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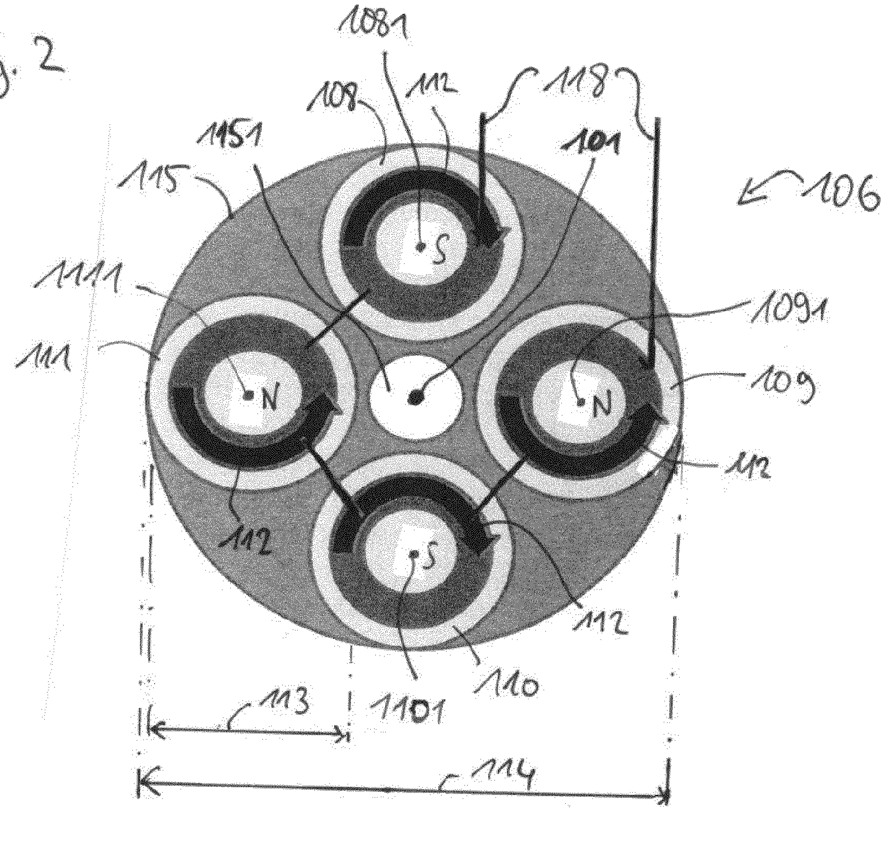
(54) Actuator assembly for a fluid injection valve and fluid injection valve

(57) An actuator assembly (105) for a fluid injection valve (100) is specified. It has a longitudinal axis (101) and comprises a stator (106) and an armature (107) which is axially displaceable with respect to the stator (106). The stator (106) comprises a plurality of coils (108, 109, 110, 111) for generating a magnetic force to displace the armature (107). The coils (108, 109, 110, 111) are laterally spaced from the longitudinal axis (101). Further, a fluid injection valve (100) is specified.

Fig. 2



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Description

[0001] The present disclosure relates to an actuator assembly and to a fluid injection valve. The fluid injection valve may be a fuel injection valve of a combustion engine.

[0002] Fluid injection valves can be used for internal combustion engines where they may be arranged in order to dose the fuel into an intake manifold of the internal combustion engine or directly into the combustion chamber of a cylinder of the internal combustion engine.

[0003] In order to enhance the combustion process in view of the avoidance of unwanted emissions, the respective fluid injection valve may be suited to dose fluids under very high pressures. In the case of a gasoline engine the pressures may be, for example, in the range of up to 500 bar and in the case of a diesel engine in the range of up to 2,500 bar.

[0004] It is an object of the invention to specify an actuator assembly for a fluid injection valve and a fluid injection valve with which a particularly precise operation of the fluid injection valve is achievable, in particular with respect to the delivery of very small fluid quantities.

[0005] According to one aspect, an actuator assembly for a fluid injection valve is specified. The actuator assembly is an electromagnetic actuator assembly. It has a central longitudinal axis.

[0006] According to a further aspect, a fluid injection valve is specified. The fluid injection valve may be a fuel injection valve for a combustion engine. The fluid injection valve expediently comprises the electromagnetic actuator assembly. The fluid injection valve further comprises a valve body with a cavity and a valve needle which is received in the cavity. The cavity extends from a fluid inlet portion to a fluid outlet portion.

[0007] The electromagnetic actuator assembly comprises a stator. The stator may be in the shape of a disc, i.e. the stator may be a stator disc stator disc.

[0008] The electromagnetic actuator assembly further comprises an armature which is axially movable with respect to the stator. The stator and the armature preferably have no axial overlap. However, the stator and the armature preferably overlap laterally. The armature may be in the shape of a disc, i.e. the armature may be an armature disc.

[0009] The stator comprises a plurality of coils, i.e. two or more coils, for generating a magnetic force to displace the armature. In other words, each coil of the stator is in particular arranged to exert a force on the armature. At least two coils may be electrically connected in series. In one development, all coils of the stator are connected in series.

[0010] The coils are laterally spaced from the longitudinal axis. In particular, in top view along the longitudinal axis, an outer contour of each of the coils does not surround the longitudinal axis. Preferably, each coil has a central axis which is parallel to the longitudinal axis and laterally offset with respect to the longitudinal axis.

[0011] The two coils of the stator are in particular smaller than the single coil which is used in conventional actuator assemblies. Therefore, the magnetic flux delay is particularly small. Thus, the actuating force on the armature can be generated particularly fast. Thus, even small fuel quantities can be injected reliably.

[0012] The magnetic path is particularly short to minimize losses with the maximum current density. Thus, an appropriate force can be generated by the coils of the stator with reduced energy consumption. To exert the same force on the armature as a conventional single coil actuator, the coils of the stator of the present actuator assembly need less energy.

[0013] In one embodiment, the stator further comprises a base body. The coils are preferably embedded in the base body. In particular, the base body comprises a ferromagnetic material. Thus, particularly advantageous characteristics of the generated magnetic field are achievable and/or losses can be avoided.

[0014] According to one embodiment, the radial dimension of each coil is smaller than half of the radial dimension of the base body. The radial dimensions of the coil and the base body are in particular the dimensions along that radial direction which extends through the geometric center of gravity of the respective coil. The "half of the radial dimension of the base body" is in particular the distance between the longitudinal axis and an outer contour of the base body in said radial direction. In this way, particularly small magnetic flux delays are achievable.

[0015] According to further embodiments each coil comprises a diameter than is smaller than the half of the diameter of the fluid injection valve. Thus, a smaller winding is realized. According to one embodiment, the actuator assembly further comprises a valve stem. The valve stem is elongated in direction of the longitudinal axis. It is mechanically coupled to the armature and axially displaceable with respect to the stator. In particular, it is positionally fixed with respect to the armature. In one development, the base body has an opening, in particular a central opening, through which the valve stem extends in axial direction. By means of the valve stem, the actuator assembly may be able to transfer a force to the valve needle particularly well.

[0016] In one embodiment, the base body has a plurality of apertures. The apertures may extend axially into the base body, for example in the shape of blind holes. Alternatively, the apertures may extend axially through the base body. The apertures are laterally spaced from the central opening. Each of the coils of the stator is preferably positioned in one of the apertures. In this way, the coils can be particularly reliably fixed with the base body.

[0017] In one embodiment, the coils of the stator are constructed and electrically connected in such fashion that the magnetic north poles of circumferentially adjacent coils are located at opposite axial ends of the stator. For example, in top view along the longitudinal axis, coils with clockwise wound turns and coils with counter-clockwise wound turns alternate in circumferential direction. In this way, a particularly large magnetic flux circulation is achievable. Fast armature response times and/or high repetition rates are possible.

[0018] According to further embodiments two electrically connected coils are respectively connected such that a direction of the electrical current is alternatively from coil to coil. Thus, a compensation of magnetic forces can be avoided and/or a particular small hysteresis due to reminiscent magnetization is achievable.

[0019] The coils may be evenly spaced in circumferential direction. In this way, the force exerted on the armature may be laterally well distributed.

[0020] According to further embodiments the number of coils of the stator disc is a multiple of two. Hence, each two adjacent coils maximize the magnetic flux circulation. Thus, a compensation of magnetic forces can be avoided.

[0021] According to further embodiments each coil comprises a cross-sectional shape transverse to the central longitudinal axis - in other words an outer contour in top view along the longitudinal axis - that differs from a circular shape. For example, the coils have a square or not regular cross-section. Thus, a better actuator packaging definition, in particular for complex actuator design, is realized.

[0022] According to further embodiments each coil is made of a wire that has a rectangular cross-sectional shape. Thus, a high fill factor - i.e. small spaces between the wire sections - is achievable. In this way, magnetic field producible by the coils at given dimensions of the coils is particularly high.

[0023] According to further embodiments the wire of the coils is coated by a silicone material. In particular, the respective coil is embedded in a block of silicone material. The coil is in particular made of aluminium in this case. In this way, in particular due to the high electrical resistance of silicone, a further increase of the filling factor is achievable.

[0024] In particular when the coils are embedded in a silicone block, each of the coils may comprise a plurality of wire sections which are connected in parallel. Thus, the coil resistance is further reduced.

[0025] In one embodiment of the fluid injection valve, the stator is positionally fixed with respect to the valve body. The valve needle is displaceable in reciprocating fashion with respect to the valve body in direction of the longitudinal axis. In this way, the valve needle is in particular movable between a closing position in which it seals the fluid outlet portion of the valve body and further positions in which it enables fluid to be dispensed from the fluid injection valve through the fluid outlet portion.

[0026] The armature is expediently operable to transfer a force to the valve needle for axially displacing the valve needle. For example, the armature and the valve needle are coupled via the valve stem. Coupling may be a direct mechanical coupling. For example the valve stem is pressed against the valve needle to transfer the force. Alternatively, the force may be transmitted via a hydraulic transmitter.

[0027] In one embodiment, the stator and the armature are hydraulically separated from the cavity. For example, the stator and the armature are arranged in an interior of an actuator housing, the interior of the actuator housing being sealed with respect to the cavity of the valve body. For example, the fluid injection valve comprises a bellows for sealing the interior of the actuator housing against the cavity of the valve body. The actuator housing may be arranged subsequent to the valve body in a direction directed from the fluid outlet portion towards the fluid inlet portion along the longitudinal axis. In other words, the actuator housing may be positioned on the side of the fluid inlet portion of the valve body opposite the fluid outlet portion.

[0028] In the following text, further aspects of the present disclosure are specified. The individual aspects are enumerated in order to facilitate the reference to features of other aspects.

1. Injector for a combustion engine comprising:

- a central longitudinal axis,
- a housing with a cavity,
- a valve needle being axially movable within the cavity,
- an electromagnetic actuator unit being designed to actuate the valve needle, the electromagnetic actuator unit comprising a coil arrangement coupled with the housing and an armature being axially movable within the cavity and being mechanically coupleable with the valve needle,

  wherein the coil arrangement comprises at least two coils that are electrically connected in series and each coil of the coil arrangement is arranged to exert a force on the armature.

The injector is in particular a fluid injection valve. The coil arrangement is in particular a stator according to at least one of the previously described embodiments.

2. Injector according to aspect 1, wherein the number of coils of the coil arrangement is a multiple of two.

3. Injector according to aspect 1 or 2, wherein two electrically connected coils respectively are connected such that a direction of the electric current is alternating from coil to coil.

4. Injector according to any of aspects 1 to 3, wherein each coil comprises a diameter that is smaller than the half of the diameter of the injector.

5. Injector according to any of aspects 1 to 4, wherein the coils are arranged in a common coil body. The common coil body may be the base body according

to at least one of the previously described embodiments.

6. Injector according to of aspect 5, wherein the coil body comprises of a ferromagnetic material.

7. Injector according to any of aspects 1 to 6, wherein each coil comprises a cross sectional shape radial to the central longitudinal axis that differs from a circular shape.

8. Injector according to any of aspects 1 to 7, wherein each coil is made of a wire, the wire comprising a cross sectional shape of a rectangular form.

9. Injector according to aspect 8, wherein the wire is coated by a silicone material.

[0029] Further advantages and advantageous embodiments and developments of the actuator assembly and the fluid injection valve will become apparent from the exemplary embodiments which are described in the following with the aid of schematic drawings. Elements of the same construction or function can have the same reference sign throughout the figures.

[0030] In the figures:

Figure 1 shows a schematic longitudinal section of a fluid injection valve with an actuator assembly according to an exemplary embodiment;

Figure 2 shows a schematic top view of a stator of the actuator assembly of the embodiment according to Fig. 1; and

Figure 3 shows a longitudinal section view of a portion of the actuator assembly of the embodiment of Fig. 1.

[0031] Figure 1 schematically shows an fluid injection valve 100 for injecting fluid. Particularly, the fluid injection valve 100 is a fuel injection valve. It is in particular configured for injecting fuel into a cylinder of an internal combustion engine of, for example, a vehicle and particularly an automobile. The fluid injection valve comprises a valve body 102. The valve body extends along a longitudinal axis 101. The valve body 102 has a cavity 103 which extends in longitudinal direction 101 from a fluid inlet portion FI to a fluid outlet portion FO. A valve needle 104 is received in the cavity 103. The valve needle 105 is axially displaceable with respect to the valve body 102 in reciprocating fashion.

[0032] At the fluid outlet portion FO, the fluid injection valve 100 further comprises a valve seat which is positionally fixed with respect to the valve body 102 or in one piece with the valve body 102. The valve seat defines an injection nozzle. The valve needle 104 is configured to seal the injection nozzle in a closing position and to unseal the injection nozzle in further positions for dispensing fluid from the fluid injection valve 100. In the closing position, the valve needle 104 sealingly rests on the valve seat to prevent fluid flow through the injection nozzle. A fluid injection is permitted if the valve needle 104 is in further positions.

[0033] In the present embodiment, the fluid injection valve 100 is an outward opening valve. The valve needle 104 is movable in axial direction from the fluid inlet portion FI to the fluid outlet portion FO for unsealing the injection nozzle. A return spring 119 of the fluid injection valve is configured for biasing the valve needle 104 towards the closing position by means of transferring a force on the valve needle which is directed in axially towards the fluid inlet portion FI. The valve needle 104 projects beyond the valve body 102 in the axial direction directed from the fluid inlet portion FI towards the fluid outlet portion FO.

[0034] The fluid injection valve 100 comprises an electromagnetic actuator assembly 105 for displacing the valve needle 104 away from the closing position. The actuator assembly 105 shares the longitudinal axis 101 with the valve body 102. The electromagnetic actuator assembly 105 comprises a stator 106 and an armature 107. The stator 106 is positionally fixed with respect to the valve body 102. The armature 107 is axially displaceable with respect to the stator 106 in reciprocating fashion. The armature 107 is operable to transfer a force to the valve needle 104 for axially displacing the valve needle 104 away from the closing position.

[0035] In the present embodiment, the force is transferred from the armature 107 to the valve needle via a valve stem 1071 which is rigidly fixed to the armature 107. The valve stem 1071 is elongated in longitudinal direction and extends from the armature 107 through the stator 106 to an upper end of the valve needle 102. The upper end of the valve needle 102 is positioned adjacent to the fluid inlet portion FI and remote from the fluid outlet portion FO. The valve stem 1071 is pressed against the upper end of the valve needle 102 to transfer the force in the present embodiment. Alternatively, the force may be transmitted via a hydraulic transmitter which is optionally arranged between the valve stem 1071 and the upper end of the valve needle 102.

[0036] In the present embodiment, the actuator assembly 105 is arranged in an interior 1201 of an actuator housing 120. The actuator housing 120 is positioned axially subsequent to the valve body 102 on its side remote from the fluid outlet portion FO. The interior 1201 of the actuator housing 120 is hydraulically separated from the cavity 103 of the valve body 102 by means of a bellows 1021 which is fixed to the valve body 102 with one axial end and to the valve needle 104 with the opposite axial end. In this way, the stator 106, the armature 107 and in the present embodiment also the valve stem 1071 and the upper end of the valve needle 104 - are not in contact with the fluid which is dispensed by the fluid injection valve 100.

[0037] In the present embodiment, the stator 106 is in the shape of a disc. The armature 107 is also in the shape of a disc. The stator 106 and the armature 107 have no axial overlap. However, the stator 106 and the armature 107 overlap laterally. Specifically, the stator disc 106 and the armature disc 107 are arranged coaxially with respect to the longitudinal axis 101.

[0038] The stator 106 comprises a multitude of coils 108 and 109.

[0039] Figure 2 shows a top view of the stator 106 along the longitudinal axis 101. The stator 106 of Figure 2 comprises four coils 108, 109, 110, and 111. According to further embodiments the stator comprises only two or three coils or more than four coils, for example five or six coils.

[0040] The coils 108 and 109 of the stator disc 106 are arranged in one area radial to the longitudinal axis 101. In other words, the geometric centers of all coils lie in a common radial plane, i.e. in a plane which extends perpendicular to the longitudinal axis 101.

[0041] The coils 108, 109, 110, 111 are laterally spaced from the longitudinal axis 101. Each coil has a central axis 1081, 1091, 1101, 1111 which is parallel to the longitudinal axis 101 and laterally offset with respect to the longitudinal axis 101. The coils are not arranged coaxial. The centres of the coils are arranged side by side.

[0042] The coils 108, 109, 110, and 111 are embedded in a common base body 115. The base body 115 has a central opening 1151 which perforates the base body 115 in longitudinal direction 101 and through which the valve stem 1071 extends. The valve stem 1071 may be axially guided by the base body 115 by means of the central opening 1151.

[0043] The coils 108 to 111 are distributed in the base body 115 around the center of the base body 115. Specifically, the base body has a plurality of apertures 1152 which axially extend into the base body 115 in the shape of blind holes from the side of the base body 115 which faces towards the armature 107. The number of apertures 1152 preferably equals the number of coils 108, 109, 110, 111. Each coil 108; 109; 110; 111 is arranged in a respective one of the apertures 1152.

[0044] The coils 108, 109, 110, 111 are evenly spaced in circumferential direction. In other words, the angles between each two distance vectors from the longitudinal axis 101 to the central axis 1081, 1091, 1101, 1111 of the coils 108, 109, 110, 111 which follow one another in angular direction around the longitudinal axis 101 are equal.

[0045] The coils 108 and 109 are operable to exert a force on a common armature 107 when the coils are energized. The distances between each of the coils 108, 109 and the armature 107 are basically the same. When the coils are energized, the armature 107 moves in axial direction towards the stator 106.

[0046] In the present embodiments, the coils have a cylindrical shape with the central axes 1081, 1091, 1101, 1111 representing the respective cylinder axes. A diameter 113 of the coils is smaller than half of a diameter 114 of the base body 115 in top view along the longitudinal axis 101. The diameter 113 of the coils can be adapted to a predetermined actuator packaging. According to further embodiments the coils can have squared, polygonal, or irregular cross-sections.

[0047] The coils 108 to 111 are electrically connected in series. The coil 108 and the coil 111 are connected to a power supply via electrical connectors 118 for energizing the coils. Further electrical connectors 118 are led from coil 108 to coil 109, from coil 109 to coil 110, and from coil 110 to coil 111.

[0048] The coils 108, 109, 110, 111 are arranged such that a direction 112 of the electric current alternates from coil to coil. The direction 112 in coils 108 and 110 is clockwise while the direction 112 in coils 109 and 111 is counter clockwise. This is achieved by means of the turns of the coils 108, 109, 110, 111 being wound clockwise or counter-clockwise, respectively around the respective central axis 1081, 1091, 1101, 1111.

[0049] In this way, the magnetic flux circulation is maximized. In particular, the magnetic north poles N of circumferentially adjacent coils 108, 109 / 109, 110 / 110, 111 /111, 108 are located at opposite axial sides of the stator 106. In other words, the actuator assembly 105 - by means of the construction and electrical connection of the coils 108, 109, 110, 111 - is configured such that magnetic north poles N and magnetic south poles S of the stator 106 alternate in angular course around the longitudinal axis 101 in top view along the longitudinal axis 101. According to embodiments, the coils 108 to 111 are simply made of a wound wire.

[0050] Figure 3 schematically shows a longitudinal sectional view of a portion of the actuator assembly 105 through the coil 108. A wire 116 is wound around the central axis 1081 for producing the turns of the coil 108. The wire 116 may be a copper or an aluminium wire. The wire 116 has a squared cross-section. The wire turns 116 are embedded in a block of a silicone material 117. The high electrical resistivity of the silicone material realizes a reliable electrical flow in the wire with a small risk of short circuits or flashovers in spite of a high filling factor, i.e. a particularly small distance between adjacent turns of the coil.

[0051] By use of the multitude of coils 108 to 111 to exert the force on the armature 107, the magnetic flux delay is reduced. A magnetic diffusion due to eddy current flow that normally generates losses can be reduced. Thus, the magnetic force on the armature 107 is established faster. The coils 108 to 111 of the stator 106 can be reduced in size to minimize the magnetic transient. In the embodiments with the squared section of the wire the filling factor of the coil is maximized. According to the embodiments in which the coil is made of a multilayer aluminium embedded into a silicone bulk, the filling factor is further improved. The term "filling factor" relates to the ratio of wire volume and complete coil volume. The coil volume 115 may comprise the shape of a flat disk.

[0052] Due to the alternating current direction in the adjacent coils, the magnetic flux circulation is maximized. The reduced dimension of the stator 106 and the even smaller dimension of the coils 108 to 111 minimizes the magnetic path and improves the dynamic response when the electrical current is applied to the system. With respect to usual fluid injection valves with the same energy a faster movement of the valve needle 104 is realized. Especially in case of a free lift concept where the cumulative instantaneous force improves the momentum of the armature an opening of the fluid injection valve 100 is improved. The electromagnetic actuator assembly 105 is for example used in dry conditions to generate high force for a fast outward opening direct solenoid fluid injection valve 100. Due to the multitude of coils 108 to 111 in the stator 106 the magnetic path is minimized and the dynamic response is improved. Thus, the force generation is fast and the energy consumption is reduced to achieve the same force level under dynamic operating conditions. The use of the multitude of coils 108 to 111 allows a reduction of the dimension of each single coil achieving a smaller winding diameter with minimum of one layer of turns. In case of the wire that is embedded into a silicone bulk, the turns can be electrically connected in parallel. Due to the alternating wire or current orientation respectively, the coils of the stator 106 are in phase. Thus, a fast actuation is realized.

Claims

1. Actuator assembly (105) for a fluid injection valve (100), having a longitudinal axis (101) comprising a stator (106) and an armature (107) which is axially displaceable with respect to the stator (106), wherein the stator (106) comprises a plurality of coils (108, 109, 110, 111) for generating a magnetic force to displace the armature (107),
   the coils (108, 109, 110, 111) being laterally spaced from the longitudinal axis (101).

2. The actuator assembly (105) according to claim 1, wherein the armature (107) and the stator (106) have no axial overlap.

3. The actuator assembly (105) according to claim 1 or 2, wherein the stator (106) further comprises a base body (115) and the coils (108, 109, 110, 111) are embedded in the base body (115).

4. The actuator assembly (105) according claim 3, wherein the radial dimension (113) of each coil (108, 109, 110, 111) is smaller than half of the radial dimension (114) of the base body (115).

5. The actuator assembly (105) according to claim 3 or 4, wherein the base body (115) comprises or consists of a ferromagnetic material.

6. The actuator assembly (105) according to one of claims 3 to 5 further comprising an axially elongated valve stem (1071), wherein

   - the valve stem (1071) is mechanically coupled to the armature (107),
   - the base body (115) has a central opening (1151) through which the valve stem (1071) extends in axial direction,
   - the base body (115) has a plurality of apertures (1152) which axially extend into or through the base body (115) and are laterally spaced from the central opening (1151), and
   - each coil (108, 109, 110, 111) is positioned in one of the apertures (1152).

7. The actuator assembly (105) according to one of the preceding claims, wherein the coils are constructed and electrically connected in such fashion that the magnetic north poles (N) of circumferentially adjacent coils (108, 109, 110, 111) are located at opposite axial ends of the stator (106).

8. The actuator assembly (105) according to one of the preceding claims, wherein, in top view along the longitudinal axis (101), coils with clockwise wound turns (108, 110) and coils with counter-clockwise wound turns (109, 111) alternate in circumferential direction.

9. The actuator assembly (105) according to one of the preceding claims, wherein the coils (108, 109, 110, 111) are evenly spaced in circumferential direction.

10. The actuator assembly (105) according to one of the preceding claims, wherein the number of coils (108, 109) comprised by the stator (106) is a multiple of two.

11. The actuator assembly (105) according to one of the preceding claims, wherein each coil (108, 109, 110, 111) comprises a cross sectional shape radial to the central longitudinal axis that differs from a circular shape.

12. The actuator assembly (105) according to one of the preceding claims, wherein each coil (108, 109) is made of a wire (116), the wire (116) comprising a rectangular cross-sectional shape.

13. The actuator assembly (105) according to claim 12, wherein the wire (116) is coated by a silicone material.

14. Fluid injection valve (100) for a combustion engine comprising:

   - a valve body (102) with a cavity (103) extending

from a fluid inlet portion to a fluid outlet portion,
- a valve needle (104) which is received in the cavity (103),
- an electromagnetic actuator assembly (105) according to one of the preceding claims wherein

the stator (106) is positionally fixed with respect to the valve body (102),

- the valve needle is displaceable in reciprocating fashion with respect to the valve body (102) in direction of the longitudinal axis (102)
- the armature (107) is operable to transfer a force to the valve needle (104) for axially displacing the valve needle (104).

15. The fluid injection valve of claim 14, wherein the stator (106) and the armature (107) are hydraulically separated from the cavity (103).

Fig. 1

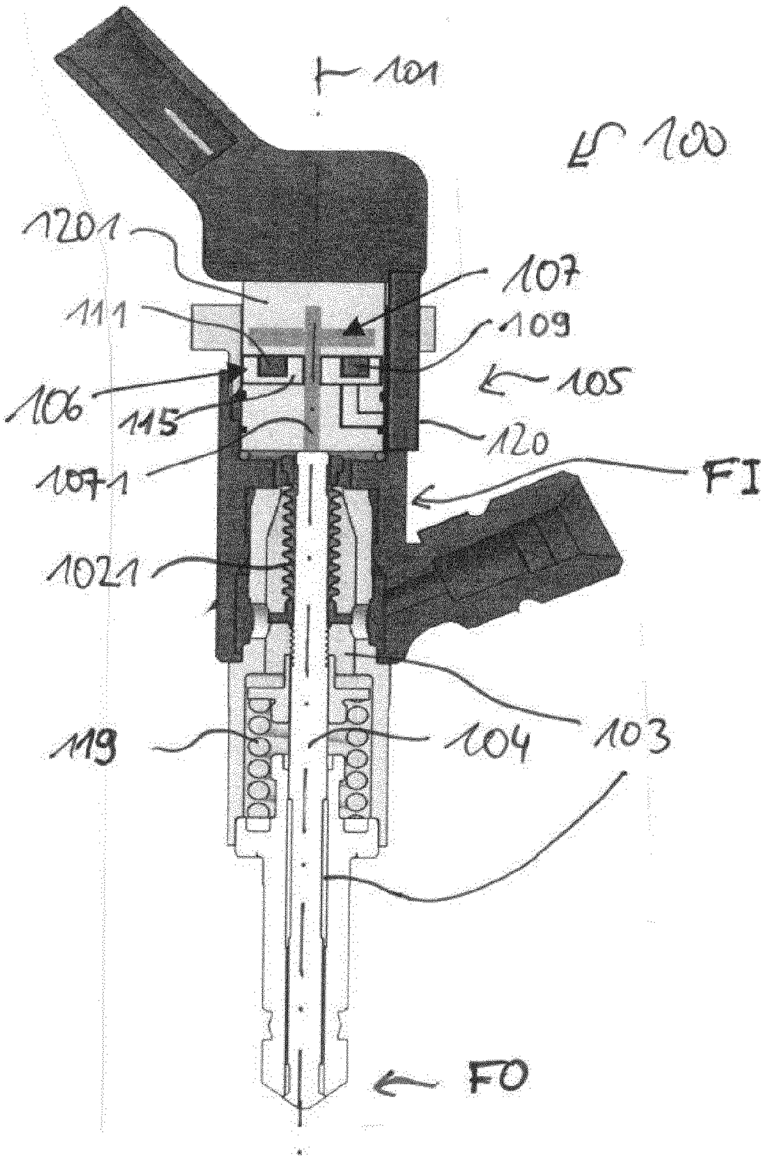
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Fig. 2

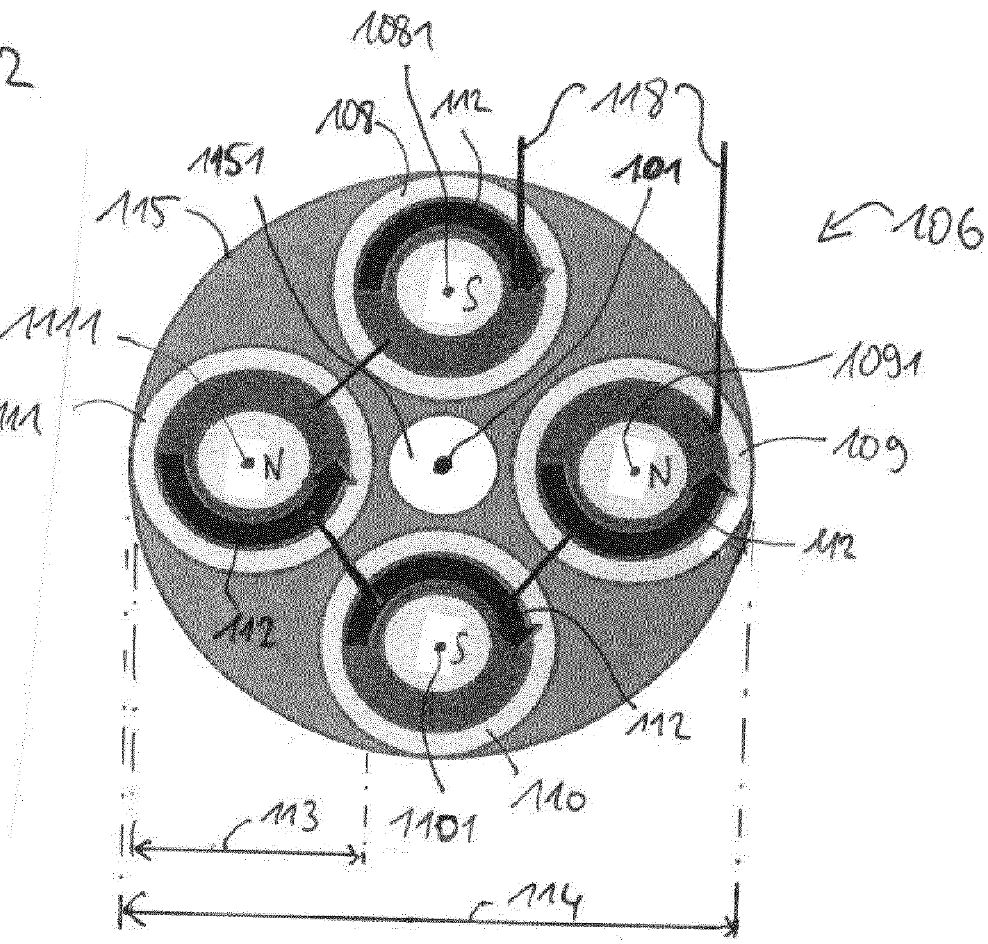
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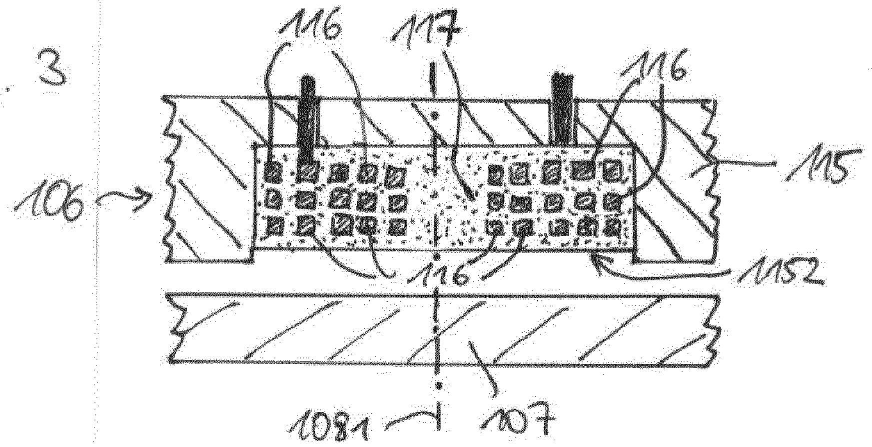
Fig. 3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EUROPEAN SEARCH REPORT

Application Number
EP 13 18 0328

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	22 November 2013	Landriscina, V

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 18 0328

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