate shape to avoid the Ti-mapping S-shape, achieves good spray behaviors at the opening phase and better supports the $Q_{d_{\min}}$ capability for high pressure application (i.e. 350 bar to 500 bar). The U-shaped housing design in combination with the external non-magnetic shell 33 can avoid radial magnetic forces, preferably in combination with a permanent magnet 37 to act in axial direction on the armature 32.

[0058] The combination of the previous design parameters can support the catalyst heating strategy, too. The combination of the previous design parameters can serve for both stratified and homogenous multiple injections

strategy.

[0059] These design aspects can be used for direct multi-streaming injector applications with a solenoid actuator at pressures of less than 350 bar, too, as well as for low pressure indirect injector applications.

[0060] The invention is not restricted to the exemplary embodiments by the description on the basis of said exemplary embodiments. Rather, the invention encompasses any new feature and also any combination of features which, in particular, comprises any combination of features in the patent claims and any combination of features in the exemplary embodiments, even if this feature or this combination itself is not explicitly specified in the patent claims or exemplary embodiments.

Claims

1. Injection valve (1) for an automotive engine comprising:

- a valve body (14) comprising a cavity (18) and a fluid outlet portion (40),
- a valve needle (20) axially movable in the cavity (18), the valve needle (20) preventing a fluid flow through the fluid outlet portion (40) in a closing position and displaceable in an opening direction (62) along a longitudinal axis (60) to other positions for releasing the fluid flow through the fluid outlet portion (40),
- an electro-magnetic actuator unit (30) being configured to actuate the valve needle (20),

wherein the actuator unit (30) comprises

- an armature (32) which is arranged in the cavity (18) and being axially moveable relative to the valve needle (20), the armature (32) being operable to move the valve needle (20),
- an acceleration device (50) comprising a pole piece (34) which is arranged in the cavity (18) subsequent to the armature (32) in the opening direction (62), the acceleration device (50) being fixed to the cavity (18) and being operable to move the armature (32) by applying a magnetic force,
- a deceleration device (35) being arranged in the cavity (18), the deceleration device (35) being configured to dampen or to avoid an impact of the armature (32) onto the pole piece (34).

2. Injection valve (1) according to the preceding claim, wherein the deceleration device (35) comprises a spring located on a side of the armature (32) remote from the pole piece (34), the spring having a spring constant between 100 N/mm and 400 N/mm, and wherein the spring is fixed between a body rest (15) and a needle rest (25),

the body rest (15) being a part of the valve body (14) located between the armature (32) and the spring, and the needle rest (25) being fixed onto the needle (20) on a side of the spring remote from the body rest (15).

3. Injection valve (1) according to the preceding claim, wherein the spring is located between the armature (32) and the fluid outlet portion (40) and the needle rest (25) is fixed onto the needle between the spring and the fluid outlet portion (40).

4. Injection valve (1) according to claim 2 or 3, wherein in the closing position the spring of the deceleration device (35) has a pre-stressing of between 7.5 N and 20 N, inclusive.

5. Injection valve (1) according to any one of the preceding claims, wherein the deceleration device (35) is operable to prevent a direct contact between the armature and the pole piece (34) in the intended use of the injection valve (1).

6. Injection valve (1) according to any one of the preceding claims, wherein the actuator unit (30) comprises at least one permanent magnet (37) which is arranged between the armature (32) and the deceleration device (35) in an axial direction along the valve needle (20).

7. Injection valve (1) according to the preceding claim, wherein the armature (32) is or comprises a permanent magnet.

8. Injection valve (1) according to any one of the preceding claims, wherein the acceleration device (50) comprises at least one electro-magnet (36) with a coil (38) and a core (39), wherein the coil (38) and the core (39) are arranged on a side of the pole piece (32) remote from the armature (30).

9. Injection valve (1) according to the preceding claim, wherein the core (39) comprises or consists of a soft magnetic composite which is composed of metal powder particles with an electrically isolating surface.

10. Injection valve (1) according to claim 8 or 9, wherein the coil (38) and the core (39) are formed symmetrically with regard to the longitudinal axis (60) along which the valve needle (20) can be moved.

11. Injection valve (1) according to the preceding claim, wherein the core (39) is of a U-shape or of a double U-shape when seen in a cross-sectional view.

12. Injection valve (1) according to any one of the preceding claims,
wherein the valve body (14) comprises a non-magnetic shell (33) which is arranged around the armature (32) when seen in a radial direction. 5
13. Injection valve (1) according to any one of the preceding claims,
wherein, in the closing position, the armature (32) rests on a supporting part (26) of the valve needle (20), the supporting part (26) is located on a side of the armature (32) facing away from the pole piece (34), 10
wherein in the closing position the armature (32) is distant from a top part (27) of the valve needle (20), 15
wherein the acceleration device (50) is designed to accelerate the armature (32) from the supporting part (26) to the top part (27) and
wherein the armature (32) is operable to engage the top part (27) in order to move the valve needle (20) 20
in the opening direction (62) for opening the injection valve (1).
14. Injection valve (1) according to any one of the preceding claims, 25
wherein the injection valve (1) is designed for high-pressure application with a fluid pressure between 350 bar and 500 bar,
15. Injection valve (1) according to any one of the preceding claims, 30
wherein the acceleration device (50) and/or the armature (32) is free of a chrome plating.

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FIG 1

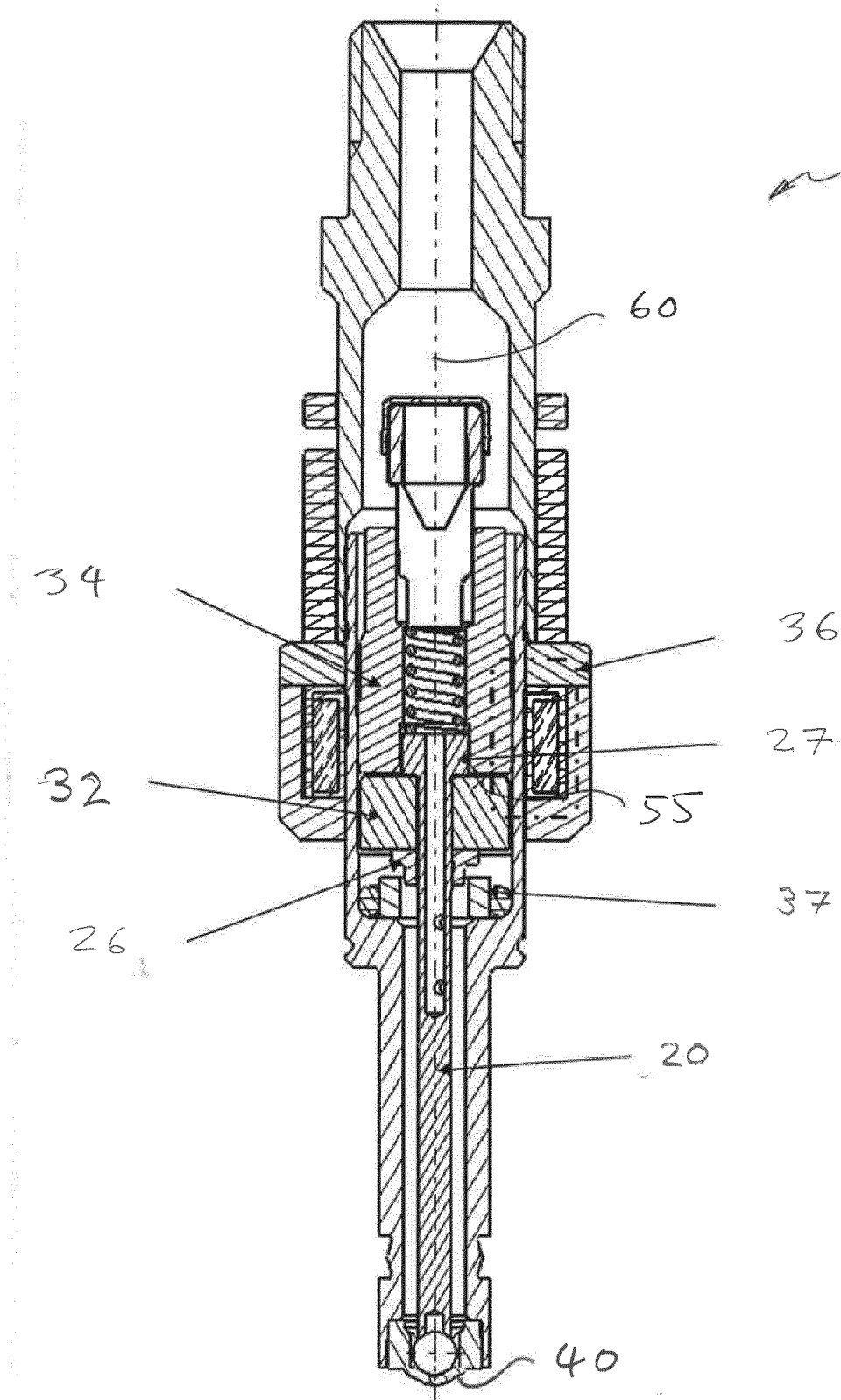


FIG 2

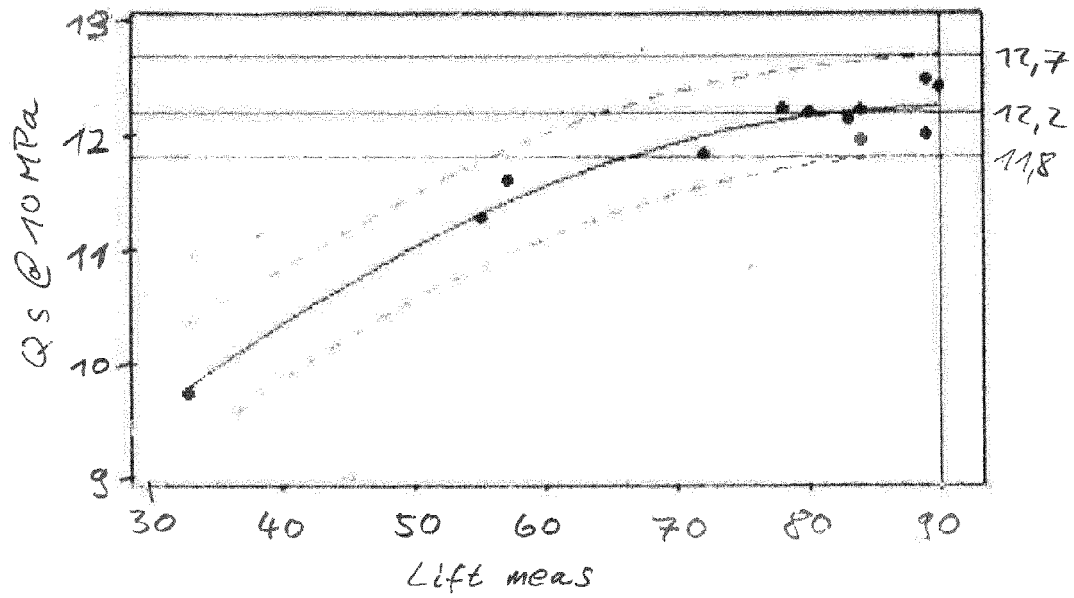


FIG 3

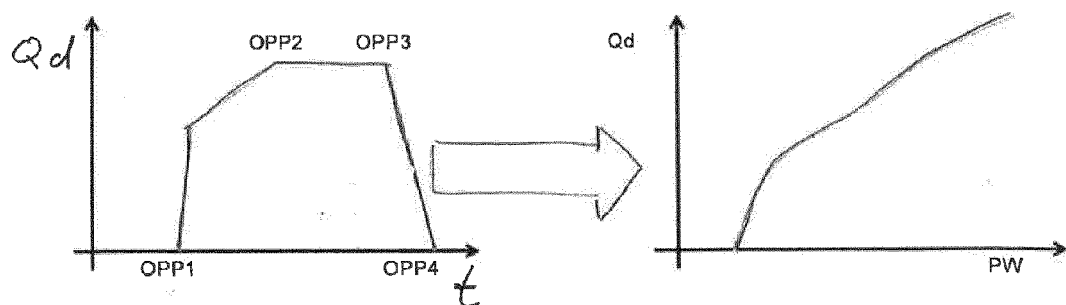


FIG 4

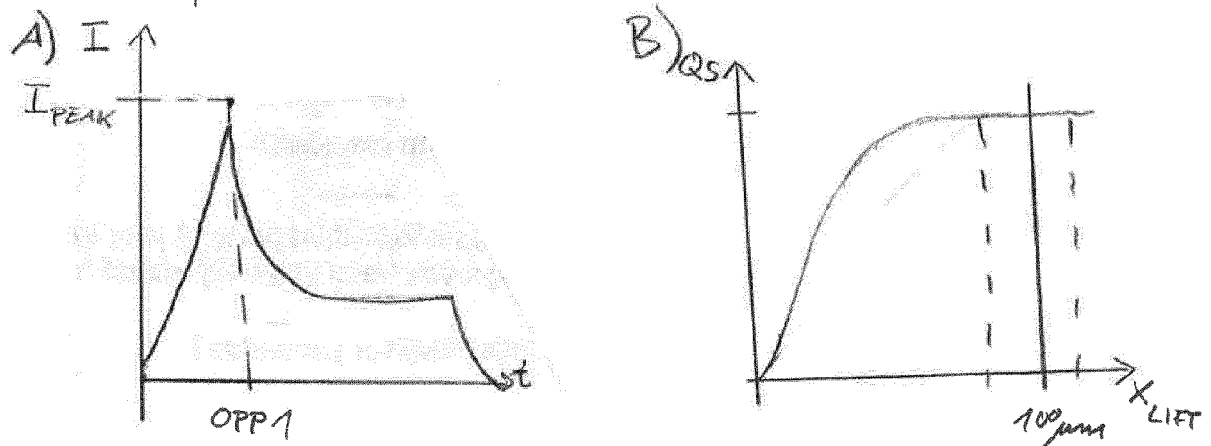
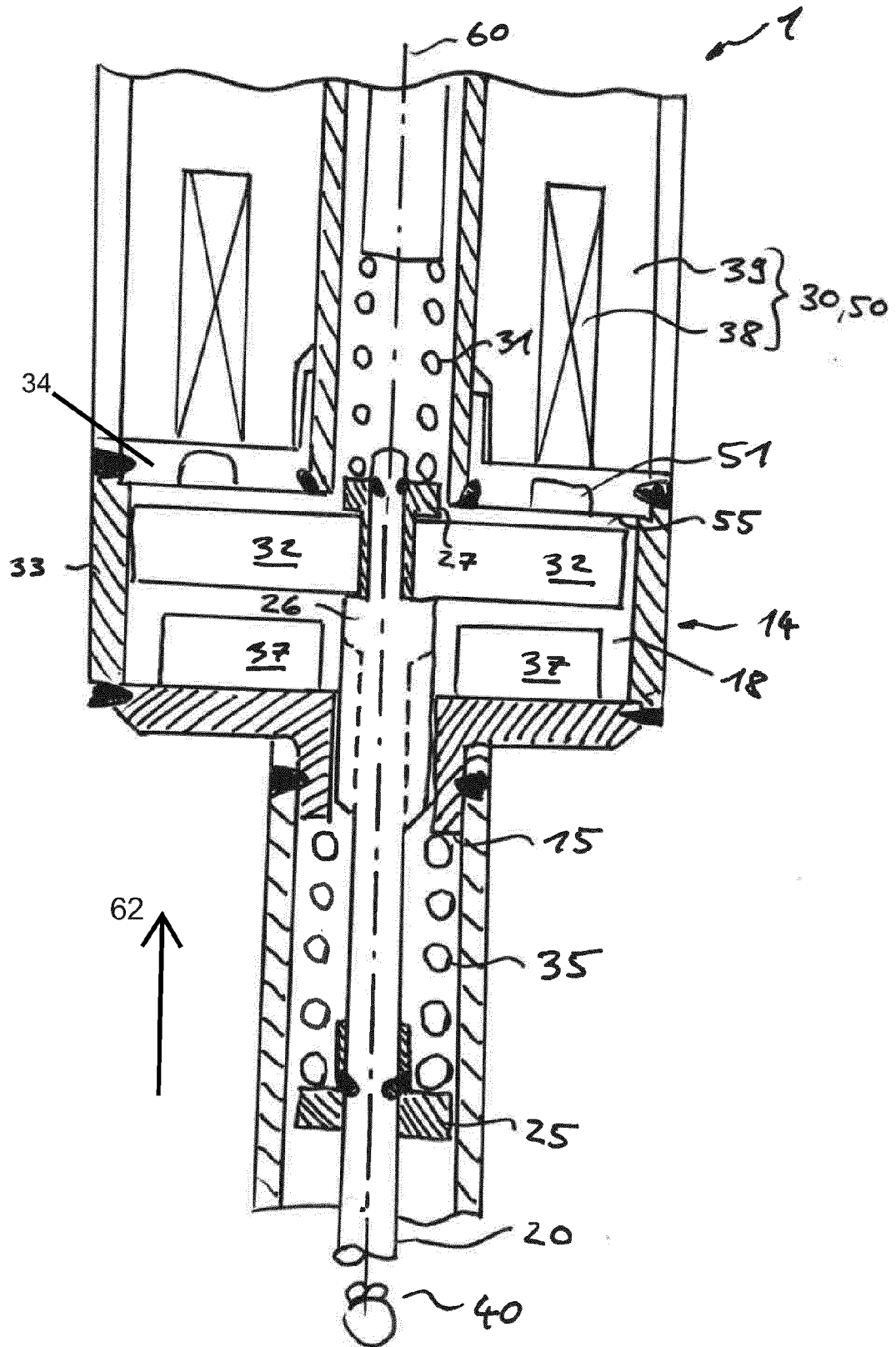


FIG 5





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