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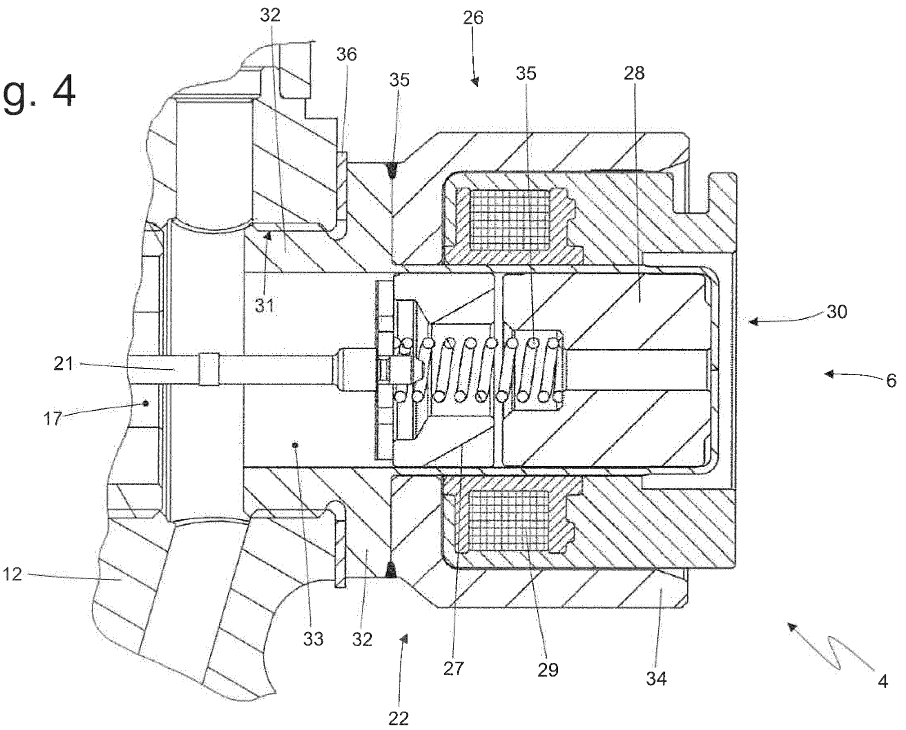
(54) **FUEL PUMP FOR A DIRECT INJECTION SYSTEM AND RELATIVE ASSEMBLING METHOD**

(57) A fuel pump (4) for a direct injection system provided with a common rail (3); the fuel pump (4) having: a main body (12); a pumping chamber (14) formed in the main body (12); an intake valve (18) arranged along an intake channel (17); a flow rate adjusting device (6), which acts on the intake valve (18) and is provided with an electromagnetic actuator (22); and a support body (30), which houses the electromagnetic actuator (22) and is integral with the main body (12); the main body (12) having a threaded coupling hole (31) arranged at the intake channel (17) and the support body (30) having a threaded assembling portion (32) screwed inside the coupling hole (31).

Fig. 4



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Description

Technical field

[0001] The present invention relates to a fuel pump for a direct injection system and a relative assembling method. Preferably (but not necessarily), the direct injection system is used in an internal combustion engine with spark ignition and then fed with gasoline or similar fuels.

Prior art

[0002] A direct injection system comprises a plurality of injectors, a common rail, which feeds the pressurized fuel to the injectors, a high-pressure fuel pump, which feeds the fuel to the common rail by means of a high-pressure supply duct and is provided with a flow rate adjusting device, and a control unit, which controls the flow rate adjusting device to maintain the fuel pressure in the common rail equal to a desired value, generally changing over time based on the engine operating conditions.

[0003] The high-pressure fuel pump described in the patent application EP2236809A1 or in the patent application EP2508744A1 comprises a main body defining a cylindrical pumping chamber in which a piston slides with a reciprocating motion; it is provided an intake channel, regulated by an intake valve for supplying the low-pressure fuel into the pumping chamber, and a delivery duct regulated by a delivery valve for supplying the high-pressure fuel out of the pumping chamber and toward the common rail through the supply duct.

[0004] The pressure of the intake valve is normally controlled, and in the absence of any external intervention, the intake valve is closed when the fuel pressure in the pumping chamber is higher than the fuel pressure in the intake channel and is open when the fuel pressure in the pumping chamber is lower than the fuel pressure in the intake channel. The flow rate adjusting device is mechanically coupled to the intake valve to keep, when necessary, the intake valve open during the pumping phase of the piston and therefore to allow a flow of fuel out of the pumping chamber through the intake channel. In particular, the flow rate adjusting device comprises a control rod, which is coupled to the intake valve and is movable between a passive position, where it allows closing the intake valve, and an active position, where it does not allow closing the intake valve. The flow rate adjusting device further comprises an electromagnetic actuator, which is coupled to the control rod to move the control rod between the active position and the passive position. The electromagnetic actuator comprises a spring holding the control rod in the active position and an electromagnet that can move the control rod into the passive position by magnetically attracting a ferromagnetic armature integral with the control rod toward a fixed magnetic armature.

[0005] Usually, the main body (housing the pumping chamber) is made of steel, which has excellent mechanical characteristics but is relatively heavy; motor sport competitions require the use of particularly lightweight components, and therefore it has been proposed that the main body is made of materials lighter than steel, e.g. titanium. However, the titanium does not have good ferromagnetic characteristics and a main body of titanium would therefore impair the efficiency of the electromagnetic actuator controlling the flow rate adjusting device.

[0006] The patent application DE102013220768A1 discloses an intake valve for a fuel pump of a direct injection system, wherein a support body of the intake valve is provided with an externally threaded fastening ring, which is screwed into a corresponding threaded hole made in a main body of the pump.

Description of the invention

[0007] The object of the present invention is to provide a fuel pump for a direct injection system and a relating assembling method, said fuel pump having a low weight and at the same time being inexpensive and easy to produce. According to the present invention, it is provided a fuel pump for a direct injection system and a relative assembling method as claimed in the appended claims.

Brief description of the drawings

[0008] The present invention will now be described with reference to the accompanying drawings showing a non-limiting embodiment, wherein:

- Figure 1 is a schematic view, with the removal of some components for clarity's sake, of a fuel direct injection system of the common rail type;
- Figure 2 is a longitudinal section view, with the removal of some components for clarity's sake, of the high-pressure pump of a fuel direct injection system of Figure 1;
- Figure 3 is a schematic cross section view, with the removal of some components for clarity's sake, of the high-pressure fuel pump of Figure 2; and
- Figure 4 is an enlarged view of a detail of Figure 2.

Preferred embodiments of the invention

[0009] In Figure 1, the number 1 indicates as a whole a fuel direct injection system of the common rail type for an internal combustion engine.

[0010] The direct injection system 1 comprises a plurality of injectors 2, a common rail 3 which supplies the pressurized fuel to the injectors 2, a high-pressure pump 4, which supplies the fuel to the common rail 3 through a supply duct 5 and is provided with a flow rate adjusting device 6, a control unit 7 which maintains the fuel pressure in the common rail 3 equal to a desired value, generally changing over time based on the engine operating conditions, and a low-pressure pump 8, which supplies the fuel from a tank 9 to the high-pressure pump 4 through a supply duct 10.

[0011] The control unit 7 is coupled to the flow rate adjusting device 6 to continuously control the flow rate of the high-pressure pump 4 supplying to the common rail 3 the required fuel amount to obtain the desired pressure value in the common rail 3; in particular, the control unit 7 regulates the flow rate of the high-pressure pump 4 by means of a feedback control, using as a feedback variable the fuel pressure value in the common rail 3, which is a pressure value detected in real time by a pressure sensor 11.

[0012] As shown in Figure 2, the high-pressure pump 4 comprises a main body 12 having a longitudinal axis 13 and housing a cylindrical pumping chamber 14. A piston 15 is slidably mounted in the pumping chamber 14. By reciprocatingly moving along the longitudinal axis 13, the piston determines a cyclic variation of the volume of the pumping chamber 14. A lower portion of the piston 15 is, on the one side, coupled to an implementing spring 16 pushing the piston 15 toward a maximum volume position of the pumping chamber 14 and, on the other side, coupled to a cam (not shown), which is brought into rotation by an engine drive shaft to move cyclically the piston 15 upward, thus compressing the implementing spring 16.

[0013] An intake channel 17, originating from a side wall of the pumping chamber 14, is connected to the low-pressure pump 8 through the supply duct 10 and is regulated by an intake valve 18 arranged at the pumping chamber 14. The pressure of the intake valve 18 is normally controlled, and in the absence of any external intervention, the intake valve 18 is closed when the fuel pressure in the pumping chamber 14 is higher than the fuel pressure in the intake channel 17, and is open when the fuel pressure in the pumping chamber 14 is lower than the fuel pressure in the intake channel 17.

[0014] A delivery channel 19, originating from a side wall of the pumping chamber 14 and from the opposite side with respect to the intake channel 17, is coupled to the common rail 3 through the supply duct 5 and is regulated by a unidirectional delivery valve 20 arranged at the pumping chamber 14 and allowing only a fuel flow exiting the pumping chamber 14. The pressure of the delivery valve 20 is controlled, and the valve is open when the fuel pressure in the pumping chamber 14 is higher than the fuel pressure in the delivery channel 19, and is closed when the fuel pressure in the pumping chamber 14 is lower than the fuel pressure in the delivery channel 19.

[0015] As shown in Figure 2, the flow rate adjusting device 6 is mechanically coupled to the intake valve 18 to allow the control unit 7 to keep, when necessary, the intake valve 18 open during a pumping phase of the piston 15 and therefore to allow a fuel flow exiting the pumping chamber 14 through the intake channel 17. The flow rate adjusting device 6 comprises a control rod 21, which is coupled to the intake valve 18 and is movable between a passive position, where it allows closing the intake valve 18, and an active position, where it does not allow closing the intake valve 18. In particular, the flow rate adjusting device 6 is coupled to the intake valve 18 to allow the control unit 7 to keep the intake valve 18 open during a pumping phase of the piston 15 and therefore to allow a fuel flow exiting the pumping chamber 14 through the intake channel 17. The flow rate adjusting device 6 further comprises an electromagnetic actuator 22, which is coupled to the control rod 21 to move the control rod 21 between the active position and the passive position.

[0016] As shown in Figure 3, an exhaust channel 23 originating from a side wall of the pumping chamber 14 connects the pumping chamber 14 with the delivery channel 19 and is regulated by a unidirectional maximum pressure valve 24 allowing only a fuel flow entering the pumping chamber 14. The function of the maximum pressure valve 24 is to allow a venting of the fuel in the case where the fuel pressure in the common rail 3 exceeds a maximum value set in the design phase (typically, in case of any control error made by the control unit 7); in other words, the maximum pressure valve 24 is designed to open automatically when the pressure difference at its ends is higher than a threshold value set in the design phase and therefore to prevent the fuel pressure in the common rail 3 from exceeding a maximum value set in the design phase.

[0017] As shown in Figure 4, the electromagnetic actuator 22 comprises a spring 25, which keeps the control rod 21 in the active position, and an electromagnet 26 controlled by the control unit 7 and adapted to move the control rod 21 in the passive position by magnetically attracting a ferromagnetic armature 27 integral with the control rod 21 toward a fixed magnetic armature 28 (the control rod 21 on the one side is integral with the armature 27 and on the other side is coupled to the intake valve 18). In particular, when the electromagnet 26 is excited, the control rod 21 comes back to the aforementioned passive position and the communication between the intake channel 17 and the pumping chamber 14 can be stopped by closing the intake valve 18. The electromagnet 26 comprises the magnetic armature 28 which is fixed, the armature 27 which is movable and close to the magnetic armature 28, and a coil 29, which is fixed and can generate a magnetic field which passes through the armature 27 and the magnetic armature 28 and hence tends to magnetically attract the armature 27 toward the magnetic armature 28.

[0018] As shown in Figure 4, it is provided a support body 30 housing the electromagnetic actuator 22 (i.e. housing the armature 27, the magnetic armature 28, the coil 29 and the spring 25) and integral with the main body 12. In particular, the main body 12 comprises a threaded coupling hole 31 arranged at the intake channel 17, and the support body 30 has a threaded assembling portion 32 which is screwed inside the coupling hole 31. The support body 30 internally comprises a tubular housing cavity 33 (having a cylindrical section) fixedly housing the magnetic armature 28 and slidingly housing the armature 27; the housing cavity 33 is open toward the main body 12 (i.e. toward the intake channel 17 formed in the main body 12) and is sealed on the opposite side, toward the outside (i.e. toward the electromagnetic actuator 22). In other words, the magnetic armature 28 is fixed inside the housing cavity 33 and is integral with the support body 30, whereas the armature 27 is movable inside the housing cavity 33 and close to the magnetic armature 28 and can slide with respect to the magnetic armature 28 and therefore with respect to the support body 30. Preferably, the spring 25 is arranged inside the housing cavity 33 and is interposed (compressed) between the magnetic armature 28 and the armature 27 to apply an elastic thrust to the armature 27.

[0019] According to a preferred embodiment, the coil 29 is arranged out of the housing cavity 33; in this way, the coil 29 is not in contact with the fuel (which is confined inside the housing cavity 33) and therefore is not subjected to the chemical aggression of the fuel (in other words, the coil 29 is mounted according to the "dry-coil" mounting pattern). In particular, the support body 30 is coupled to a bearing element 34, which houses the coil 29, is initially independent of the support body 30, and is integral with the support body 30 by means of an annular weld 35. According to an alternative embodiment not shown, the bearing element 34 housing the coil 29 is made integral with the support body 30 by screwing, and not by means of the annular weld 35; in other words, the annular weld 35 is replaced by threaded portions that are mutually screwed (i.e. the bearing element 34 has a threaded portion which is screwed into a corresponding threaded portion of the support body 30).

[0020] It is provided a spacer ring 36 with an adjusted thickness that is separate and independent both of the main body 12 and of the support body 30, is interposed between the main body 12 and the support body 30, and on the one side is in abutment against the main body 12 and on the opposite side is in abutment against the support body 30; as a consequence, the spacer ring 36 is sandwiched (i.e. stapled) between the main body 12 and the support body 30 when the main body 12 is screwed into the support body 30 and keeps the support body 30 at a constant predetermined distance from the main body 12. In particular, the thickness of the spacer ring 36 determines the length of the stroke of the control rod 21: the thicker the spacer ring 36, the longer the stroke of the control rod 21. According to a preferred embodiment, the main body 12 is made of a first metal material having a reduced density (i.e. having a reduced weight), such as e.g. titanium (having a density of about 1,9 g/cm^3) or aluminium (having a density of about 2,7 g/cm^3); inevitably, the first metal material (low weight) is a non-ferromagnetic material (i.e. is nonmagnetic), because low-weight metal materials have poor magnetic characteristics. However, the support body 30 is made of a second metal material that is different from the first metal material and is a ferromagnetic material, such as e.g. magnetic steel (having a density of about 7.5-8.0 g/cm^3).

[0021] By assembling the fuel pump 4, a spacer ring 36 with an adjusted thickness having a standard thickness (i.e. a thickness determined by the theoretical design size) is initially interposed between the support body 30 and the main body 12. Subsequently, the support body 30 is screwed into the threaded coupling hole 31 of the main body 12 (always by interposing the spacer ring 36). Then it is measured (directly or indirectly) the actual stroke of the movable armature 27 of the electromagnetic actuator 22 and it is verified whether the actual stroke of the armature 27 meets the required specifications. If the actual stroke of the armature 27 meets the required specifications, then the coupling of the support body 30 to the main body 12 is completed and you may proceed to the next assembly steps, otherwise if the actual stroke of the armature 27 differs from the required specifications, the spacer ring 36 is replaced by unscrewing and then rescrewing the support body 30 in the threaded coupling hole 31 of the main body 12 with another spacer ring 36 having a different thickness; obviously, the thickness of the spacer ring 36 is increased if the actual stroke of the armature 27 is too short with respect to the required specifications, while the thickness of the spacer ring 36 is decreased if the actual stroke of the armature 27 is too long with respect to the required specifications.

[0022] The actual stroke of the armature 27 may be different from the required specifications due to the inevitable manufacturing tolerances that, in some cases, compensate each other (so that, however, the actual stroke of the armature 27 meets the required specifications) and in other cases add up, thus making the actual stroke of the armature 27 different from the required specifications. By measuring (directly or indirectly) the actual stroke of the movable armature 27 after mounting the spacer ring 36 having a standard thickness, and possibly by correcting the actual stroke of the armature 27 by mounting another spacer ring 36 having a different thickness, any possible error due to the manufacturing tolerances may be effectively compensated. The actual stroke of the movable armature 27 can be measured directly or indirectly; in this latter case, the actual stroke of the movable armature 27 is estimated (then indirectly measured) based on another measurement (e.g. based on the current absorbed by the coil 29 when a given voltage is applied to the ends of the coil 28).

[0023] By assembling the fuel pump 4, the support body 30 is initially screwed into the threaded coupling hole 31 of the main body 12 (by interposing the spacer ring 36 according to the aforesaid modalities). Subsequently, the bearing element 34 housing the coil 29 of the electromagnetic actuator 22 is arranged around the support body 30. Finally, the bearing element 34 is welded to the support body 30 (by means of the annular weld 35) only after having definitively screwed the support body 30 into the threaded coupling hole 31 of the main body 12, and obviously only after having arranged the support body 30 in the desired angular position. In particular, almost all of the support body 30 has a cylindrical symmetry, except for the connector of the coil 29 (not shown in the accompanying figures), and then the support body 30 is arranged in the desired angular position to place the connector of the coil 29 in the desired position with respect to the rest of the high-pressure pump 4. In other words, if the bearing element 34 had been integral with the support body 30 from the beginning, by screwing the support body 30 into the threaded coupling hole 31 of the main body 12 there would have been a certain dispersion by positioning the connector of the coil 29; however, by welding the bearing element 34 to the support body 30 only after having definitively screwed the support body 30 into the threaded coupling hole 31 of the main body 12, the connector of the coil 29 can be always arranged in the desired position.

[0024] The aforesaid high-pressure pump 4 has several advantages. First, the aforesaid high-pressure pump 4 allows using for the main body 12 a first light and non-magnetic metal material without compromising the operation of the electromagnet 26: in fact, the support body 30 housing the electromagnet 26 can be made of a second ferromagnetic metal material. By screwing the support body 30 into the main body 12, any kind of weld between different metal materials (i.e. the first metal material constituting the main body 12 and the second metal material constituting the support body 30) showing remarkable manufacturing problems (actually, it is quite difficult welding different metal materials having a high mechanical resistance) can be avoided.

[0025] Moreover, the aforesaid high-pressure pump 4 allows an effective compensation of any possible error due to the manufacturing tolerances on the stroke of the armature 27 (and therefore on the correct operation of the electromagnetic actuator 22 of the flow rate adjusting device 6).

[0026] The aforesaid high-pressure pump 4 always allows arranging the connector of the coil 29 in the desired position, regardless of the inevitable manufacturing dispersions (i.e. by effectively compensating any possible error due to the manufacturing tolerances in positioning the connector of the coil 29)

[0027] Finally, the aforesaid high-pressure pump 4 is inexpensive and easy to implement, since the modifications with respect to a similar known fuel pump are limited to some simple mechanical machining.

Claims

1. A fuel pump (4) for a direct injection system provided with a common rail (3); the fuel pump (4) comprising:

    a main body (12);
    a pumping chamber (14) defined in the main body (12);
    a piston (15), which is slidingly mounted inside the pumping chamber (14) to cyclically vary the volume of the pumping chamber (14);
    an intake channel (17), which originates from a wall of the pumping chamber (14);
    an intake valve (18), which is arranged along the intake channel (17);
    a delivery channel (19), which originates from a wall of the pumping chamber (14);
    a delivery valve (20), which is arranged along the delivery channel (19);
    a flow rate adjusting device (6), which acts upon the intake valve (18) and is provided with an electromagnetic actuator (22); and
    a support body (30), which houses the electromagnetic actuator (22) and is integral with the main body (12);
    wherein the main body (12) comprises a threaded coupling hole (31), which is arranged in the area of the intake channel (17), and
    wherein the support body (30) comprises a threaded assembling portion (32), which is screwed into the coupling hole (31);
    the fuel pump (4) being **characterized in that** it comprises a spacer ring (36) with an adjusted thickness, which is separate from and independent of both the main body (12) and the support body (30), is interposed between the main body (12) and the support body (30), and on the one side is in abutment against the main body (12) and on the opposite side is in abutment against the support body (30) so that the spacer ring (36) is sandwiched between the main body (12) and the support body (30) and keeps the support body (30) at a constant and predetermined distance from the main body (12).

2. A fuel pump (4) according to claim 1, wherein the electromagnetic actuator (22) comprises:

    a magnetic armature (28), which is fixed and integral with the support body (30);
    a coil (39), which is fixed and integral with the support body (30); and
    an armature (27), which is movable, is close to the magnetic armature (28) and can slide relative to the magnetic armature (28) and, therefore, relative to the support body (30).

3. A fuel pump (4) according to claim 2, wherein the flow rate adjusting device (6) comprises a control rod (21), which, on the one side, is integral with the armature (27) and, on the other side, is coupled to the intake valve (18).

4. A fuel pump (4) according to claim 2 or 3, wherein the electromagnetic actuator (22) comprises a spring (25), which is interposed between the magnetic armature (28) and the armature (27), so as to apply an elastic thrust to the armature (27).

5. A fuel pump (4) according to claim 2, 3 or 4, wherein the support body (30) comprises, on the inside, a housing cavity (33), which houses the magnetic armature (28) in a fixed position and houses the armature (27) in a sliding manner.

6. A fuel pump (4) according to claim 5, wherein the coil (29) is arranged out of the housing cavity (33).

7. A fuel pump (4) according to any one of the claims from 1 to 6, wherein:

the electromagnetic actuator (22) comprises a coil (29); and
the support body (30) is coupled to a bearing element (34), which houses the coil (29), is initially independent of the support body (30) and becomes integral with the support body (30).

8. A fuel pump (4) according to claim 7, wherein the bearing element (34) housing the coil (29) becomes integral with the support body (30) by means of an annular weld (35).

9. A fuel pump (4) according to any one of the claims from 1 to 8, wherein the main body (12) is made of a first material, whereas the support body (30) is made of a second material, which is different from the first material.

10. A fuel pump (4) according to claim 9, wherein the first material is not ferromagnetic, whereas the second material is ferromagnetic.

11. A fuel pump (4) according to claim 9 or 10, wherein the first material is titanium and the second material is magnetic steel.

12. A method for assembling the fuel pump (4) according to any one of the claims from 1 to 11; the assembling method comprising the steps of:

interposing a spacer ring (36) with an adjusted thickness between the support body (30) and the main body (12);
screwing the support body (30) into the threaded coupling hole (31) of the main body (12);
determining the actual stroke of a movable armature (27) of the electromagnetic actuator (22); and
replacing, by unscrewing and then re-screwing the support body (30) into the threaded coupling hole (31) of the main body (12), the spacer ring (36) with another spacer ring (36) having a different thickness, if the actual stroke of the movable armature (27) does not meet the required specifications.

13. An assembling method according to claim 12 and comprising the further steps of:

arranging around the support body (30) a bearing element (34) housing a coil (29) of the electromagnetic actuator (22); and
fastening the bearing element (34) to the support body (30) only after having definitely screwed the support body (30) into the threaded coupling hole (31) of the main body (12).

14. A method for assembling the fuel pump (4) according to any one of the claims from 1 to 11; the assembling method comprising the steps of:

screwing the support body (30) into the threaded coupling hole (31) of the main body (12);
arranging, around the support body (30), a bearing element (34) housing a coil (29) of the electromagnetic actuator (22); and
fastening the bearing element (34) to the support body (30) only after having definitively screwed the support body (30) into the threaded coupling hole (31) of the main body (12).

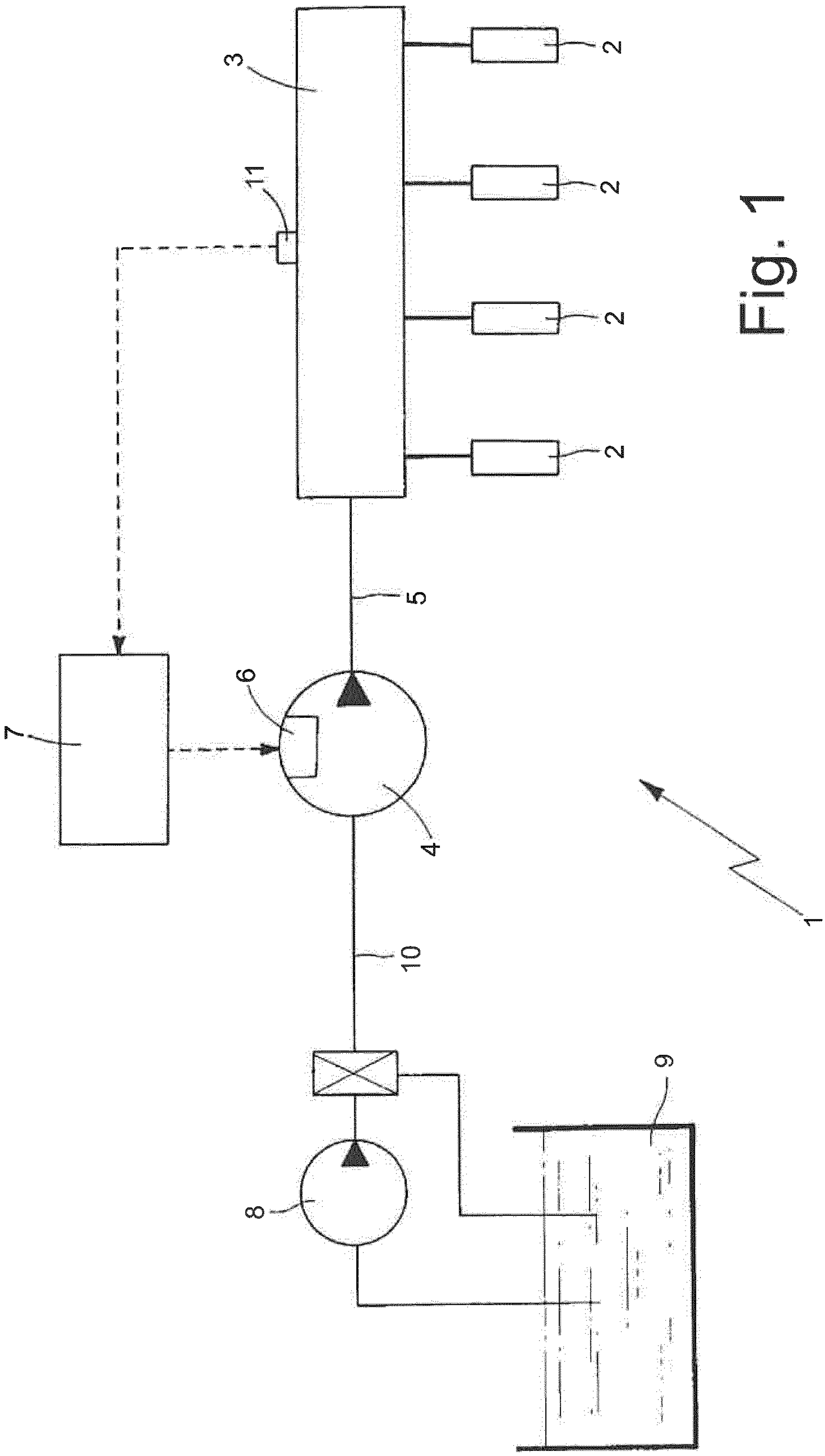

Fig. 1

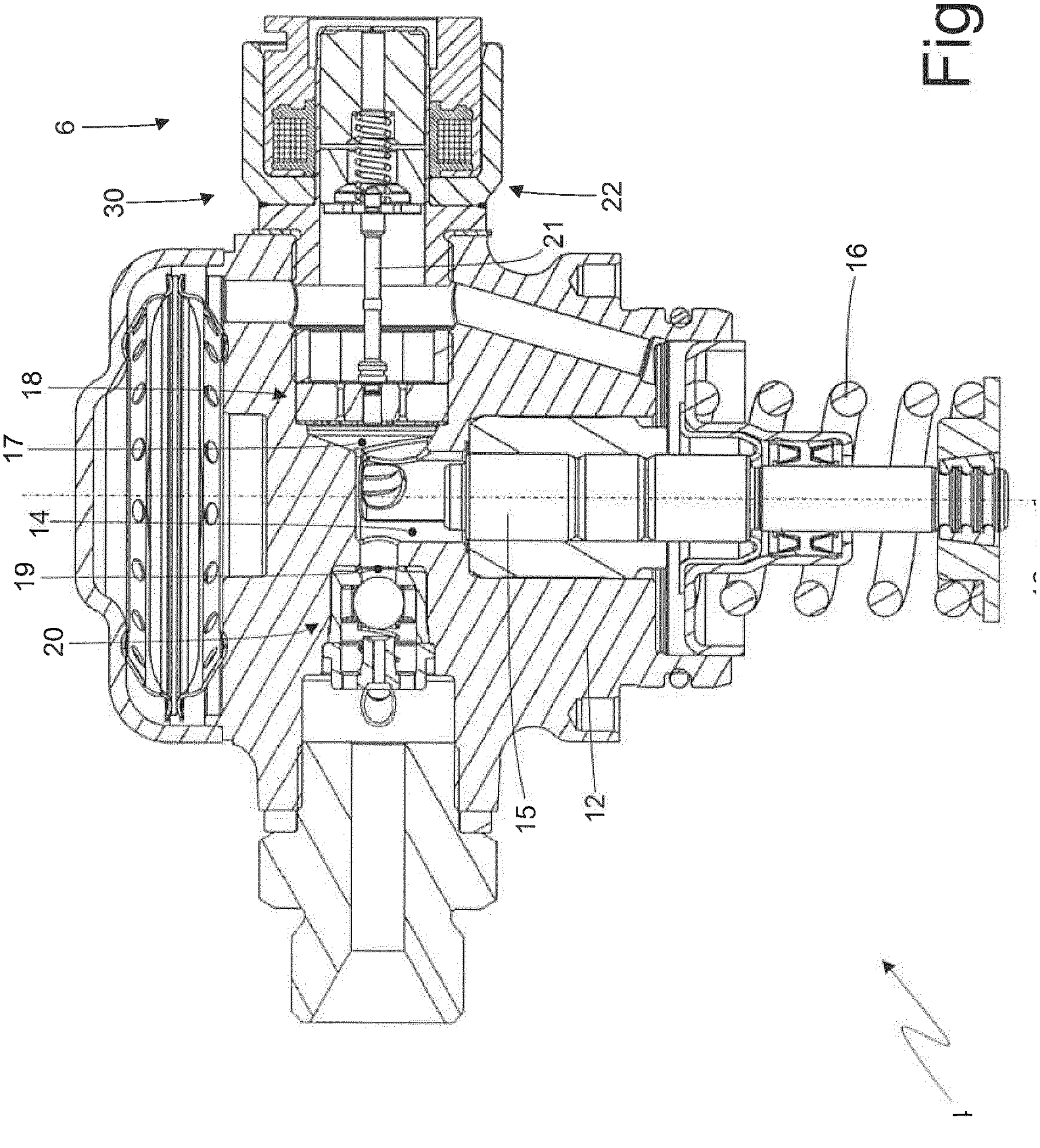

Fig. 2

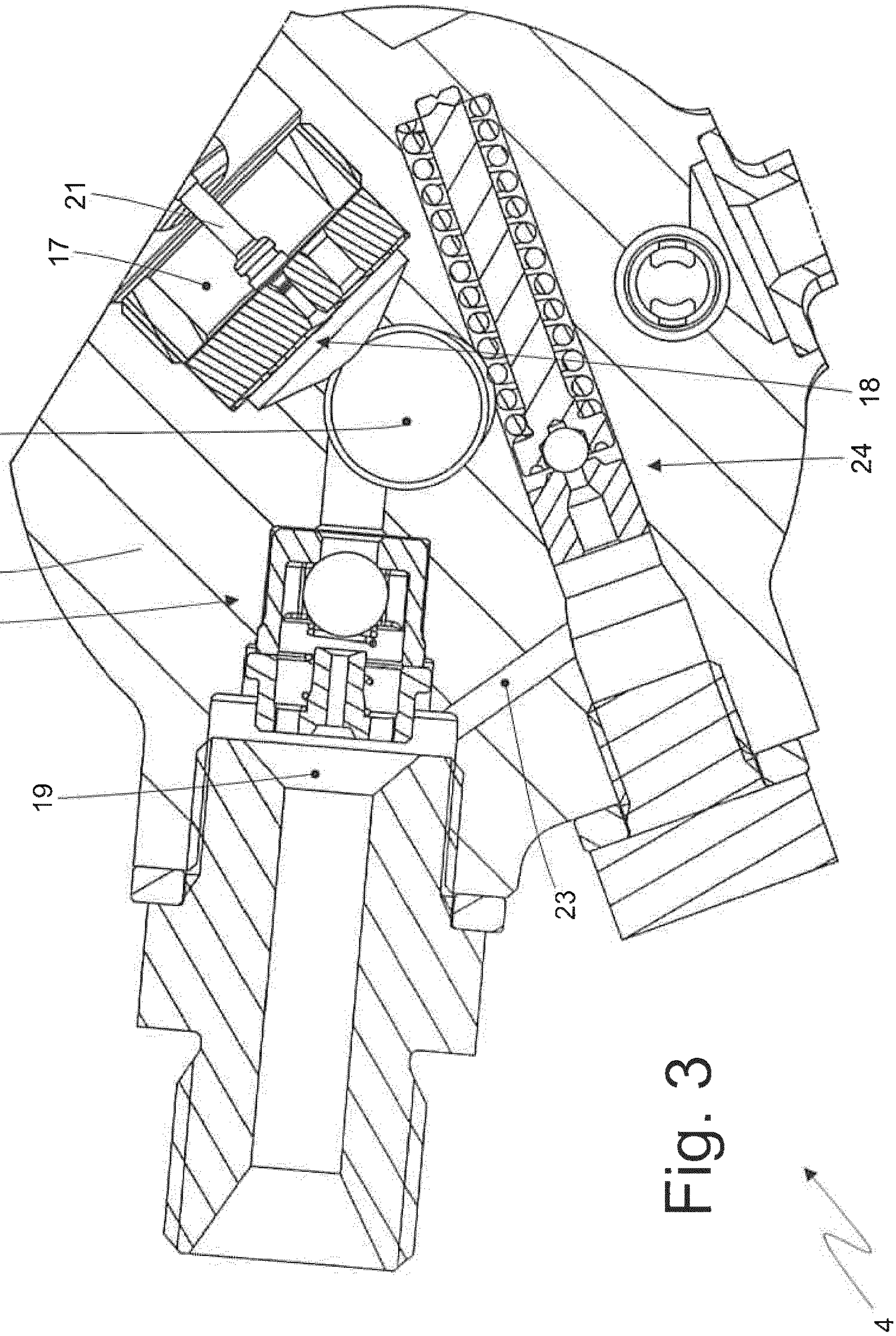

Fig. 3

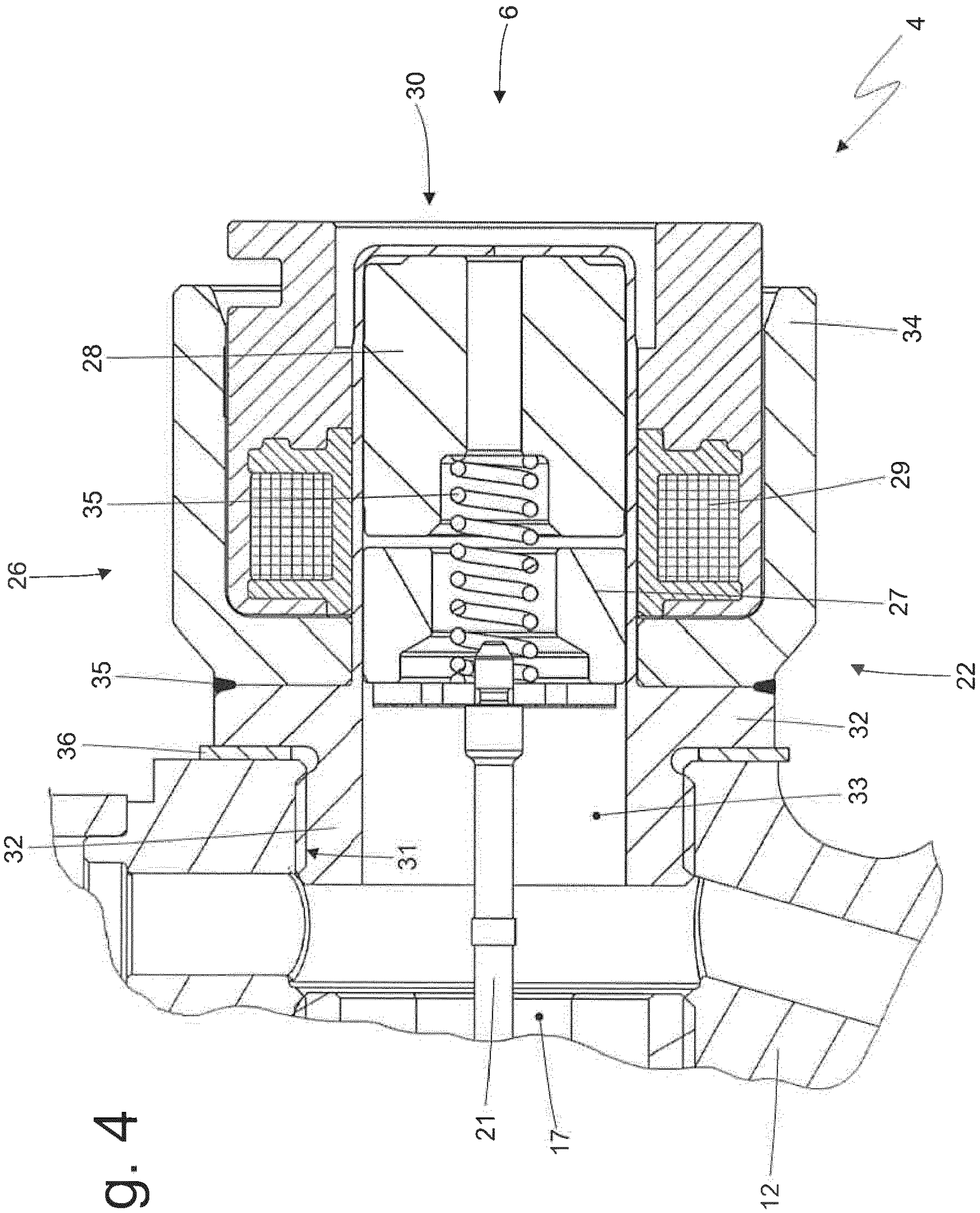

Fig. 4

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EUROPEAN SEARCH REPORT

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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	13 March 2017	Landriscina, V

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 20 3320

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- DE 102013220768 A1 **[0006]**