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(54) ELECTROMAGNETIC FUEL INJECTOR WITH OPTIMIZATION OF THE WELDS

(57) An electromagnetic fuel injector (1) having: an injection jet (3); an injection valve (7), which is provided with a mobile plunger (19); an electromagnetic actuator (6) to move the plunger (19) and provided with at least one electromagnet (8) having a coil (11), a fixed armature (12), and a mobile armature (9), which is mechanically connected to the plunger (19); a closing spring (10), which pushes the plunger (19) towards the closed position; a supporting body (4), which has a tubular shape and is provided with a central channel (5), which houses the fixed armature (12) and the mobile armature (9); and an extension (14), which is partially arranged on the inside of the supporting body (4) on the fixed armature (12) and is mechanically constrained to the supporting body (4) by means of a first annular weld (29); the fixed armature (12) is mechanically locked in a fixed position on the inside of the supporting body by means of a second annular weld (28), which constrains the first fixed armature (12) to the extension (14).

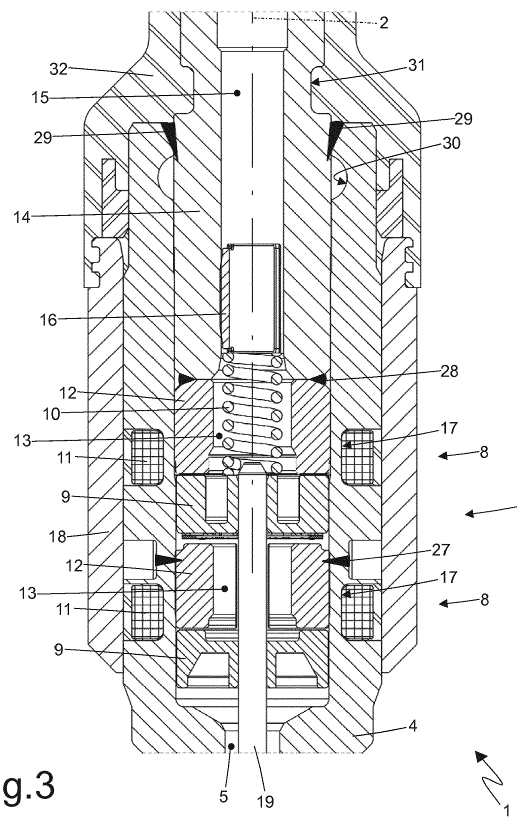

Fig.3

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Description

TECHNICAL FIELD

[0001] The present invention relates to an electromagnetic fuel injector.

PRIOR ART

[0002] An electromagnetic fuel injector (for example like the one described in patent application EP1619384A2) normally comprises a cylindrical, tubular supporting body provided with a central feeding channel which performs the function of a fuel duct and ends with an injection jet controlled by an injection valve operated by an electromagnetic actuator. The injection valve is provided with a plunger, which is displaced by the action of the electromagnetic actuator between a closed position and an open position of the injection jet against the action of a closing spring which pushes the plunger towards the closed position.

[0003] The electromagnet comprises a coil, which is arranged on the outside and in a fixed position around the supporting body, a mobile armature made of a ferromagnetic material, which is rigidly connected to the plunger and is mounted so as to be mobile on the inside of the supporting body, and a fixed armature made of a ferromagnetic material, which is arranged on the inside of the supporting body in the area of the coil and is designed to magnetically attract the mobile armature. The fixed armature has a central through hole, which fulfils the function of allowing fuel to flow towards the injection jet. On the inside of the central hole of the fixed armature there is provided the closing spring, which is compressed between a perforated striker body fitted into the central hole and the mobile armature, so as to push the mobile armature and, hence, the plunger integral to the mobile armature towards the closing position of the injection valve.

[0004] To obtain a high precision in the length of the axial stroke of the mobile armature (thus compensating possible errors caused by unavoidable building tolerances), the fuel injector is mounted leaving, at first, the fixed armature free to axially slide on the inside of the supporting body; subsequently, the fixed armature is caused to strike against the mobile armature, then it is axially pulled away from the mobile armature by a distance that is equal to the desired axial stroke of the mobile armature and, after that, the fixed armature is locked in the final position by means of an annular weld, which constrains the fixed armature to the supporting body and is made on the outside of the supporting body.

[0005] Manufacturers of Otto-cycle heat engines (i.e. engines with controlled ignition) need both to increase the fuel feeding pressure (above 70-80 Mpa) to improve the mixing of the fuel with the oxidizer (i.e. the air sucked into the cylinders) and reduce the production of black smoke (indicating bad combustion) and to increase the dynamic performance of the electromagnetic injectors (thus increasing the speed of reaction of the electromagnetic injectors to orders) so as to inject small quantities of fuel for the purpose of dividing the injection of fuel into different injection operations (by so doing, the production of polluting substances during the combustion is reduced).

[0006] It has been proven that an increase in the fuel feeding pressure (above 70-80 Mpa) leads to an increase in the frequency of faults of the fuel injector due to the occurrence of cracking or other types of structural defects of the supporting body in the area of or close to the annular weld mechanically constraining the fixed armature to the supporting body. In order to solve this problem, manufacturers have tried to increase the thickness of the supporting body, but this solution has the unavoidable drawback of increasing the manufacturing costs of the fuel injector (both due the greater quantity of material used and due to a greater manufacturing complexity) and of increasing the diameter of the fuel injector (thus making it more difficult for the fuel injector to be housed in the crown end of the cylinders, especially in case of internal combustion engines with small displacements).

[0007] Patent US6244526B1 describes an electromagnetic fuel injector comprising: an injection jet 32; an injection valve 21, which is provided with a mobile plunger 20, so as to adjust the flow of fuel through the injection jet 32; an electromagnetic actuator to move the plunger 20 between a closed position and an open position of the injection valve 21 and provided with at least one electromagnet comprising a coil 1, a fixed armature 13, and a mobile armature 19, which is mechanically connected to the plunger 20; a closing spring 33, which pushes the plunger 20 towards the closed position; a supporting body 14, which has a tubular shape and is provided with a central channel 24, which houses the first fixed armature 13 and the mobile armature 19; and an extension 10, which is completely (not partially) arranged on the inside of the supporting body 14 on the fixed armature 13 and is mechanically constrained to the supporting body 14 by means of a first annular weld 56.

[0008] As shown in the embodiment of figure 4, the fixed armature 13 is mechanically locked in a fixed position on the inside of the supporting body 14 by means of a second annular weld 60/31, which constrains the fixed armature 13 to the extension 10.

[0009] However, in the injector described in patent US6244526B1, the fixed armature is made integral to the supporting body also by means of a direct connection between the fixed armature and the supporting body ("...*with connecting piece 4, which is also attached fixedly and tightly, e.g., by welding or hard soldering, to the leg of pole part 13 running in the axial direction...*" - column 3, lines 32-34). This type of structure has some advantages, but, on the other hand, it prevents users from easily assembling the injector, obtaining, at the same time, a high precision in the length of the axial stroke of the mobile armature, thus compensating possible errors caused by unavoidable building tolerances.

DESCRIPTION OF THE INVENTION

[0010] The object of the present invention is to provide an electromagnetic fuel injector, which is not affected by the aforementioned drawbacks and, at the same time, can be manufactured in a straightforward and low-cost manner.

[0011] According to the present invention, there is provided an electromagnetic fuel injector according to the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The present invention will now be described with reference to the accompanying drawings, showing a nonlimiting embodiment thereof, wherein:

- figure 1 is a longitudinal section of a fuel injector according to the present invention;
- figure 2 shows a detail of figure 1 on a larger scale;
- figure 3 shows a detail of figure 2 on a further larger scale;
- figure 4 shows a detail of figure 3 on a further larger scale;
- figure 5 shows an injection valve of the injector of figure 1; and
- figure 6 shows a detail of figure 5 on a larger scale.

PREFERRED EMBODIMENTS OF THE INVENTION

[0013] In Figure 1, number 1 indicates, as a whole, a fuel injector, which has a cylindrical symmetry around a longitudinal axis 2 and is designed to be operated so as to inject fuel through an injection jet 3, which leads directly into an explosion chamber (not shown) of a cylinder. The injector 1 comprises a supporting body 4, which has a tubular cylindrical shape with a variable cross-section along the longitudinal axis 2 and comprises a feeding channel 5 extending along the entire length of the supporting body 4 to feed the pressurized fuel to the injection jet 3.

[0014] The supporting body 4 houses an electromagnetic actuator 6 in the area of an upper portion of its and an injection valve 7 (better visible in figure 5) in the area of a lower portion of its; in use, the injection valve 7 is operated by the electromagnetic actuator 6 so as to adjust the flow of fuel through the injection jet 3, which is obtained in the area of the injection valve 7.

[0015] According to figures 2 and 3, the electromagnetic actuator 6 comprises a pair of twin electromagnets 8 (an upper one and a lower one, respectively), which are activated together, so as to operate simultaneously. Each electromagnet 8, when it is excited, is designed to move, along the axis 2, a respective mobile armature 9 made of a ferromagnetic material from a closed position to an open position of the injection valve 7 against the action of a single, common closing spring 10, which pushes the mobile armature 9 towards the closed position of the injection valve 7. Each electromagnet 8 comprises a coil 11, which is supplied with power by an electronic control unit (not shown) and is fitted on the outside relative to the supporting body 4, as well as a fixed armature 12 made of a ferromagnetic material, which is housed on the inside of the supporting body 4 in a fixed position and has a central hole 13, so as to allow fuel to flow towards the injection jet 3.

[0016] A metal extension 14 is partially arranged on the inside of the supporting body 4, in a fixed position and immediately on the upper fixed armature 12 (i.e. the fixed armature 12 of the upper electromagnet 8), said extension 14 having a central hole 15 to allow fuel to flow towards the injection jet 3. The extension 14 is only partially arranged on the inside of the supporting body 14, as an upper part of the extension 14 is arranged on the outside of the supporting body 4; in particular, the greatest part of the extension 14 is arranged on the outside of the supporting body 4, as you can clearly see in figure 1. On the inside of the central hole 15 of the extension 14 there is fitted, in a fixed position, a striker body 16, which has a cylindrical tubular shape (if necessary, open along a generating line) to allow fuel to flow towards the injection jet 3 and is designed to keep the closing spring 10 compressed against the upper mobile armature 9 (i.e. against the mobile armature 9 of the upper magnet 8).

[0017] Each coil 11 is directly wound on the inside of is own annular slot 17, which is obtained by removing material from the outer surface of the supporting body 4. Each coil 11 consists of an enamelled conductor wire, which is provided with a self-bonding layer and has an axial size (namely, measured along the longitudinal axis 2) that is kept small to minimize dispersed magnetic fluxes. In the area of the coils 11, a protection body 18 made of a ferromagnetic material is coupled around the supporting body 4, said protection body 18 having a tubular shape and being used to ensure an adequate mechanical protection of the coils 11, to enable the closing of the streamlines of the magnetic flux generated by the coils 11, and to the increase the mechanical resistance of the supporting body 4 in the area of the structural weak spots unavoidably caused by the presence of the slots 17.

[0018] The mobile armatures 9 are part of a mobile equipment, which comprises, furthermore, a shutter or plunger 19 having an upper portion integral to each mobile armature 9 and a lower portion cooperating with a valve seat 20 (shown in figure 5) of the injection valve 7 so as to adjust, in a known manner, the flow of fuel towards the injection jet 3.

[0019] In user, when the electromagnets 8 are not excited, each mobile armature 9 is not attracted by its fixed armature 12 and the elastic force of the closing spring 10 pushes the mobile armatures 9, together with the plunger 19, downwards; in this situation, the injection valve 7 is closed. When the electromagnets 8 are excited, each mobile armature 9 is magnetically attracted by its fixed armature 12 against the elastic force of the closing spring 10 and the mobile armatures 9, together with the plunger 19, move upwards so as to determine the opening of the injection valve 7.

[0020] In order to precisely determine the upwards stroke covered by the plunger 19, the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) has a usable stroke that is shorter than the usable stroke of the lower mobile armature 9 (i.e. the mobile armature 9 of the lower electromagnet 8). In this way, when the electromagnets 8 are excited, it is always only the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) that moves so as to be in contact with and strike against its fixed armature 12, regardless of unavoidable building tolerances. In order to limit the usable stroke of the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8), the lower surface of the upper fixed armature 12 or the upper surface of the upper mobile armature 9 are covered with a layer of a hard, non-ferromagnetic metal material, preferably chromium; in this way, the thickness of the chromium layer determines the reduction of the usable stroke of the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8). Further functions of the chromium layer are: increasing the resistance to impacts of the area and, especially, avoiding magnetic adhesion phenomena due to a direct contact between the ferromagnetic material of the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) and the ferromagnetic material of the upper fixed armature 12. In other words, the chromium layer defines a gap, which prevents the magnetic attraction forces caused by the residual magnetism between the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) and the upper fixed armature 12 from reaching values that are too high, namely greater than the elastic force generated by the closing spring 10.

[0021] Furthermore, only the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) is subjected to precision mechanical processing so as to have an adjusted outer diameter, which is substantially equal (obviously, rounded down) to the inner diameter of the feeding channel 5; on the contrary, the lower mobile armature 9 (i.e. the mobile armature 9 of the lower electromagnet 8) has an unadjusted outer diameter, which is always smaller than the inner diameter of the feeding channel 5. In this way, only the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) fulfils the function of upper guide of the plunger 19 to control the axial sliding of the plunger 19 along the longitudinal axis 2. This building solution allows manufacturers to reduce manufacturing costs, as only the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) must be subjected to precision mechanical processing, which is very expensive.

[0022] According to figure 5, the valve seat 20 is defined in a sealing element 21, which is made in one piece, seals the feeding channel 5 of the supporting body 4 on the lower side, and is crossed by the injection jet 3. In particular, the sealing element 21 comprises a disc-shaped plugging element 22, which seals the feeding channel 5 of the supporting body 4 on the lower side and is crossed by the injection jet 3. A guide element 23 projects from the plugging element 22, has a tubular shape, receives, on the inside, the plunger 19 so as to define a lower guide for the plunger 19 itself, and has an outer diameter that is smaller than the inner diameter of the feeding channel 5 of the supporting body 4 so as to define an outer annular channel 24, through which fuel under pressure can flow.

[0023] In the lower part of the guide element 23 there are obtained feeding through hoes (not shown in figure 5), which lead to the valve seat 20, so as to allow fuel under pressure to flow towards the valve seat 20. The feeding holes can be staggered relative to the longitudinal axis 2, so as not to converge towards the longitudinal axis 2 itself and cause, in use, a vortex movement of the respective fuel flows, or the feeding holes can converge towards the longitudinal axis 2. In the embodiment shown in the appended drawings, the feeding holes are arranged so as to be inclined at an angle of 80° (more in general, at an angle ranging from 70° to 90°) with the longitudinal axis 2; according to a different embodiment that is not shown herein, the feeding holes form a 90° angle with the longitudinal axis 2.

[0024] The plunger 19 ends with a shutting head 25 with a substantially spherical shape, which is designed to rest against and seal the valve seat 20; alternatively, the shutting head 25 might have a basically cylindrical shape and have the sole striking area with a spherical shape. Furthermore, the shutting head 25 rests, in a sliding manner, against an inner surface of the guide element 23, so as to be guided in its movement along the longitudinal axis 2. The injection jet 3 is defined by a plurality of injection through holes (not shown), which are obtained starting from an injection chamber 26 arranged downstream of the valve seat 20.

[0025] As already mentioned above, the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) has an outer diameter that is substantially identical to the inner diameter of the corresponding portion of the feeding channel 5 of the supporting body 4; in this way, the upper mobile armature 9 can slide relative to the supporting body 4 along the longitudinal axis 2, but it cannot make any movement transversely to the longitudinal axis 2 relative to the supporting body 4. As the plunger 19 is rigidly connected to the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8), the upper mobile armature 9 clearly fulfils the further function of upper guide of the plunger 19; as a consequence, the plunger 19 is guided by the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) on the upper side and by the guide element 23 on the lower side.

[0026] According to figures 2 and 3, the lower face of the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8) is connected to a hydraulic braking device, which brakes (slows down) the movement of the plunger 19 both when the plunger 19 moves from the open position to the closed position of the injection valve 7 and when the plunger 19 moves from the closed position to the open position of the injection valve 7.

[0027] The plunger 19 has a stem with a cylindrical symmetry, to which the substantially spherical shutting head 26 is connected by means of an annular weld. In turn, the stem is connected to each mobile armature 9 by means of an annular weld.

[0028] According to figure 3, the lower fixed armature 12 (i.e. the fixed armature 12 of the lower electromagnet 8) is mechanically locked in a fixed position on the inside of the supporting body 4 by means of a spot weld 27 (alternatively, it could also be an annular weld), which constrains the lower fixed armature 12 to the supporting body 4; preferably, the supporting body 4 has a counterbore, which is made in the area of the lower fixed armature 12 (i.e. the fixed armature 12 of the lower electromagnet 8) and houses, on the inside, the weld 27. The weld 27 is oriented radially (namely, perpendicularly to the longitudinal axis 2) and, therefore, it develops from the outside to the inside of the supporting body 4 along a radial direction (namely, perpendicularly to the longitudinal axis 2). The weld 27 is never mechanically stressed in a significant manner, as it is completely on the inside of the supporting body 4 (which means that it does not have to resist to hydraulic stresses caused by the pressure of the fuel) and it is not subjected to mechanical stresses (as already mentioned above, only the upper mobile armature 9 strikes against the upper fixed armature 12 at the end of the opening stroke of the plunger 19).

[0029] According to figure 3, the upper fixed armature 12 (i.e. the fixed armature 12 of the upper electromagnet 8) is mechanically locked in a fixed position on the inside of the supporting body 4 by means of an annular weld 28, which constrains the upper fixed armature 12 to the extension 14. The annular weld 28 between the upper fixed armature 12 (i.e. the fixed armature 12 of the upper electromagnet 8) and the extension 14 is made on the outside of the supporting body 4, namely before inserting the upper fixed armature 12 and the extension 14, together, into the supporting body 4; in other words, the upper fixed armature 12 and the extension 14 are connected to one another (preassembled) by means of the annular weld 28 on the outside of the supporting body 4 and then the upper fixed armature 12 and the extension 14, joined to one another, are inserted, together, into the supporting body 4. The annular weld 28 is oriented radially (namely, perpendicularly to the longitudinal axis 2) and, therefore, it develops between the upper fixed armature 12 and the extension 14 along a radial direction (namely, perpendicularly to the longitudinal axis 2). The annular weld 28 has a good mechanical resistance, as it is made in ideal conditions (namely, on the outside of the supporting body 4); furthermore, the annular weld 28 is never mechanically stressed in a significant manner, as it is completely on the inside of the supporting body 4 (which means that it does not have to resist to hydraulic stresses caused by the pressure of the fuel) and works only in compression (when the upper mobile armature 9 strikes against the upper fixed armature 12 at the end of the opening stroke of the plunger 19).

[0030] It should be pointed put that the upper fixed armature 12 (i.e. the fixed armature 12 of the upper electromagnet 8) does not have any direct mechanical constraint to the supporting body 4, which is means that the upper fixed armature 12 does not have any direct mechanical connection to the supporting body 4; as a matter of fact, the upper fixed armature 12 is kept still on the inside of the supporting body 4 exclusively through the annular weld 28, which mechanically constrains the fixed armature 12 to the extension 14.

[0031] According to figure 3, the extension 14 is mechanically constrained to the supporting body 4 by means of an annular weld 29, which is made in the area of an upper end of the supporting body 4 and starting from an upper wall of the supporting body 4. The annular weld 29 is oriented axially (namely, parallel to the longitudinal axis 2) and, therefore, it develops between the supporting body 4 and the extension 14 along an axial direction (namely, parallel to the longitudinal axis 2). The annular weld 29 has a good mechanical resistance, as it is made in ideal conditions (namely, on the outside of the supporting body 4) and between materials having a high mechanical resistance (the extension 14 is not affected by the magnetic flux and, therefore, it is made of a non-ferromagnetic steel having high mechanical performances, and the supporting body 4 is made of a steel having high mechanical performances, as well). It is important for the annular weld 29 to have a good mechanical resistance, as the annular weld 29 is mechanically stressed in a significant manner; the annular weld 29 must ensure the the upper sealing of the supporting body 4 and, therefore, it must resist hydraulic stresses caused by the pressure of the fuel and, furthermore, the annular weld 29 must resist a shearing stress when the upper mobile armature 9 hits the upper fixed armature 12 at the end of the opening stroke of the plunger 19.

[0032] According to figure 4, the supporting body 4 has an annular recess 30, which is obtained starting from an inner surface of the supporting body 4 (namely, it faces the extension 14, which is arranged on the inside of the supporting body 4) and is arranged (immediately) below the annular weld 29 (namely, below the root of the annular weld 29). The annular recess 30 is arranged below the annular weld 29 at a very small distance from the annular weld 29 itself; basically, the beginning of the annular recess 30 borders (i.e. is arranged flush with) the end of the annular weld 29 (i.e. the root of the annular weld 29). Alternatively, the annular recess 30 could also partially overlap the annular weld 29 (namely, the root of the annular weld 29). According to a preferred, though not binding, embodiment, the annular recess 30 has, in its cross-sectional view, a semicircular shape. Furthermore, according to a preferred, though not binding, embodiment, the annular recess 30 has an axial length that is equal to or greater than the axial length of the annular weld 29. The annular recess 30 fulfils the function of protecting the root of the annular weld 29 from mechanical stresses; obviously, mechanical stresses cannot go through the annular recess 30, which is empty, and, therefore, they must go from the supporting body 4 to the extension 14 moving past the annular recess 30 and spreading relatively far from the root of the annular weld 29; in other words, the annular recess 30 allows the root of the annular weld 29 to be released from tensions (in this area of the annular weld 29 there is a concentration of tensions) and to have a more uniform distribution of stresses in the weld section. To sum up, thanks to the presence of the annular recess 30, it is possible to significantly reduce the chance of formation of cracks or slits in the area of the root of the annular weld 29 (which is the most fragile area and, therefore, the one most subjected to risks in the annular weld 29) and it is also possible to allow the weld section to work in a more uniform and distributed manner.

[0033] According to figure 4, the extension 14 has an annular recess 31, which is obtained starting from an outer surface of the extension 14 and is arranged (immediately) above the annular weld 29 (namely, above the base of the annular weld 29). In other words, the annular recess 31 is arranged above the annular weld 29 at a very small distance from the annular weld 29 itself; generally speaking, the axial distance between the annular recess 31 and the annular weld 29 is other than zero (namely, greater than zero) and is smaller than 50% of the axial length of the annular weld 29 (it should be pointed out that the axial distance between the annular recess 31 and the annular weld 29 could also be equal to zero). According to a preferred, though not binding, embodiment, the annular recess 31 has, in its cross-sectional view, a rectangular shape with rounded vertices. Furthermore, according to a preferred, though not binding, embodiment, the annular recess 31 has an axial length that is equal to or greater than the axial length of the annular weld 29. The annular recess 31 fulfils the function of directing the mechanical stresses transmitted between the supporting body 4 and the extension 14 in such a way that said mechanical stresses move past the annular recess 31 and spread relatively far from the outer surface of the annular weld 29 (area of concentration of tensions), thus allowing the weld section to work in a more uniform and distributed manner. In other words, thanks to the presence of the annular recess 31, it is possible to have the annular weld 29 work better, thus substantially reducing the chance of formation of cracks or slits in the area of the outer surface of the annular weld 29. It should be pointed out that the two annular recesses 30 and 31 work in synergy; as they are arranged above and below the annular weld 29, they ensure a significant variation in the direction of mechanical stresses, which turn out to spread far away from both points of concentration of tensions in the weld (root and outer surface), which constitute the most fragile areas and, therefore, the ones most subjected to risks in the annular weld 29; if there were only one of the annular recesses 30 and 31, there would not be a simultaneous reduction of the stress state in the root and in outer surface of the annular weld 29, but, on the contrary, only one of them would be released from stresses to the detriment of the other one.

[0034] In order to obtain a high precision in the length of the axial stroke of the upper mobile armature 9 (i.e. the mobile armature 9 of the upper electromagnet 8), thus compensating possible errors caused by unavoidable building tolerances, the upper fixed armature 12, together with the extension 14 (as already mentioned above, the upper fixed armature 12 was previously welded to the extension 14 by means of the annular weld 28), is inserted into the supporting body 4, is caused to strike against the upper mobile armature 9 and, then, it is axially pulled away from the upper mobile armature 9 by a distance that is correlated to the desired axial stroke of the upper mobile armature 9 and permits a compensation of the shrinkages following the welding (in particular, the distance can be greater or smaller than the desired axial stroke so as to take into account the shrinkages following the welding); finally, the extension 14 is locked in the final position by means of the annular weld 29, which constrains the extension 14 (integral to the upper fixed armature 12) to the supporting body 4.

[0035] According to a preferred embodiment shown in the appended drawings, part of the supporting body 4 and part of the extension 14 are covered by a plastic coating 32, which is overmoulded and fulfils the function of protecting them from outer agents.

[0036] According to a preferred embodiment shown in the appended drawings, the extension 14 is also used to connect the fuel injector 1 to a pressurized fuel feeding pipe; to this aim, the upper part of the extension 14 is threaded, so as to be connected to the pressurized fuel feeding pipe by means of screwing.

[0037] According to figures 5 and 6, the sealing element 21 is mechanically constrained to the supporting body 4 by means of an annular weld 33, which is made in the area of a lower end of the supporting body 4 and starting from a lower wall of the supporting body 4. The annular weld 33 is oriented axially (namely, parallel to the longitudinal axis 2) and, therefore, it develops between the supporting body 4 and the extension 14 along an axial direction (namely, parallel to the longitudinal axis 2). The annular weld 33 has a good mechanical resistance, as it is made in ideal conditions (namely, on the outside of the supporting body 4) and between materials having a high mechanical resistance (the sealing element 21 and the supporting body 4 are both made of a steel having high mechanical performances). It is important for the annular weld 33 to have a good mechanical resistance, as the annular weld 33 is mechanically stressed in a significant manner; on the one hand, the annular weld 33 must ensure the the lower sealing of the supporting body 4 and, therefore, it must resist hydraulic stresses caused by the pressure of the fuel and, on the other hand, the annular weld 33 is arranged on the inside of a cylinder and, therefore, it is subjected to all the mechanical stresses of the combustion cycle.

[0038] According to figures 5 and 6, the supporting body 4 has an annular recess 34, which is obtained starting from an inner surface of the supporting body 4 (namely, it faces the sealing element 21) and is arranged (immediately) above the annular weld 33 (namely, above the root of the annular weld 33). The annular recess 34 is arranged above the annular weld 33 at a very small distance from the annular weld 33; basically, the beginning of the annular recess 34 borders (i.e. is arranged flush with) the end of the annular weld 33 (i.e. the root of the annular weld 33). Alternatively, the annular recess 34 could also partially overlap the annular weld 33 (namely, the root of the annular weld 33). According to a preferred, though not binding, embodiment, the annular recess 34 has, in its cross-sectional view, a semicircular shape. Furthermore, according to a preferred, though not binding, embodiment, the annular recess 34 has an axial length that is equal to or smaller than three times the axial length of the annular weld 33. The annular recess 34 fulfils the function of protecting the root of the annular weld 33 from mechanical stresses; obviously, mechanical stresses cannot go through the annular recess 34, which is empty, and, therefore, they must go from the supporting body 4 to the extension 14 moving past the annular recess 34 and spreading relatively far from the root of the annular weld 33; in other words, the annular recess 34 allows the root of the annular weld 33 (area of concentration of tensions) to be released from tensions and to have a more uniform distribution of stresses in the weld section. To sum up, thanks to the presence of the annular recess 34, it is possible to significantly reduce the chance of formation of cracks or slits in the area of the root of the annular weld 33 (which is the most fragile area and, therefore, the one most subjected to risks in the annular weld 33) and it is also possible to allow the weld section to work in a more uniform and distributed manner.

[0039] The fuel injector 1 described above has numerous advantages.

[0040] First of all, the fuel injector 1 described above has a low frequency of faults due to the occurrence of cracking or other types of structural defects of the supporting body 4 in the area of or close to the annular welds 28, 29 and 30, even when the fuel injector 1 operates with a high fuel feeding pressure (above 70-80 Mpa).

[0041] Furthermore, the fuel injector 1 described above is simple and cheap to be manufactured, as, compared to a known similar fuel injector, it has differences that can easily be produced.

[0042] It should be pointed out that the fuel injector 1 described above can be used for the injection of any type of fuel in internal combustion engines operating according to the Otto cycle (namely, with a controlled ignition of the mixture) or in internal combustion engines operating according to the Diesel cycle (namely, with a spontaneous ignition of the mixture).

Claims

1. An electromagnetic fuel injector (1) comprising:

   an injection jet (3);
   an injection valve (7), which is provided with a mobile plunger (19), so as to adjust the flow of fuel through the injection jet (3);
   an electromagnetic actuator (6) to move the plunger (19) between a closed position and an open position of the injection valve (7) and provided with at least one first electromagnet (8) comprising a first coil (11), a first fixed armature (12), and a first mobile armature (9), which is mechanically connected to the plunger (19);
   a closing spring (10), which pushes the plunger (19) towards the closed position;
   a supporting body (4), which has a tubular shape and is provided with a central channel (5), which houses the first fixed armature (12) and the first mobile armature (9); and
   an extension (14), which is partially arranged on the inside of the supporting body (4) on the first fixed armature (12) and is mechanically constrained to the supporting body (4) by means of a first annular weld (29);
   wherein the first fixed armature (12) is mechanically locked in a fixed position on the inside of the supporting body by means of a second annular weld (28), which constrains the first fixed armature (12) to the extension (14) ;
   the injector (1) is **characterized in that** the first fixed armature (12) has no direct mechanical constraint to the supporting body (4) and is kept still on the inside of the supporting body (4) only through the second annular weld (28), which mechanically constrains the first fixed armature (12) to the extension (14).

2. An injector (1) according to claim 1, wherein the first annular weld (29) is made in the area of an upper end of the supporting body (4) and starting from an upper wall of the supporting body (4).

3. An injector (1) according to one of the claims 1 or 2, wherein the supporting body (4) has a first annular recess (30), which is obtained starting from an inner surface of the supporting body (4) and is arranged below the first annular weld (29).

4. An injector (1) according to claim 3, wherein the beginning of the first annular recess (30) borders the

end of the first annular weld (29) or the first annular recess (30) partially overlaps the first annular weld (29).

5. An injector (1) according to claim 3 or 4, wherein the first annular recess (30) has, in its cross-sectional view, a semicircular shape.

6. An injector (1) according to any of the claims from 1 to 5, wherein the extension (14) has a second annular recess (31), which is obtained starting from an outer surface of the extension (14) and is arranged above the first annular weld (29).

7. An injector (1) according to claim 6, wherein the second annular recess (31) is arranged close to the first annular weld (29).

8. An injector (1) according to claim 6 or 7, wherein the second annular recess (31) has, in its cross-sectional view, a rectangular shape.

9. An injector (1) according to any of the claims from 1 to 8, wherein the extension (14) has a central hole (15), which allows fuel to flow towards the injection jet (3) and partially houses the closing spring (10); and
on the inside of the central hole (15) of the extension (14) there is fitted, in a fixed position, a striker body (16), which has a cylindrical tubular shape and is designed to keep the closing spring (10) compressed against the first mobile armature (9).

10. An injector (1) according to any of the claims from 1 to 9, wherein:

the electromagnetic actuator (6) is provided with a second electromagnet (8), which is arranged below the first electromagnet (8) and comprises a second coil (11), a second fixed armature (12), and a second mobile armature (9), which is mechanically connected to the plunger (19);
the first mobile armature (9) has a usable stroke that is shorter than the usable stroke of the second mobile armature (9); and
the second fixed armature (12) is mechanically locked in a fixed position on the inside of the supporting body (4) by means of a third weld (27), which directly constrains the second fixed armature (12) to the supporting body (4) and develops from the outside to the inside of the supporting body (4) along a radial direction.

11. An injector (1) according to claim 10, wherein the supporting body (4) has a spot-face, which is obtained in the area of the second fixed armature (12), so that the third weld (27) can be made therein.

12. An injector (1) according to any of the claims from 1 to 11, wherein the extension (14) has an upper threaded part for the connection to a feeding pipe for fuel under pressure.

13. A method to manufacture a fuel injector (1) comprising:

an injection jet (3);
an injection valve (7), which is provided with a mobile plunger (19), so as to adjust the flow of fuel through the injection jet (3);
an electromagnetic actuator (6) to move the plunger (19) between a closed position and an open position of the injection valve (7) and provided with at least one electromagnet (8) comprising a coil (11), a fixed armature (12), and a mobile armature (9), which is mechanically connected to the plunger (19);
a closing spring (10), which pushes the plunger (19) towards the closed position;
a supporting body (4), which has a tubular shape and is provided with a central channel (5), which houses the fixed armature (12) and the mobile armature (9); and
an extension (14), which is partially arranged on the inside of the supporting body (4) on the fixed armature (12) and is mechanically constrained to the supporting body (4) by means of a first annular weld (29);
wherein the first fixed armature (12) is mechanically locked in a fixed position on the inside of the supporting body by means of a second annular weld (28), which constrains the first fixed armature (12) to the elongating rod (14); and
wherein the first fixed armature (12) has no direct mechanical constraint to the supporting body (4) and is kept still on the inside of the supporting body (4) only through the second annular weld (28), which mechanically constrains the first fixed armature (12) to the elongating rod (14).
the manufacturing method is **characterized in that** it comprises the steps of:

constraining the fixed armature (12) and the extension (14) to one another, by means of the second annular weld (28), on the outside of the supporting body (4), so as to pre-assemble the first fixed armature (12) and the extension (14) on the outside of the supporting body (4);
inserting the fixed armature (12) and the extension (14) into the supporting body (4);
causing the fixed armature (12) and the extension (14) to strike against the mobile rod (9);
pulling the fixed armature (12) and the ex-

tension (14) away by a distance that is correlated to the desired axial stroke of the mobile armature (9), so as to determine the final position of the extension (14) before making the first annular weld (29); and constraining the extension (14) to the supporting body (4) by means of the first annular weld (29).

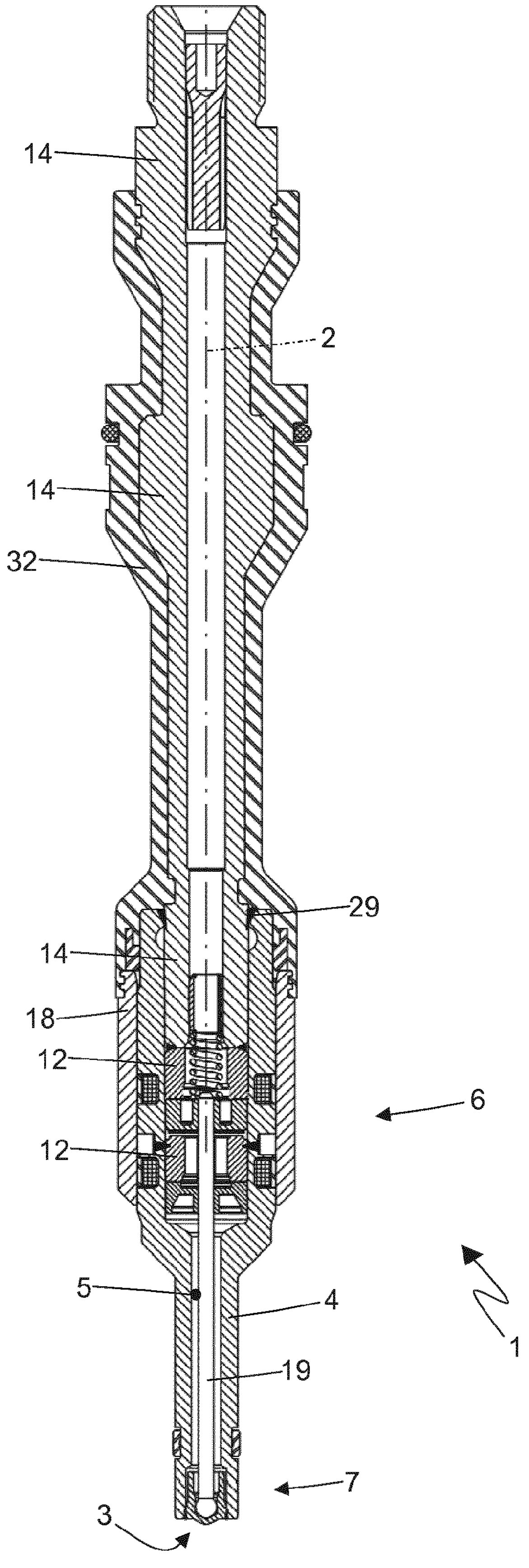

Fig.1

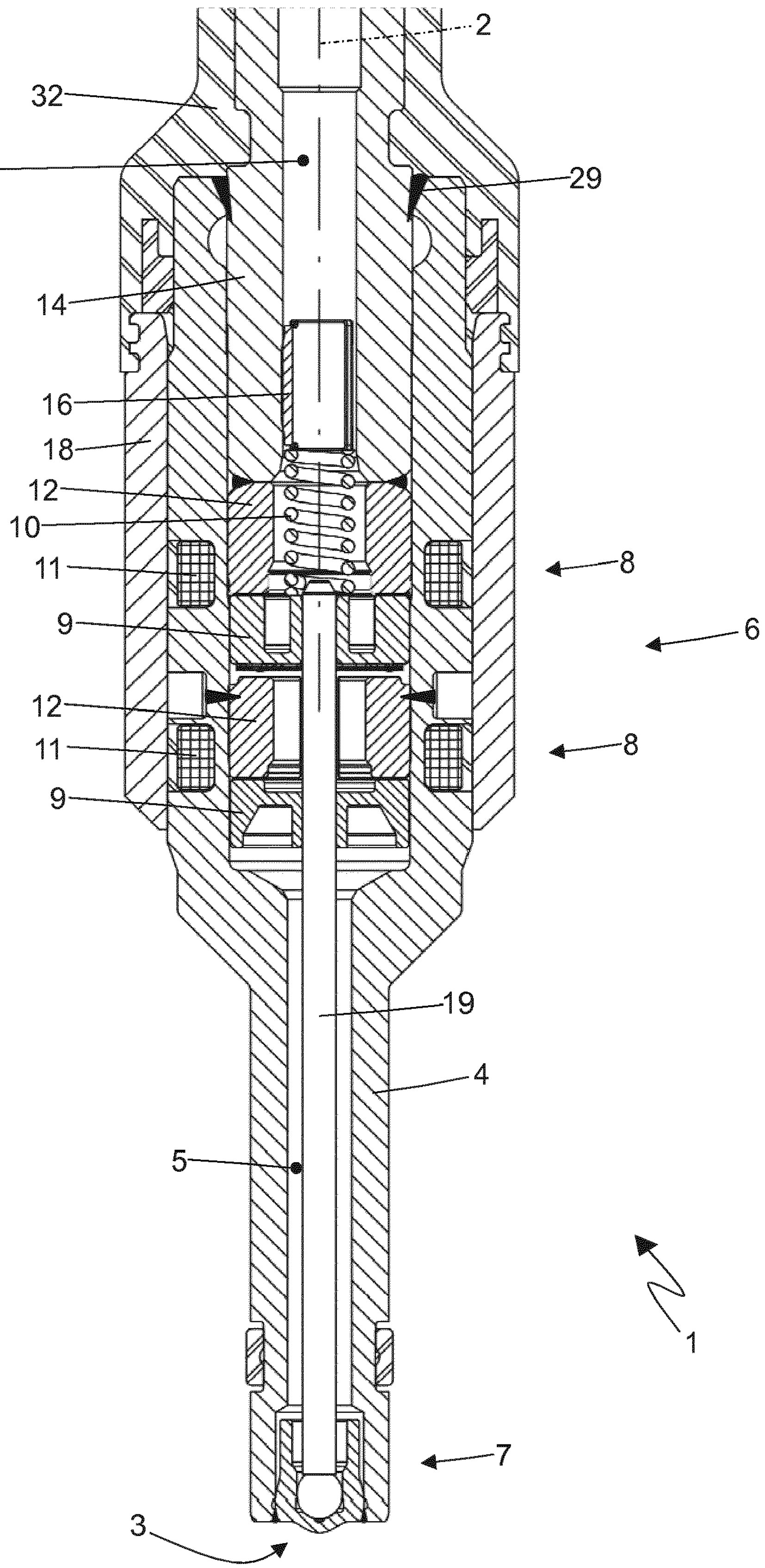

Fig.2

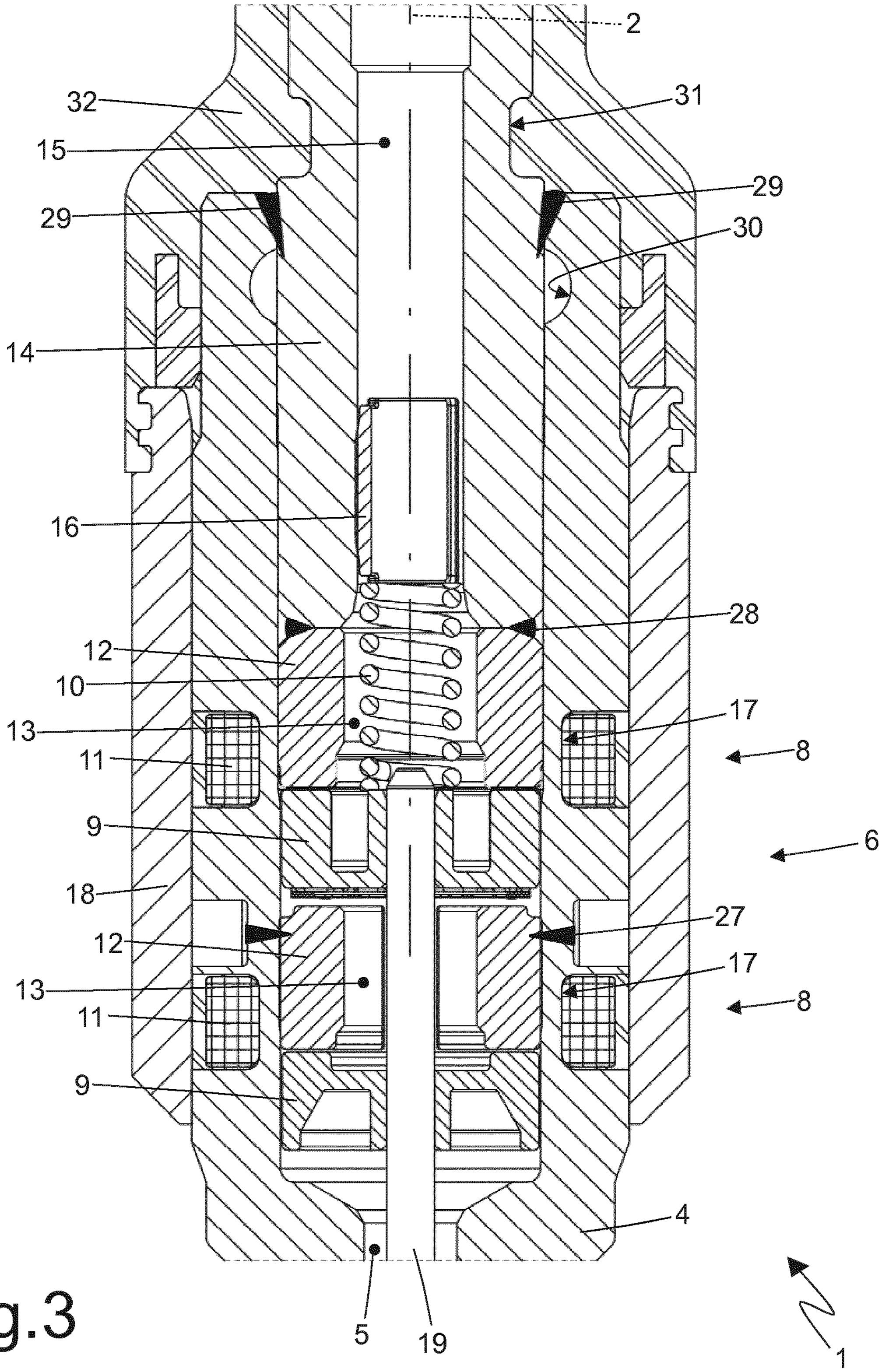
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Fig.3

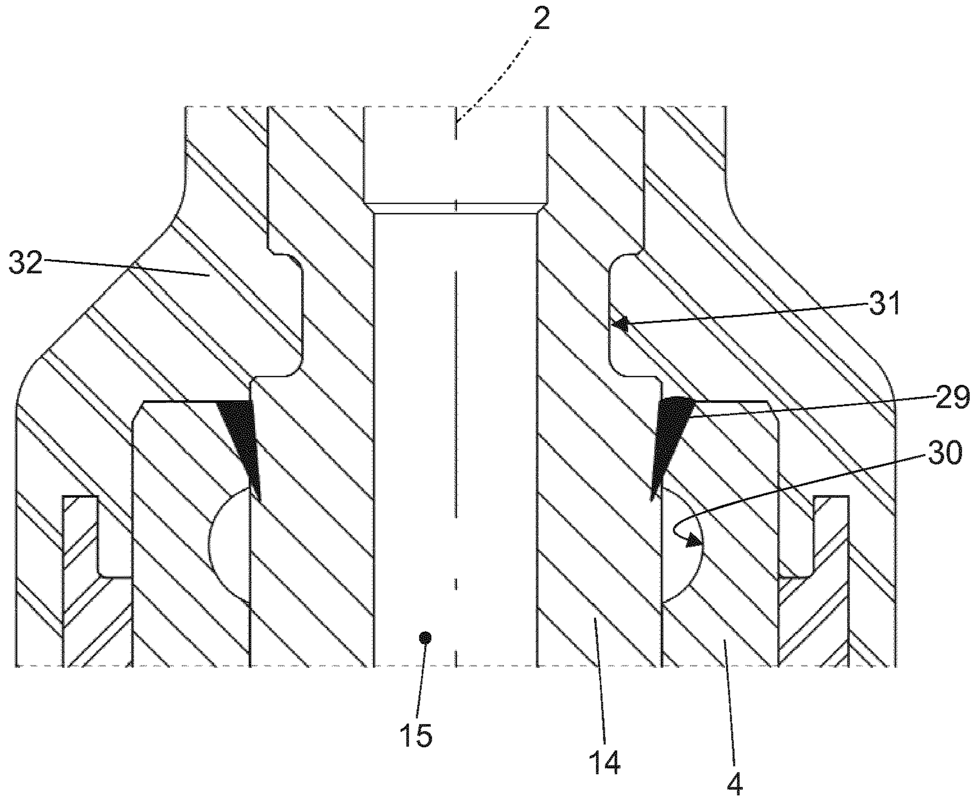

Fig.4

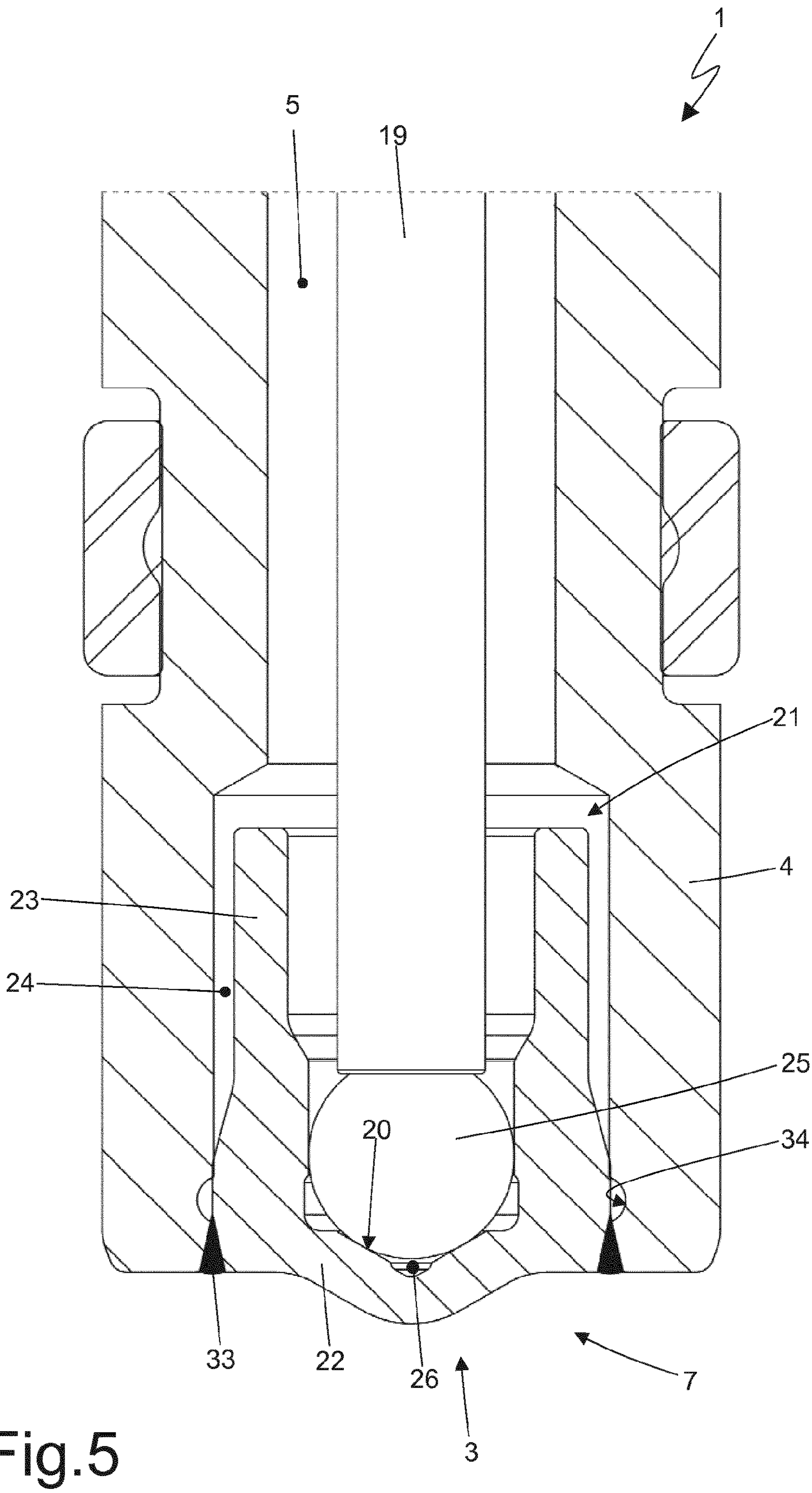

Fig.5

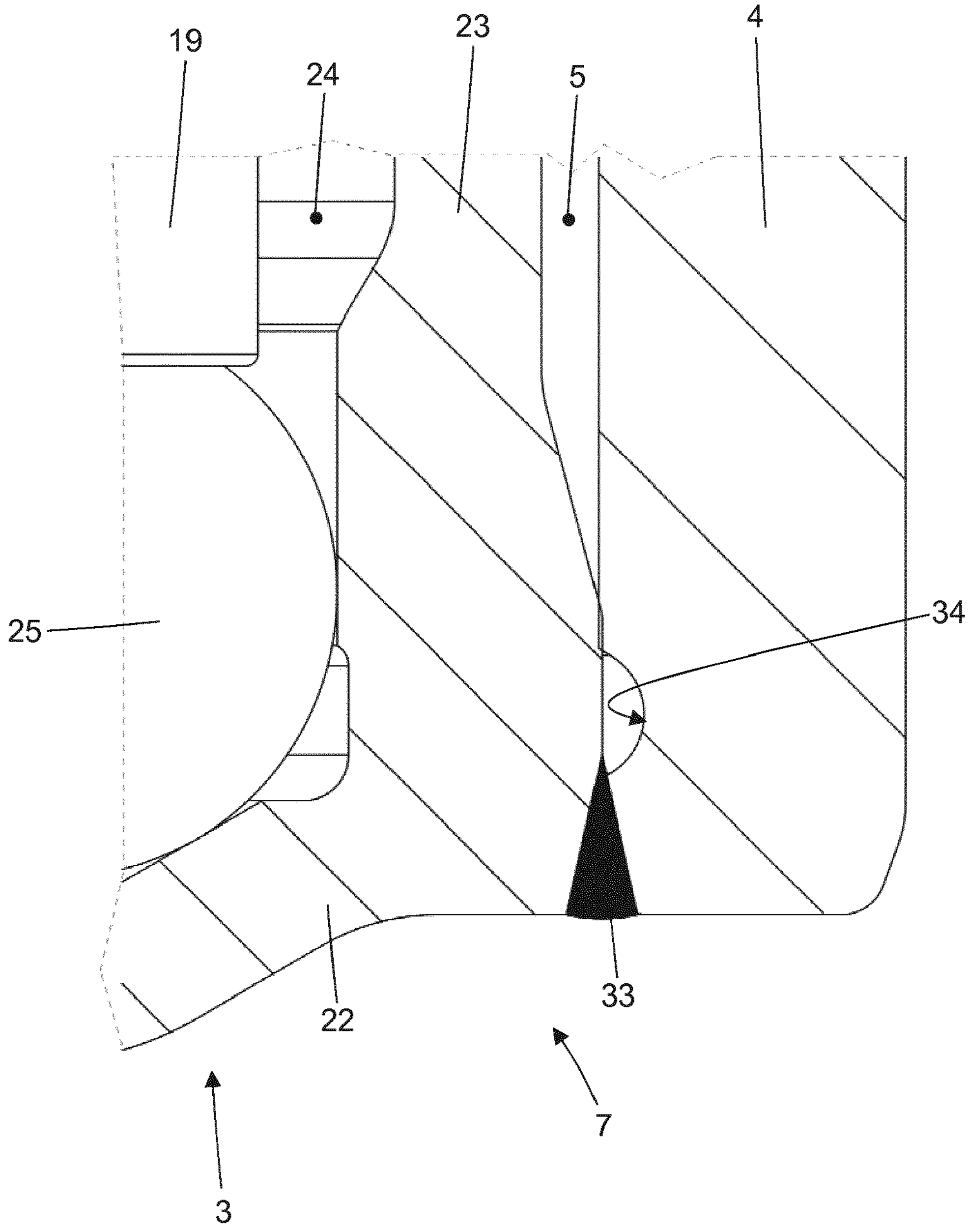

Fig.6

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EUROPEAN SEARCH REPORT

Application Number
EP 16 16 8518

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F02M

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	29 August 2016	Morales Gonzalez, M

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