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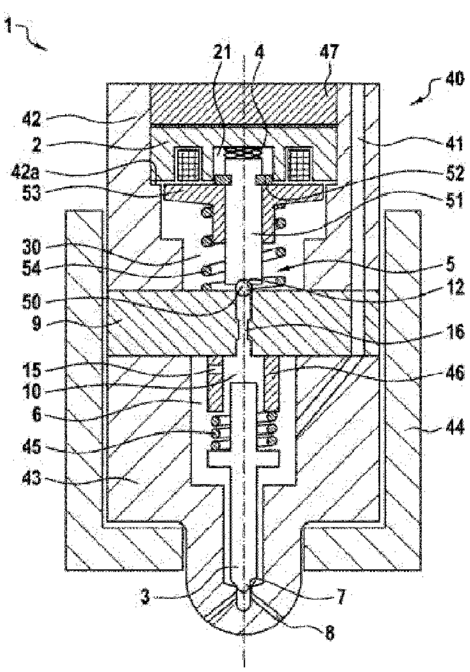
(54) **Title**: FUEL INJECTOR

Fig. 1




(57) **Abstract**: Fuel injector (1) for injecting fuel into a combustion chamber of an internal combustion engine having a nozzle needle (3) which is arranged longitudinally displaceably in a pressure space (6). The pressure space (6) can be filled with highly pressurized fuel. The nozzle needle (3) interacts as a result of its longitudinal movement with a nozzle needle seat (7) and as a result opens and closes at least one injection opening (8) into the combustion chamber. The longitudinal movement of the nozzle needle (3) is controlled by way of the pressure in a control space (10), it being possible for the control space (10) to be connected to a low-pressure space (30) by means of a control valve (5) which can be actuated by an actuator (2). The control valve (5) comprises a closing body (50) which can be moved by the actuator (2), a valve seat (12) and a closing spring (4), the closing body (50) interacting with the valve seat (12) in order to open and close a hydraulic connection from the control space (10) to the low-pressure space (30). The closing body (50) is pressed at least indirectly by the closing spring (4) against the valve seat (12). According to the invention, the closing spring (4) is configured as a wave spring.

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# SPECIFICATION

# FUEL INJECTOR

## TECHNICAL FIELD

The invention relates to a fuel injector having a control valve.

## PRIOR ART

Patent specification EP 851114 B1 has disclosed a fuel injector having a control valve for injecting fuel into a combustion chamber of an internal combustion engine.

The known fuel injector has a nozzle needle which is arranged longitudinally displaceably in a pressure space. The pressure space is fed with highly pressurized fuel. The nozzle needle interacts as a result of its longitudinal movement with a nozzle needle seat and as a result opens and closes at least one injection opening into the combustion chamber. The longitudinal movement of the nozzle needle is controlled by the pressure in the control space, it being possible for the control space to be connected to a low-pressure space by means of a control valve which can be actuated by an actuator. The control valve comprises a closing body which can be moved by the actuator, a valve seat and a closing spring. The closing body interacts with the valve seat in order to open and close a hydraulic connection from the control space to the low-pressure space. The closing body is pressed at least indirectly by the closing spring against the valve seat.

The closing spring of the known control valve is configured as a conventional helical spring which has a low stiffness. In order to achieve the required closing forces for the control valve, the compression spring therefore requires a comparatively large amount of installation space. As a result, the overall structural size of the fuel injector is large and the actuator possibly has only a small amount of installation space available, with the result that the actuator force turns out to be comparatively low.

## BRIEF DESCRIPTION OF THE INVENTION

In comparison, the fuel injector according to the invention for injecting fuel into a combustion chamber of an internal combustion engine minimizes the installation space requirement for the closing spring of the control valve. As a result, the overall size of the fuel injector is reduced.

To this end, the fuel injector has a nozzle needle which is arranged longitudinally displaceably in a pressure space. The pressure space can be filled with highly pressurized fuel. The nozzle needle interacts as a result of its longitudinal movement with a nozzle needle seat and as a result opens and closes at least one injection opening into the combustion chamber. The longitudinal movement of the nozzle needle is controlled by the pressure in a control space, it being possible for the control space to be connected to a low-pressure space by means of a control valve which can be actuated by an actuator. The control valve comprises a closing body which can be moved by the actuator, a valve seat and a closing spring. The closing body interacts with the valve seat in order to open and close a hydraulic connection from the control space to the low-pressure space. The closing body is pressed at least indirectly by the closing spring against the valve seat. According to the invention, the closing spring is configured as a wave spring.

As a result of the configuration as a wave spring, the closing spring has a high spring stiffness in a comparatively small amount of installation space. As a result of this embodiment, the overall size of the entire fuel injector can thus be reduced. In addition or as an alternative, the actuator can be of more powerful configuration, which leads to an improved injection characteristic because the control valve can be actuated more rapidly.

In advantageous embodiments, the closing spring has from 2.5 to 4.5 waves per revolution. This ensures the required stiffness of the closing spring in the case of the diameters in the millimetre range which are customary for the closing spring.

Furthermore, the closing spring advantageously has from 3 to 4 windings. As a result, a sufficient stroke of the control valve can be carried out with a low overall height.

In one advantageous embodiment, the closing spring is arranged in a recess of the actuator. As a result, the installation space of the fuel injector is reduced or a larger actuator can also be used as an alternative, since the spring no longer protrudes through a through hole of the actuator. Furthermore, the closing spring is therefore supported directly on the actuator, which signifies a simplification of the setting of the control valve during the assembly of the fuel injector.

In one advantageous development, the valve seat is configured on a valve body. As a result, the valve seat can be of robust design. For example, the valve body can be manufactured from a particularly wear-resistant steel and/or can be correspondingly coated.

In advantageous embodiments, the control valve comprises an armature which is operatively connected at least indirectly to the closing body. The armature can be actuated directly by the actuator in a simple way. As a result, no time delay occurs within the control valve during the actuation.

Furthermore, the control valve advantageously comprises a valve bolt, the valve bolt being operatively connected to the armature and interacting with the closing body. The actuator force is thus transmitted by the armature via the valve bolt to the closing body in a simple way. Any tolerances, for example with regard to the coaxiality, in the region of the control valve can be compensated for as a result.

Here, the closing spring advantageously interacts with the valve bolt. The closing spring can therefore be positioned advantageously and does not have to act directly on the armature.

In one alternative advantageous embodiment, the closing body is configured as an armature sleeve which interacts with the actuator. As a result, the actuator force is transmitted directly to the closing body. Furthermore, a pressure-equalized and/or force-equalized control valve can be realized by way of this embodiment.

In one advantageous development, the control valve comprises a valve bolt, the armature sleeve being guided longitudinally movably on the valve bolt. In this embodiment, the valve bolt does not serve to transmit force from the armature to the closing body, but rather it absorbs the hydraulic force in front of the valve seat and is supported on the opposite side at least indirectly on a housing of the fuel injector. Here, the diameter of the valve bolt advantageously corresponds to the diameter of the valve seat, with the result that the control valve is force-equalized; this means that the armature sleeve is equalized with regard to the hydraulic forces in the opening direction in the closed state of the control valve.

In advantageous embodiments, the actuator is an electromagnetic actuator. Electromagnetic actuators usually require a comparatively large closing spring. The embodiment of the closing spring as a wave spring and the associated reduction in installation space are correspondingly particularly suitable for electromagnetic actuators.

**BRIEF DESCRIPTION OF THE FIGURES**

Fig. 1 diagrammatically shows a longitudinal section through a fuel injector, only the essential regions being shown.

Fig. 2 shows a further embodiment of the fuel injector in the region of a control valve.

Fig. 3 shows a further embodiment of the fuel injector in the region of the control valve.

**REFERENCE NUMBERS**

1 fuel injector
2 actuator
3 nozzle needle
4 closing spring
5 control valve
6 pressure space
7 nozzle needle seat
8 injection opening
9 valve body
10 control space
12 valve seat
15 inflow throttle
16 outflow throttle
21 recess
30 low-pressure space
40 housing
41 high-pressure feed line
42 holding body
42a shoulder
43 nozzle body
44 nozzle clamping nut
45 nozzle needle
46 sleeve
47 lock nut
48 leaf spring
50 closing body
50.53 armature sleeve
51 valve bolt
52 driver ring
53 armature
53a continuous guide hole
54 valve spring

**THE DETAILED DESCRIPTION OF THE INVENTION**

Fig. 1 diagrammatically shows a longitudinal section through a fuel injector (1) for injecting fuel into a combustion chamber of an internal combustion engine, only the essential regions being shown. The fuel injector (1) comprises a housing (40) which, in the embodiment which is shown, has substantially three components which are braced with one another: a holding body (42), a valve body (9) and a nozzle body (43) which adjoins the combustion chamber.

These components are braced with one another in the longitudinal direction in a medium-tight manner by way of a nozzle clamping nut (44).

A pressure space (6) is configured in the nozzle body (43), in which pressure space (6) a nozzle needle (3) is arranged longitudinally displaceably. The pressure space (6) is supplied via a high-pressure feed line (41) which is configured in the housing 40 with highly pressurized fuel from a fuel source (not shown), for example a high-pressure reservoir.

A nozzle needle seat (7) is configured on the nozzle body (43). Furthermore, an injection opening (8) which branches off from the pressure space (6) and opens into the combustion chamber is configured on the nozzle body (43). The nozzle needle (3) interacts as a result of its longitudinal movement with the nozzle needle seat (7) and as a result opens and closes the at least one injection opening (8). A nozzle needle (45) which is arranged on the pressure space (6) acts on a shoulder of the nozzle needle (3) and presses the nozzle needle (3) against the nozzle needle seat (7) as a result. At the end which lies opposite the shoulder, the nozzle needle (45) interacts with a sleeve (46) and presses it against the valve body (9). Here, the nozzle needle (3) is arranged longitudinally movably in the sleeve (46).

That end of the nozzle needle (3) which lies opposite the combustion chamber, the sleeve (46) and the valve body (9) delimit a control space (10). The control space (10) is connected to the pressure space (6) via an inflow throttle (15) which is configured in the sleeve (46). The longitudinal movement of the nozzle needle (3) is controlled by the pressure in the control space (10), the pressure in the control space (10) in turn being controlled by a control valve (5) which is arranged in the housing (40).

The control valve (5) of the exemplary embodiment of Fig. 1 comprises a spherical closing body (50), a valve seat (12), a valve bolt 51, a driver ring 52, an armature 53 and a closing spring 4. The valve seat 12 is configured on the valve body (9). The closing body (50) interacts with the valve seat (12) and as a result opens and closes a hydraulic connection from the control space (10) to a low-pressure space (30) which is configured in the housing (40). Here, the hydraulic connection comprises an outflow throttle (16) which is configured in the valve body (9). The closing body (50) is guided in a receptacle of the valve bolt (51). The driver ring (52) is arranged in a groove of the valve bolt (51). The armature (53) is arranged so as to surround the valve bolt (51) radially and is braced against the driver ring (52) via the valve spring (54) which is arranged in the low-pressure space (30).

In alternative embodiments, the armature (53), the driver ring (52), the valve bolt (51) and optionally also the closing body (50) can be configured in one piece. In the embodiments of this type, the valve spring (54) can then also be dispensed with.

The control valve (5) can be actuated by an actuator (2) which is arranged in the housing (40) and is configured as an electromagnetic actuator in the exemplary embodiment of Fig. 1. In alternative embodiments, the actuator (2) can also be configured, for example, as a piezoelectric actuator. The actuator (2) is braced against a shoulder (42a) of the holding body (42) by way of a lock nut (47) and is therefore fixed in the housing (40). The actuator (2) acts on the armature (53) in the opening direction of the control valve (5). The closing spring (4) is arranged in the recess (21) of the actuator (2), which closing spring (4) acts on the valve bolt (51) in the closing direction of the control valve (5), that is to say presses the closing body (50) indirectly against the valve seat (12).

According to the invention, the closing spring (4) is configured as a wave spring. In comparison with a conventional helical spring, the said wave spring has the advantage that it has a higher specific stiffness with regard to the installation space. As a result, the installation space required for the closing spring (4) can be reduced in size and the overall design size of the fuel injector (1) can therefore be decreased. Furthermore, the size of the actuator (2) can also be enlarged in turn, with the result that a greater actuator force can be generated.

The closing spring (4) which is configured as a wave spring advantageously has a number of from 2.5 to 4.5 waves over the circumference. Here, the number of windings is preferably from 3 to 4. The spring rate in these advantageous embodiments is from 200 to 500 N/mm. As a result, the closing force of the closing spring (4) which is required for the control valve (5) is achieved. The closing force of the closing spring (4) is preferably approximately from 100 to 130 N. In advantageous embodiments, the height of the closing spring (4) is merely from 4 to 7 mm, with the result that the control valve (5) can be of extremely compact configuration.

In the following text, alternative embodiments of the fuel injector (1), in particular of the control valve (5), will be described.

Fig. 2 shows a further embodiment of the fuel injector (1) in the region of the control valve (5) in longitudinal section, only the essential regions being shown.

The electromagnetically configured actuator (2) is stressed against the shoulder (42a) of the holding body (42) by the lock nut (47) with a leaf spring (48) positioned in between. The holding body (42) is screwed to the valve body (9) by way of the nozzle clamping nut (44). In alternative embodiments, this screw connection can also comprise the nozzle body (43) (not shown).

In this embodiment, the control valve (5) is of substantially pressure-equalized and/or force-equalized configuration. This means that the hydraulically resulting overall force on the closing body (50) is virtually zero in the closed state of the control valve (5). To this end, the armature (53) and the closing body (50) are configured in one piece: the closing body (50) is an end section of the armature (53) and interacts with the valve seat (12) which is configured on the valve body (9). In this embodiment, the closing body (50) and the armature (53) can also be called an armature sleeve (50.53). The armature sleeve (50,53) is pressed against the valve seat (12) by the closing spring (4) which is configured as a wave spring, the closing spring (4) being supported on the lock nut (47).

The armature sleeve (50.53) has a continuous guide hole (53a), in which the valve bolt (51) is arranged. Unlike in the exemplary embodiment of Fig. 1, however, the valve bolt (51) is not operatively connected to the armature (53). The valve bolt (51) is loaded merely on one end side with the hydraulic pressure of the fuel which is to be sealed at the valve seat (12), and is supported on the opposite end side on the lock nut (47). Since the guide hole (53a) has the same diameter as the valve seat (12), this embodiment of the control valve (5) is pressure-equalized and/or force-equalized.

Fig. 3 shows a similar embodiment of the fuel injector to Fig. 2, namely with a pressure-equalized control valve (5). However, in a similar manner to the exemplary embodiment of Fig. 1, the actuator (2) has a recess (21), in which the closing spring (4) is arranged. As a result, the closing spring (4) is supported on the actuator (2) and presses the armature (53), with the closing body (50) which is connected in one piece with it, or the armature sleeve (50), (53) against the valve seat (12).

The method of operation of the fuel injector 1 is as follows:

The pressure space (6) is in permanent hydraulic connection via the high-pressure feed line (41) to a high-pressure reservoir, for example a common rail or a high-pressure pump. In order to inject fuel into the combustion chamber of the internal combustion engine, the nozzle needle (3) is raised up from the nozzle needle seat (7). The movement of the nozzle needle (3) is controlled by the control valve (5).

The control valve (5) is actuated by the actuator (2) and controls the pressure in the control space (10). If high pressure prevails in the control space (10), the said high pressure presses the nozzle needle (3) against the nozzle needle seat (7) counter to the force of the nozzle spring (45) and counter to a resulting hydraulic force which acts on the nozzle needle (3) in the pressure space (6).

If an injection of the fuel into the combustion chamber of the internal combustion engine is to take place, the control valve (5) is actuated in such a way that the closing body (50) is raised up from the valve seat (12). As a result, the pressure in the control space (10) is relieved into the low-pressure space (30) by way of the outflow throttle (16). As a result of the reduced pressure in the control space (10), the nozzle needle (3) is raised up from the nozzle needle seat (7) counter to the nozzle spring (45) by way of the resulting hydraulic force in the nozzle space (6), and the injection of the highly pressurized fuel from the pressure space (6) through the injection openings (8) into the combustion chamber of the internal combustion engine takes place as a result.

In order to end the injection operation, the actuation of the actuator (2) is ended, with the result that the closing body (50) is pressed by the closing spring (4) against the valve seat (12) again and the outflow throttle (16) is therefore closed. As a result, the pressure in the control space (10) is again increased as a result of the inflow via the inflow throttle (15), to such an extent that the said pressure, together with the force of the nozzle spring (45), brings about closure of the nozzle needle (3).

For rapid ending of the injection operation, the closing spring (4) has to press the closing body (50) against the valve seat (12) rapidly, that is to say with a high force. This requires a high spring stiffness of the closing spring (4). Since the closing spring (4) is configured as a wave spring, it has a high spring stiffness in a comparatively small installation space. As a result of this configuration, the overall size of the entire fuel injector (1) can therefore be reduced.

## CLAIMS

1. Fuel injector (1) for injecting fuel into a combustion chamber of an internal combustion engine having a nozzle needle (3) which is arranged longitudinally displaceably in a pressure space (6), it being possible for the pressure space (6) to be filled with highly pressurized fuel, the nozzle needle (3) interacting as a result of its longitudinal movement with a nozzle needle seat (7) and as a result opening and closing at least one injection opening (8) into the combustion chamber, the longitudinal movement of the nozzle needle (3) being controlled by way of the pressure in a control space (10), it being possible for the control space (10) to be connected to a low-pressure space (30) by means of a control valve (5) which can be actuated by an actuator (2), the control valve (5) comprising a closing body (50) which can be moved by the actuator (2), a valve seat (12) and a closing spring (4), the closing body (50) interacting with the valve seat (12) in order to open and close a hydraulic connection from the control space (10) to the low-pressure space (30), the closing body (50) being pressed at least indirectly by the closing spring (4) against the valve seat (12), characterized in that the closing spring (4) is configured as a wave spring.

2. Fuel injector (1) according to Claim 1, characterized in that the closing spring (4) has a number of from 2.5 to 4.5 waves over the circumference.

3. Fuel injector (1) according to Claim 1 or 2, characterized in that the closing spring (4) is arranged in a recess (21) of the actuator (2).

4. Fuel injector (1) according to one of Claims 1 to 3, characterized in that the valve seat (12) is configured on a valve body (9).

5. Fuel injector (1) according to one of Claims 1 to 4, characterized in that the control valve (5) comprises an armature (53) which is operatively connected at least indirectly to the closing body (50).

6. Fuel injector (1) according to Claim 5, characterized in that the control valve (5) comprises a valve bolt (51), the valve bolt (51) being operatively connected to the armature (53) and interacting with the closing body (50).

7. Fuel injector (1) according to Claim 6, characterized in that the closing spring (4) interacts with the valve bolt (51).

8. Fuel injector (1) according to one of Claims 1 to 4, characterized in that the closing body (50) is configured as an armature sleeve (53) which interacts with the actuator (2).

9. Fuel injector (1) according to Claim 8, characterized in that the control valve (5) comprises a valve bolt (51), the armature sleeve (53) being guided longitudinally movably on the valve bolt (51).

10. Fuel injector (1) according to one of Claims 1 to 9, characterized in that the actuator (2) is an electromagnetic actuator.

Fig. 1

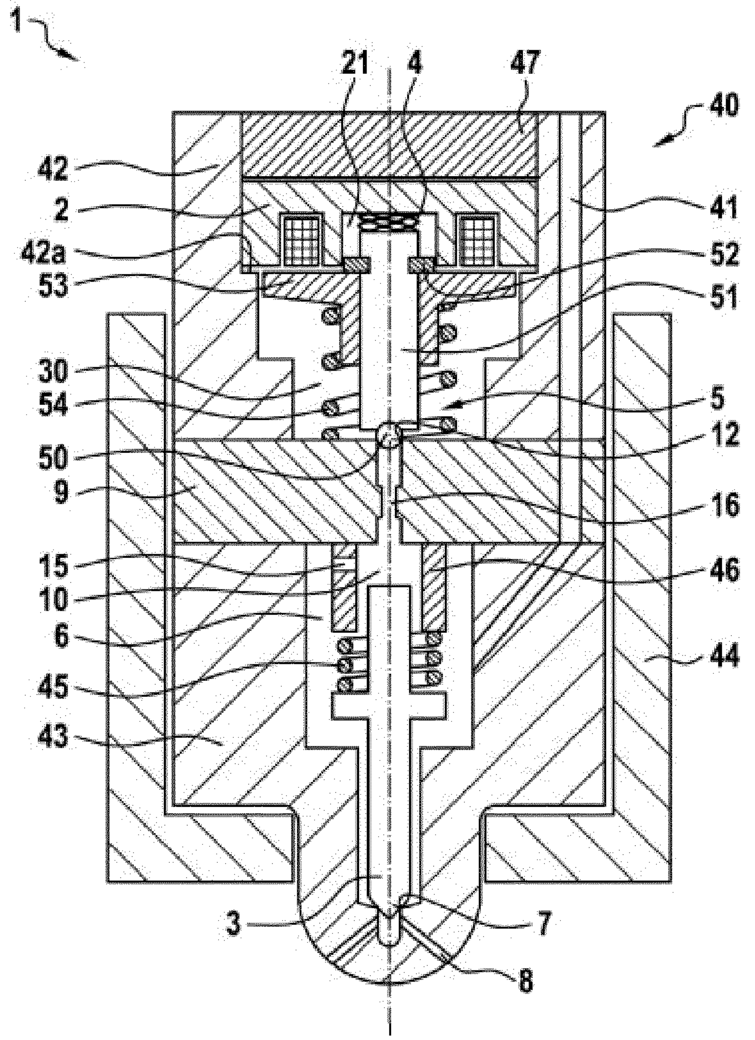
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Fig. 2

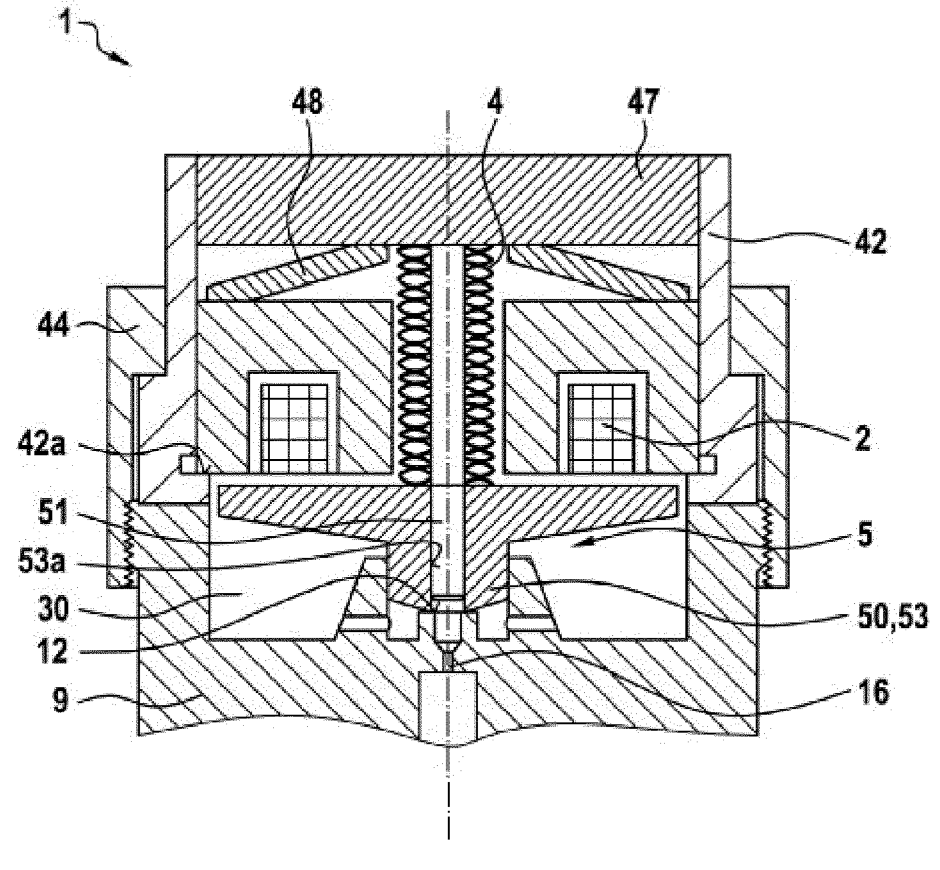
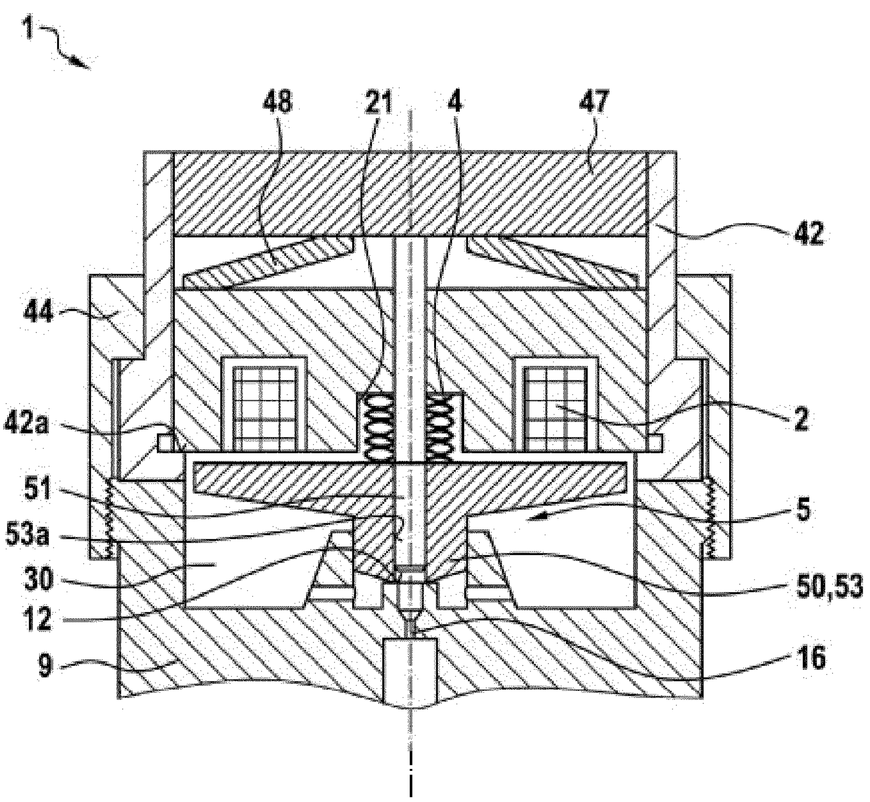


Fig. 3



# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/060300

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M47/02 F02M51/06 F16F1/02
ADD. F02M63/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| X | DE 10 2010 030390 A1 (BOSCH GMBH ROBERT [DE]) 29 December 2011 (2011-12-29)<br>abstract; figures 1,2,4,5,6<br>claims 1,2,3,6<br>paragraph [0024] - paragraph [0025]<br>paragraph [0003]<br>-----<br>-/-- | 1,2,4 |

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 July 2016 | 27/07/2016 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Barunovic, Robert |

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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