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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 which comprises a housing (2), an electromagnetic actuator with an armature (20) and a valve needle (4). The armature (20) is axially movable relative to the housing (2) and to the valve needle (4) and has a recess (36). The valve needle (4) comprises a stopper element (38) being positioned in the recess (36) of the armature (20). The stopper element (38) and the recess (36) are configured such that the stopper element (38) is operable to engage into a form-fit connection with the armature (20) for initiating a movement of the valve needle (4) and to engage in a further form-fit connection with the armature (20) for limiting a movement of the valve needle (4) relative to the armature (20).

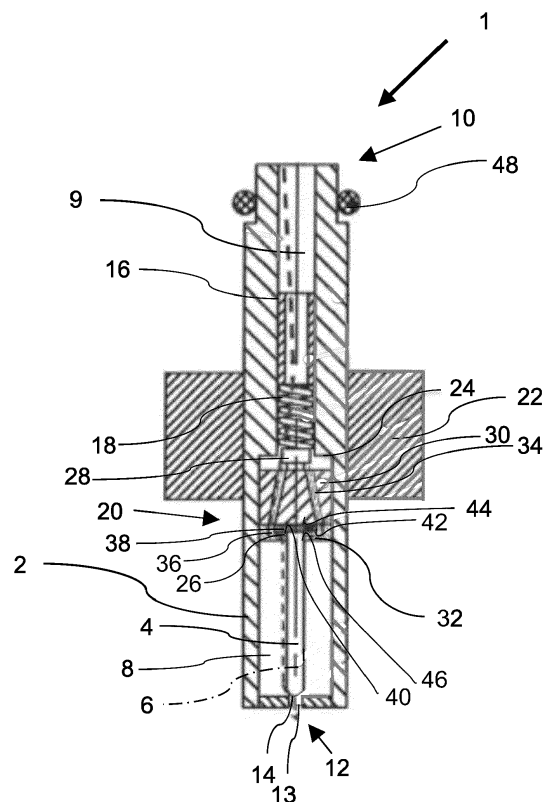


Fig. 1

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 an electromagnetic actuator having a magnetic coil which is chargeable by electricity to generate a magnetic field, a magnetizable armature which may be combined with a valve needle, will be stimulated for movement. Normally, the movement is an axial movement along a valve axis of the valve.

[0003] If the valve needle and the armature are coupled, the valve needle also starts moving due to the movement of the armature. Depending on the direction of the armature's movement, a nozzle orifice may be opened or closed with the aid of the valve needle. In order to ensure that the nozzle orifice is opened exactly only for certain times during the injection process, a valve spring is normally positioned in the fuel injection valve, which urges the valve needle against the nozzle orifice. This means, that the valve needle has to be moved by the aid of the armature against the spring force of the valve spring, when the nozzle orifice is to be opened. When the nozzle orifice is open, a fuel quantity positioned in the fuel injection valve can flow through the nozzle orifice into a combustion chamber, normally a combustion chamber of an internal combustion engine.

[0004] A problem of fuel injection valves in the state of the art is a so-called overshoot of the valve needle. The valve needle is detachably coupled with the armature. Due to an impact of the armature with the stop element, the valve needle and the armature decouple and the valve needle may move without being contacted to the armature. So an extraordinary lift is initiated, also called needle overshoot. More fuel as expected may be sprayed into the combustion engine due to the needle overshoot.

[0005] A combustion process of the internal combustion engine depends among several other criteria, e.g. fuel quantity or fuel temperature or fuel pressure, on the opening and closing of the nozzle orifice. Therefore, an exactly defined opening and closing of the nozzle orifice are very important for reaching a desired power rate, fuel consumption or emissions of the internal combustion engine.

[0006] The international application WO 2013/060717 A1 discloses a fuel injection valve for an internal combustion engine which comprises a valve body with a cavity and a valve needle being movably arranged in the cavity. A movable armature is positioned in the cavity and may axially move along a central longitudinal axis of the valve body. The moving is initiated by an electromagnetic actuator due to a magnetic field. The valve needle comprises a stop element fixed to the valve needle for coupling a movable armature with the valve needle. The stop element is arranged between an armature body of the armature and a flange of the armature. For enabling a contact of the stopper with the flange, an armature spring is provided between the armature body and the

stopper.

[0007] It is an object of the invention to specify a fuel injection valve which has a particularly predictable and/or precise injection behavior and/or a particularly simple construction.

[0008] 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.

[0009] A fuel injection valve for an internal combustion engine is specified. The fuel injection valve comprises a housing having a central longitudinal valve axis and a cavity with a fluid inlet portion and a fluid outlet portion. It further comprises a valve needle which is axially movable in the cavity.

[0010] The valve needle is operable to prevent fuel flow through the fluid outlet portion in a closing position of the valve needle and to allow fuel flow through the fluid outlet portion in opening positions of the valve needle. In particular, it is operable to prevent fuel flow through at least one injection nozzle of the fuel injection valve in the closing position and to allow fuel flow through the at least one injection nozzle in the opening positions. In one embodiment, the housing comprises the injection nozzle(s). In another embodiment, a needle tip of the valve needle forms the - in particular only - injection nozzle together with the fluid outlet portion. Expediently, the fuel injection valve comprises a valve spring which is operable to bias the valve needle towards the closing position.

[0011] The fuel injection valve comprises an electromagnetic actuator with a magnetic coil, an armature and a pole element. The armature is positioned in the cavity. It is axially movable relative to the housing and to the valve needle. The armature has a recess.

[0012] The valve needle comprises a stopper element. The stopper element is positioned in the recess of the armature. In one embodiment, the stopper element is disc-shaped or comprises a disc-shaped portion. The stopper element preferably extends circumferentially around a shaft of the valve needle. It may be fixed to the shaft or in one piece with the shaft. In one embodiment, the valve needle has a seat element at its axial end facing towards the fluid outlet portion and a spring seat at the opposite axial end. The valve spring may expediently bears on the spring seat. The stopper element is arranged at an axial position between the seat element and the spring seat and axially spaced apart from the seat element and the spring seat.

[0013] The stopper element and the recess are configured such that a movement of the valve needle can be actuated by the electromagnetic actuator. More specifically, the stopper element and the recess are configured such that the stopper element is operable to engage into a form-fit connection with the armature for initiating a movement of the valve needle and to engage in a further form-fit connection with the armature for limiting a movement of the valve needle relative to the armature. In other words, the armature extends around the stopper in such

fashion that an axial movement of the armature towards the pole element is transferable to the valve needle by the form-fit connection with the stopper element and an axial displacement of the valve needle relative to the armature in axial direction away from the closing position is limited by the further form-fit connection.

[0014] With advantage, the dynamics of the movement of the valve needle may be improved. Because of the movable embedding of the stopper element, the armature may be used for initiating the movement of the valve needle on the one hand. On the other hand the armature may be used for limiting the movement of the valve needle relative to the armature so that the overshoot may be reduced only by embedding the stopper element in the armature.

[0015] For manufacturing in a simple manner, the armature has a first armature body and a second armature body wherein the first armature body and the second armature body are fixed to each other and are shaped to form the recess between the first armature body and the second armature body. The armature bodies are fixedly coupled, for example by welding. In one embodiment, the recess in which the stopper element is received is provided in one of the first and second armature bodies. This enables an easy way of manufacturing the embedded stopper element in the armature.

[0016] In one embodiment, the recess is manufactured by milling in one of the armature bodies. The recess has to be manufactured on a side of the armature body which faces the other armature body so that the recess may be closed by the other armature body. The stopper element may solely move between the first armature body and the second armature body in the recess. So the possible needle overshoot may be particularly small. Also, due to the possibility of a precise dimensioning of the recess, the stopper element may axially move without getting stuck.

[0017] In an advantageous embodiment, the form-fit connection for initiating the movement of the valve needle is established between a second surface of the armature facing towards the pole element and a fourth surface of the stopper element facing away from the pole element, and the further form-fit connection for limiting the movement of the valve needle relative to the armature is established between a first surface of the armature facing away from the pole element and a third surface of the stopper element facing towards the pole element. To put it differently, the movement of the armature towards the pole element is transferred to the valve needle via the form-fit connection which is established between the armature and the stopper element at a side of the stopper element facing away from the pole element. The displacement of the valve needle relative to the armature is limited via the further form-fit connection which is established between the armature and the stopper element at a side of the stopper element facing towards the pole element.

[0018] In a further advantageous embodiment the sec-

ond surface and the fourth surface are planar. The advantage of such planar surfaces which contact each other for moving the valve needle is that a contact area of the surfaces may be enhanced. Therefore a pressure resulting from a weight of the valve needle may be distributed over the enhanced contact area and causes less wear. Preferably, the contact area of the second and fourth surfaces is at least 25 %, preferable at least 50 % of the area content enclosed by an outer contour of the stopper element in top view along the longitudinal axis. In this way, a satisfactory hydraulic damping of the movement of the valve needle relative to the armature is achievable when the displacement of the latter stops - e.g. in contact with the pole element - and the form-fit connection is released. A particularly good dynamic behaviour of the valve needle is achievable in this way. In particular, the impact of the valve needle on the armature when engaging into the further form-fit connection may be particularly soft.

[0019] In another further advantageous embodiment the first surface and the third surface are planar. Therefore a pressure between the armature and the stopper element is reduced due to the enhanced contact area between the stopper and the armature during the closing phase of the injection process. Preferably, the contact area of the first and third surfaces is at least 25 %, preferable at least 50 % of the area content enclosed by the outer contour of the stopper element in top view along the longitudinal axis. An advantageously large hydraulic damping is achievable in this way, for example leading to a particularly soft impact of the valve needle on the armature when the valve spring presses the valve needle into the form-fit engagement with the armature at the end of the needle overshoot.

[0020] In another preferred embodiment, the form-fit connection for initiating the movement of the valve needle is established between a contact surface of the armature facing towards the pole element and a contact surface of the stopper element facing away from the pole element. Said contact surfaces are in particular the above-mentioned second and fourth surfaces. The contact area of the contact surfaces has a surface roughness R_a which is equal to or less than $1.2\mu\text{m}$. Because of this surface roughness the hydraulic sticking between the contact surfaces may be particularly large.

[0021] When the armature reaches the stop element which is fixed to the housing or in one piece with the housing at the end of the opening transient, the maximum lift of the valve needle - apart from the overshoot - is achieved. The stop element is in particular the pole element or a further part of the fuel injection valve which is positionally fix with respect to the pole element. Due to the hit of the armature against the stop element, the valve needle, resp. the stopper element and the armature may decouple so that the valve needle travels between the first surface and the second surface. Due to the sticking between the contact surfaces, the travel may be reduced and/or delayed and/or damped or the stopper element

will not decouple of the armature so the overshoot at all. In particular, an increased adhesion area - in particular on a microscopic scale - is achieved by reducing the surface roughness. Due to the increased adhesion area, the overshoot may be particularly small or even avoided.

[0022] In a further preferred embodiment the stopper element comprises or consists of a magnetizable material, preferably a ferromagnetic material, which is in particular not a permanent magnetic material. While conventional fuel injection valve usually use non-magnetic steel grades for the valve needle parts, the magnetization of the magnetic stopper element and the magnetic armature causes an attractive magnetic force between the stopper element and the armature which reinforces the form-fit connection or the further form-fit connection, respectively, between the stopper element and the armature. The connection can only be released against said attractive magnetic force which leads to a damping of the needle movement relative to the armature or to a complete avoidance of the overshoot.

[0023] A martensitic material is preferred for the stopper element due to its hardness and strength. Hardness is needed because of the hit after decoupling. In an advantageous embodiment the stopper element is made out of a magnetic steel. In one embodiment, the stopper element comprises or consists of stainless steel having the steel grade AISI 440C.

[0024] 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.

[0025] In the figures:

Figure 1 is a longitudinal sectional view of a fuel injection valve according to an exemplary embodiment of the invention,

Figure 2 is a longitudinal sectional view of a cut-out of the fuel injection valve of Figure 1, with an armature-needle assembly of the fuel injection valve in a first position,

Figure 3 is a longitudinal sectional view of a cut-out of the fuel injection valve of Figure 1, with the armature-needle assembly in a second position,

Figure 4 is a longitudinal sectional view of a cut-out of the fuel injection valve of Figure 1, with the armature-needle assembly in a third position,

Figure 5 is a longitudinal sectional view of a cut-out of the fuel injection valve of Figure 1, with the armature-needle assembly in a fourth position, and

Figure 6 is a fuel-time-diagram of a fuel injection curve of a fuel injection valve.

[0026] Figure 1 shows an exemplary embodiment of a fuel injection valve 1 according to the invention. The fuel injection valve 1 may be used as a fuel injection valve for an internal combustion engine, in particular for dosing fuel directly into a combustion chamber of the engine. The fuel injection valve 1 according to the present embodiment is of the inward opening type. Alternatively, the injection valve 1 may be of the outward opening type.

[0027] The fuel injection valve 1 comprises a housing 2 having a longitudinal valve axis 6. The housing 2 has a cavity 8 which hydraulically connects a fluid inlet portion 10 to a fluid outlet portion 12 of the fuel injection valve 1. A valve needle 4 is movably arranged in the cavity 8 of

the housing 2. **[0028]** The cavity 8 extends axially through the housing 2 from the fluid inlet portion 10 to the fluid outlet portion 12. The fluid inlet portion 10 is configured for hydraulically coupling the fuel injection valve 1 to a fuel rail in which the fuel is stored under high pressure. For creating a seal between the fuel injection valve 1 and the fuel rail, a sealing element 48 is provided in the area of the fluid inlet portion 10, the sealing element 48 embracing the housing 2. At the fluid outlet end 12, the fuel injection valve 1 has an injection nozzle, in the following also denoted as nozzle orifice 13. Fuel coming from the fuel rail into the fluid inlet portion 10 may flow through the cavity 8 and leave the fuel injection valve 1 through the nozzle orifice 13 at the fluid outlet portion 12. A flow of the fluid through the fuel injection valve 1 is indicated by a dotted line in Fig. 1.

[0029] The nozzle orifice 13 may be opened and closed by the valve needle 4. In Fig. 1, the valve needle 4 has a generally cylindrical shape and is not hollow. The valve needle 4 is axially displaceable relative to the housing 2 for closing and opening the nozzle orifice 13 of the housing 2 by means of its needle tip 14. More specifically, the needle tip 14 is operable to interact with a valve seat of the housing 2 for preventing fuel flow through the orifice 13 in a closing position. The needle 4 is displaceable away from the closing position to establish a gap between the valve seat and the needle tip 14 so that fuel flow through the orifice 13 is enabled in opening positions of the valve needle. The needle 4 may comprise a sealing element such as a ball which represents the needle tip 14 and interacts with the valve seat.

[0030] A valve spring 18 is arranged in the cavity 8 and preloaded so that it is operable to bias the valve needle 4 towards the closing position. A calibration tube 16 is

positioned at the end of the valve spring 18 which is remote from the valve needle 4 to preload the valve spring 18. The calibration tube 16 is coupled to the housing 2 by means of a friction-fit connection so that is positionally fix relative to the housing 2 during operation of the fuel injection valve 1 and axially displaceable relative to the housing 1 during manufacturing of the fuel injection valve 1 for calibrating the preload of the valve spring 18.

[0031] Coming through the fluid inlet portion 10 into the housing 2, the fuel flows through the calibration tube 16. The calibration tube 16 may have a filter for filtering the fuel. After passing the calibration tube 16, the fuel flows through the valve spring 18 which is positioned downstream of the calibration tube 16 in the housing 2.

[0032] The fuel injection valve 1 comprises an electromagnetic actuator assembly for moving the valve needle 4 away from the closing position against the bias of the valve spring 18. The electromagnetic actuator assembly comprises a magnetic coil 22, a pole element 24 and a movable armature 20. The coil is operable to generate a magnetic field for moving the armature 20 in axial direction towards the pole element 24 relative to the housing 2 until it hits a stop element placed in the housing 2 and fixed thereto. In the present embodiment, the stop element is represented by the pole element 24. In the present embodiment, the armature 20 is movably arranged downstream of the valve spring 18 in the housing 2. The armature 20 is made of a metallic material.

[0033] The valve needle 4 is axially completely penetrating the armature 20, in particular it projects axially from the armature 20 in direction towards the fluid inlet portion 10 and towards the fluid outlet portion 12. The armature 20 is axially displaceable relative to the valve needle 4. This is achieved by a needle channel 26 which is axially penetrating the armature 20 and in which the valve needle 4 is received.

[0034] The valve needle 4 has a spring seat element 28 which is positioned at the end of the valve needle 4 remote from the needle tip 14 in the present embodiment. The spring seat element 28 is placed between the valve spring 18 and the armature 20. It contacts the valve spring 18 which is biasing the valve needle 4 against the nozzle orifice 13, in particular at the side of the valve spring 18 remote from the calibration tube.

[0035] The armature 20 comprises or consists of a first armature body 30 and a second armature body 32 which are fixedly coupled with each other. In the present embodiment, the first armature body 30 is positioned downstream of the spring seat element 28. Channels 34 are axially and completely penetrating the first armature body 30.

[0036] The second armature body 32 has a recess 36 having a disc-shaped form and being positioned vis-à-vis of the first armature body 30. The recess 36 is not completely penetrating the second armature body 32 so that it has a bottom surface 42 remote from the first armature body 30. The recess 36 may be regarded as a widened portion of the armature channel 26. A portion of

the armature channel 26 extends from the bottom surface 42 in axial direction away from the first armature body 30. A further portion of the armature channel 26, the further portion being comprised by the first armature body 32, opens into the recess 36.

[0037] The valve needle 4 which is movably received in the needle channel 26 has a disc-shaped stopper element 38. The stopper element is fixed to a shaft of the valve needle 4 and extends circumferentially around the shaft. The stopper element 38 is positioned in the recess 36. The axial dimension of the stopper element 38 is smaller than the axial dimension of the recess 36 so that the stopper element 38 is axially displaceable relative to the armature 20 in the recess 36.

[0038] The needle channel 26 may be generally cylindrically formed and may be a bore. The recess 36 has a larger diameter than the portions of the needle channel 26 upstream and downstream of the recess 36. The stopper element 38 has a larger diameter than the shaft of the valve needle 4. It may protrude radially beyond the portions of the needle channel 26 which are arranged upstream and downstream of the recess 36 so that it overlaps the bottom surface 42 of the recess 36 and a cover surface 40 of the first armature body 30 which delimits the recess at the axial end opposite of the bottom surface 42. Therefore axial displacement of the valve needle 4 is limited by means of mechanical interaction between the stopper element 38 and the armature 20.

[0039] A side of the stopper element 38 which faces towards the pole element 24 may hit a first surface - the cover surface 40 - of the first armature body 30 when the stopper element 38 moves relative to the recess 36. A side of the stopper element 38 which faces away from the pole element 24 may hit a second surface - the bottom surface 42 of the recess 36 - of the second armature body 32. This means that the first surface (cover surface 40) may come into contact with a third surface of the stopper element 38, the third surface being positioned opposite to the first surface. The third surface is also denoted as stop surface 44 in the following. Analogously, the second surface (bottom surface 42) may come into contact with a fourth surface 46 of the stopper element 38, the fourth surface being positioned opposite to the second surface. The fourth surface is also denoted as drive surface 46 in the following

[0040] The spring seat element 28 is configured for guiding the needle. The armature 20 interacts with the stopper element 38 during an injection process to displace the valve needle 4 away from the closing position.

[0041] More specifically, a first form-fit connection between the armature 20 and the stopper element 38 initiates the moving of the valve needle 4. The first form-fit connection is established by the contact of the second surface (bottom surface 42) and the fourth surface (drive surface 46). The drive surface 46 is the surface of the stopper element 38 facing away from the pole element 24. When the armature 20 is moved towards the pole element 24, it takes the valve needle 4 with it by means

of the first form-fit connection.

[0042] A further form-fit connection, i.e. a second form-fit connection, can be established between the first surface (cover surface 40) and the third surface (stop surface 44) to limit a movement of the valve needle 4 relatively to the armature 20 at the end of the opening transient of the valve needle 4. The stop surface 44 is the surface of the stopper element 38 facing the pole element 24.

[0043] Figures 2 to 5 show exemplarily different positions of the armature 20 and of the valve needle 4, together being denoted as armature-needle assembly in the following, during the opening transient of the fuel injection valve 1.

[0044] Figure 2 shows the armature-needle assembly in a first position when the magnetic coil 22 is deactivated and the nozzle orifice 13 is closed by the needle tip 14 of the valve needle 4. The stopper element 38 contacts the first armature body 30 so that the cover surface 40 and the stop surface 44 contact each other. Between the armature 20 and the stop element 24, an axial distance L1 is established.

[0045] When the magnetic coil 22 is activated, the armature 20 moves into the direction towards the pole element 24 relative to the housing 2. The valve spring 18 presses the valve needle 4 towards the closing position so that the cover surface 40 of the first armature part 30 disengages from the stop surface 44 of the stopper element 38 and the armature 20 also moves relative to the valve needle until it hits the drive surface 46 of the stopper element 38 with the bottom surface 42 of the recess 36 in the second armature part 32.

[0046] This corresponds to a second position of the armature-needle assembly, shown in Figure 3. In the second position, the nozzle orifice 13 is still closed by the needle tip 14. Starting from the second position, the axial movement of the armature 20 is transferred to the valve needle 4. The movement of the armature 20 is transferred to the valve needle 4 by the form-fit between the bottom surface 42 and the drive surface 46. From the second position, the armature 20 and the valve needle 4 move together towards the pole element 24 due to the magnetic field. Now the nozzle orifice 13 is open due to the moving of the valve needle.

[0047] The common travel of the armature 20 and the valve needle 4 continues until the armature 20 hits the pole element 24 as may be seen in Figure 4. The hit of the armature 20 against the stop element 24 initiates a decoupling of the stopper element 38 and the second armature body 32 so that the form-fit connection between the bottom surface 42 and the drive surface 46 is released because the armature 20 comes to a rest in contact with the pole element 24 while the valve needle 4 continues its movement due to its inertia. The valve needle 4 can continue its movement for a second small lift L2 until the stop surface 44 of the stopper element 38 reaches the first surface 40 to establish the further form-fit connection. This corresponds to a fourth position of the armature-needle assembly shown in Fig. 5.

[0048] The decoupling of the stopper element 38 from the bottom surface 42 of the second armature body 32 and its further travel is a so called overshoot. The result of this overshoot is shown in Figure 6 for a conventional fuel injection valve in a fuel-time diagram of an injection.

[0049] The fuel-time diagram as seen in Figure 6 just shows the fuel mass Q in dependence of the time T_i , respectively the pre-described positions of the armature 20 and the valve needle 4 of a conventional fuel injection valve 1. The dotted curve just shows an ideal fuel mass injection over the time. A real injected fuel mass over the time T_i is shown by the solid curve. The valve needle 4 hits the armature 20 at the end of the overshoot. This may accelerate the closing transient, for example due to faster detachment of the armature from the pole element. Therefore the nozzle orifice 13 is closed earlier than expected and the injected mass Q will be lower than desired.

[0050] For reducing the overshoot, in the present embodiment

- the second lift L2 is set particularly small,
- the bottom surface 42 and the drive surface 46 may be dimensioned in that way, that their contact area is as large as possible,
- the roughness of the bottom surface 42 and the drive surface 46 is particularly small, and
- both, the armature 20 and the stopper element 38 are made from magnetic steel. The large contact area and the small surface roughness of the bottom surface 42 and the drive surface 46 may in particular lead to particular large hydraulic sticking and/or to particular large adhesion between the surfaces. The movement of the stopper element 38 away from the bottom surface 42 of the recess 36 may be highly damped in this way. A particularly good result is achieved by a roughness value R_a which is less than $1.2\mu\text{m}$. This roughness value R_a may be reached for example by polishing or lapping.

[0051] The movement of the stopper element 38 away from the bottom surface 42 of the recess 36 may be further damped magnetically. The stopper element 38 is made of a magnetic steel which loses its magnetism after deactivating the magnetic coil 22. The material may be for example AISI 440C, a martensitic steel. This material has preferred magnetic characteristics and a large fatigue strength. The martensitic steel is more preferable than a ferritic steel because of its hardness and strength.

Claims

1. Fuel injection valve for an internal combustion engine, comprising
 - a housing (2) comprising a central longitudinal valve axis (6) and having a cavity (8) with a fluid

- inlet portion (10) and a fluid outlet portion (12),
 - an electromagnetic actuator with a magnetic coil (22), an armature (20) and a pole element (24),
 - a valve needle (4) being movably positioned in the cavity (8), and having a needle tip (14) which is operable to prevent fuel flow through the fluid outlet portion (12) in a closing position of the valve needle (4) and to allow fuel flow through the fluid outlet portion (12) in opening positions of the valve needle (4), wherein
 - the armature (20) is positioned in the cavity (8), is axially movable relative to the housing (2) and to the valve needle (4) and has a recess (36),
 - the valve needle (4) comprises a stopper element (38),
 - the stopper element (38) is positioned in the recess (36) of the armature (20),
 - and the stopper element (38) and the recess (36) are configured such that the stopper element (38) is operable to engage into a form-fit connection with the armature (20) for initiating a movement of the valve needle (4) and to engage in a further form-fit connection with the armature (20) for limiting a movement of the valve needle (4) relative to the armature (20).
2. The fuel injection valve according to claim 1, characterized in that the form-fit connection for initiating the movement of the valve needle (4) is established between a second surface (42) of the armature (20) facing towards the pole element (24) and a fourth surface (44) of the stopper element (38) facing away from the pole element (24), and the form-fit connection for limiting the movement of the valve needle (4) relative to the armature (20) is established between a first surface (40) of the armature (20) facing away from the pole element (24) and a third surface (44) of the stopper element (38) facing towards the pole element (24).
3. The fuel injection valve according to claim 2 characterized in that the second surface (42) and the fourth surface (46) are planar.
4. The fuel injection valve according to claim 2 or 3, characterized in that the first surface (42) and the third surface (46) are planar.
5. The fuel injection valve according to one of the preceding claims, characterized in that the valve needle (4) extends axially through the armature (20).
6. The fuel injection valve according to claim 1 or 2, characterized in that the armature (20) has a first armature body (30) and a second armature body (32) wherein the first armature body (30) and the second armature body (32) are fixed to each other and shaped in such fashion to form the recess (36) between the first armature body (30) and the second armature body (32).
7. The fuel injection valve according to one of the preceding claims, characterized in that the form-fit connection for initiating the movement of the valve needle (4) is established between a second surface (42) of the armature (20) facing towards the pole element (24) and a fourth surface (44) of the stopper element (38) facing away from the pole element (24), wherein a contact area between the second surface (42) and the fourth surface (44) has a surface roughness R_a of 1.2 μm or less.
8. The fuel injection valve according to one of the preceding claims, characterized in that the stopper element (38) comprises or consists of a magnetizable material which is in particular not a permanent magnetic material.
9. The fuel injection valve according to claim 8, characterized in that the stopper element (38) is made out of a magnetic steel such as AISI 440C.
10. The fuel injection valve according to one of the preceding claims, characterized in that the stopper element (38) is disc-shaped or comprises a disc-shaped portion and extends circumferentially around a shaft of the valve needle.

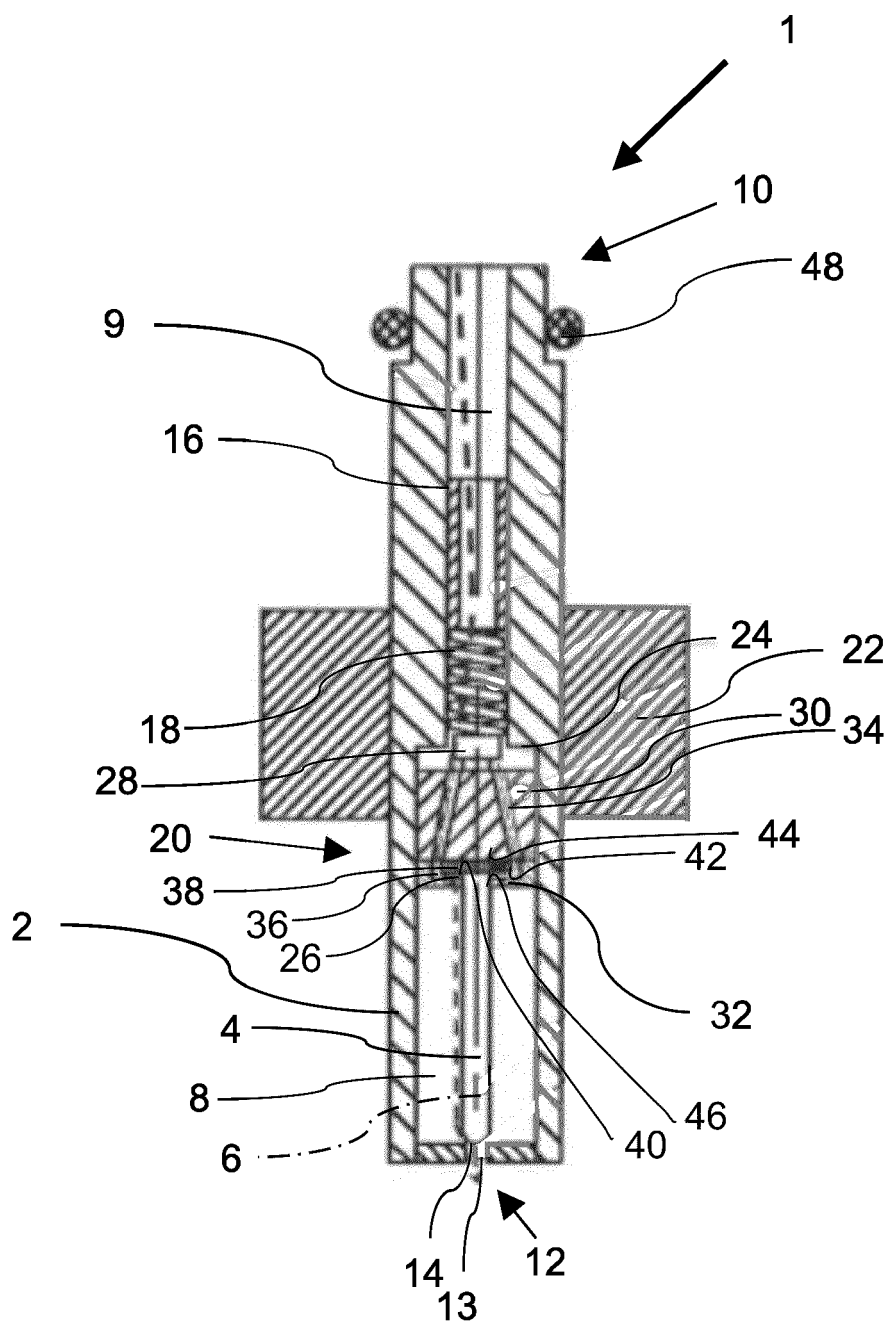
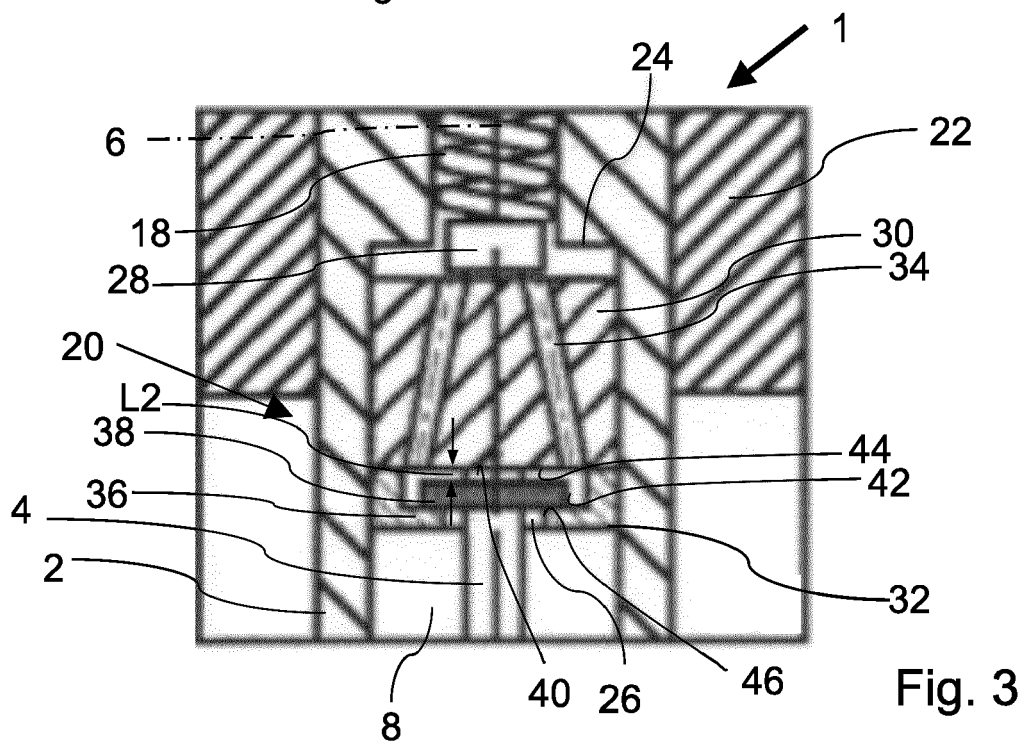
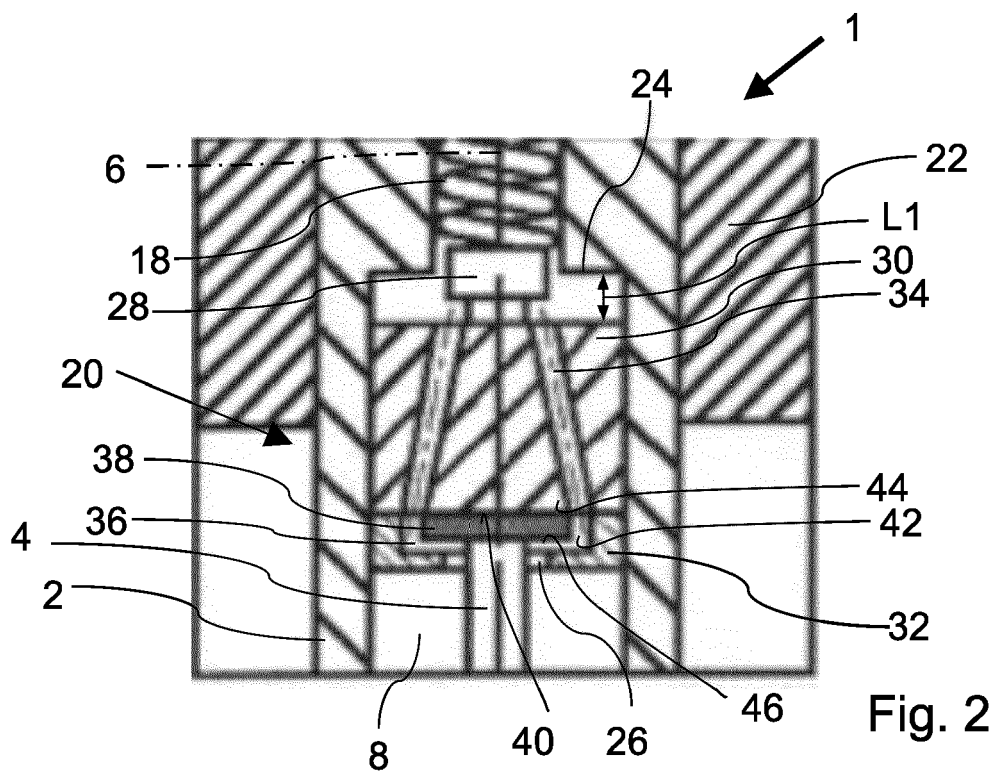
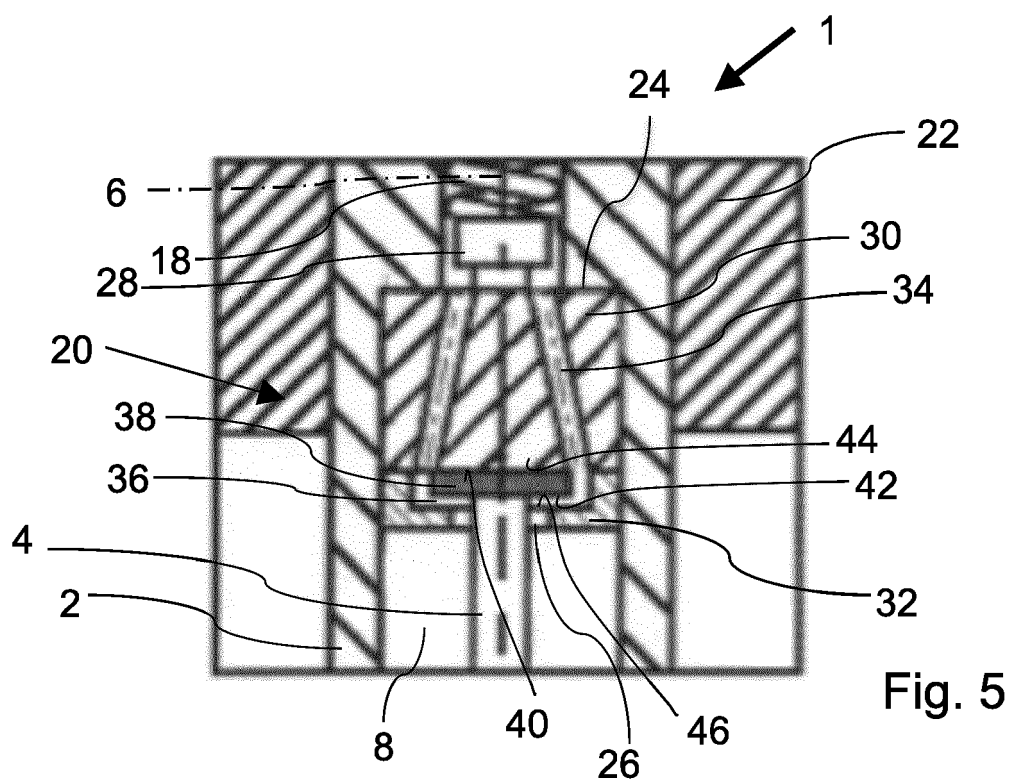
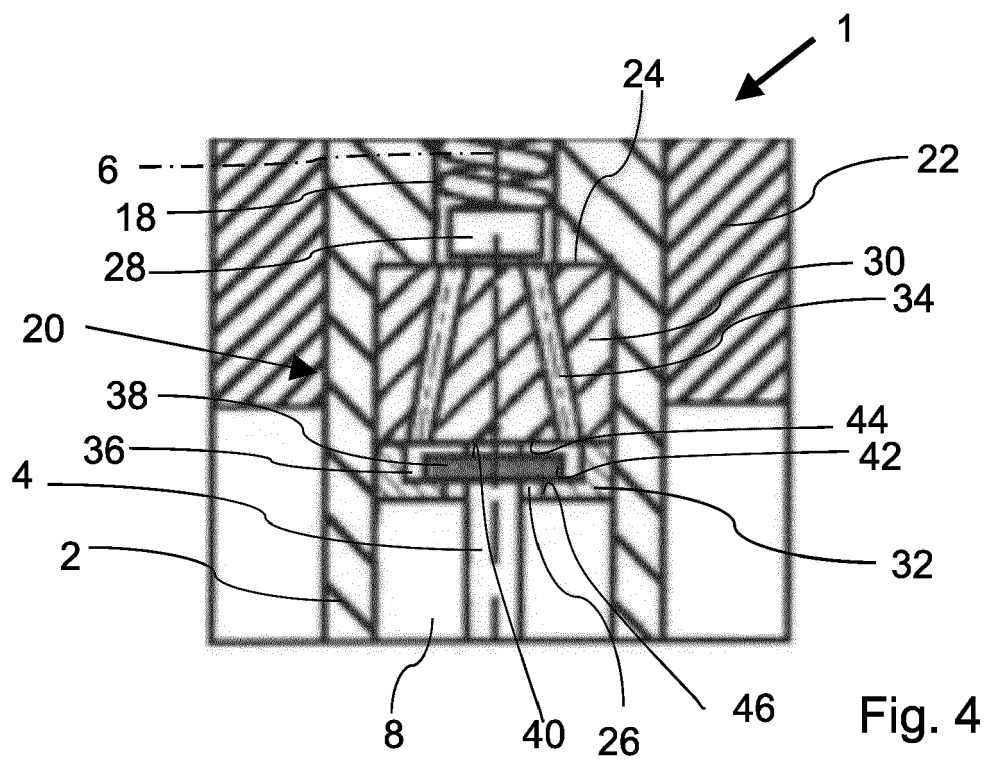


Fig. 1





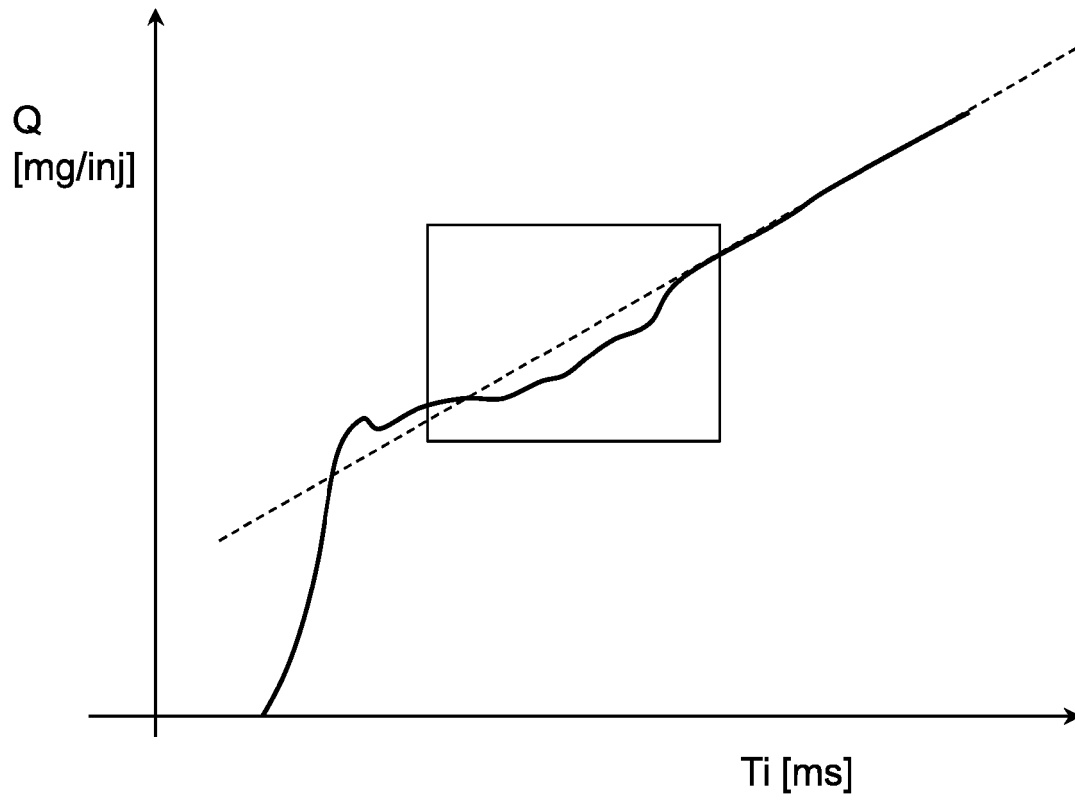


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 14 17 9027

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/080542 A1 (IMAI KEITA [JP]) 5 April 2012 (2012-04-05)	1-6,8-10	INV. F02M51/06
Y	* abstract; figures 1,2,3,4 * * claims 1,2,3,4,5,6,7,8,9,10,11 * * paragraph [0032] * * paragraph [0033] * * paragraph [0037] * * paragraph [0039] * * paragraph [0053] - paragraph [0057] * * paragraph [0065] - paragraph [0067] * * paragraph [0038] * * paragraph [0045] * * paragraph [0035] * * paragraph [0036] *	7	
X	US 2011/198419 A1 (NAGATOMO HIROAKI [JP]) 18 August 2011 (2011-08-18) * abstract; figures 1,6,7,8 * * claims 1,4,5,6 * * paragraph [0006] * * paragraph [0092] - paragraph [0093] * * paragraph [0104] - paragraph [0110] * * paragraph [0115] - paragraph [0129] *	1-6,10	TECHNICAL FIELDS SEARCHED (IPC) F02M
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 30 October 2014	Examiner Barunovic, Robert
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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