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(54) Solenoid actuated fluid injection valve

(57) A valve assembly (100) with a valve with a needle (115) and a first spring (135) for pressing said needle (115) towards a valve seat (120) is disclosed. The valve assembly (100) further comprises an electromagnetic actuator with an armature (165) being slidably positioned on said needle (115). A stopper (170) is rigidly attached to said needle (115) or comprised by said needle (115) and configured to engage with said armature (165) when the armature (165) moves towards the pole piece (140) of the actuator. The valve assembly (100) comprises a second spring (180) for biasing said armature (165) away from the stopper (170), the second spring (180) comprising a wave spring or a Belleville spring.

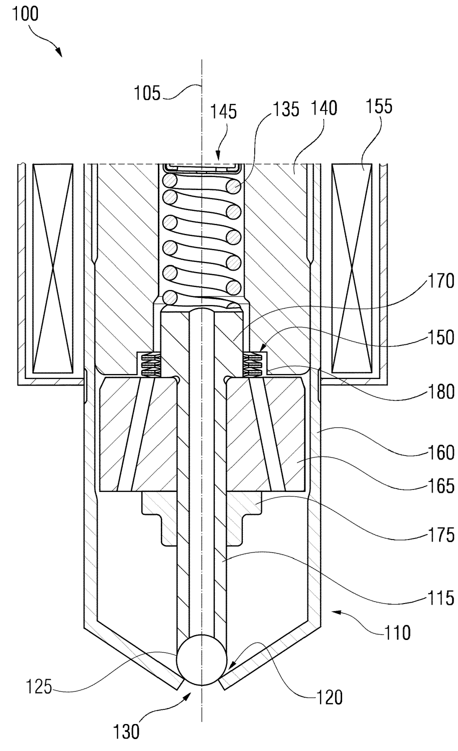

FIG 1

EP 2 985 445 A1

Description

[0001] The present invention relates to a solenoid actuated fluid injection valve. More specifically, present invention concerns a fuel injection valve for injecting fuel into a combustion engine.

[0002] An injector for injecting fuel into a combustion engine, the combustion engine being comprised for instance by a power train of a motorized vehicle, comprises a valve assembly for controlling a flow of fuel through the injector. The valve assembly comprises a valve with a needle and a valve seat. When the needle is lifted from the valve seat, fuel flows through the open valve. A spring provides a biasing force onto the needle so that the valve is normally closed. An actuator of the valve assembly comprises a solenoid and an armature. The armature is coupled to the needle and configured to lift the needle from the valve seat when the solenoid is electrically energised.

[0003] For operation with fuel under high pressure and for fast opening of the valve, a free lift concept may be employed. In this, the armature is slidably positioned on the needle so that, when the solenoid is energised, the armature firstly moves without operating the needle. After travelling a predetermined distance - also called "free lift" -, the armature hits a stopper that is rigidly attached to the needle so that the momentum of the armature carries away the needle at high speed. Movement of the armature may be stopped further on by a dedicated stopper. After the solenoid is de-energised and the needle is pressed back onto the valve seat by the spring, the armature needs to be slid back on the needle to be ready for the next operation as described above. The resetting force upon the armature needs to be large enough to ensure a quick setback and to withstand a vibration of the combustion engine.

[0004] The resetting force upon the armature may be provided by a permanent magnet. However, such a magnet may be sensitive to high temperatures and the achievable force of the magnet may be limited. The resetting force may also be generated mechanically. EP 2 336 544 A1 and EP 2 634 413 A1 propose the use of a dedicated coil spring for providing the resetting force upon the armature.

[0005] The known appliances for providing the resetting force upon the armature are complicated and may increase production costs for the injector. They may also require a significant space inside the valve assembly and in some designs, the resetting spring is part of the moving mass of the valve.

[0006] It is therefore an object of present invention to provide an improved solenoid actuated valve assembly that overcomes at least some of the mentioned shortcomings.

[0007] The invention achieves this object through a solenoid according to the features of the independent claim. Dependent claims give preferred embodiments.

[0008] According to the invention, a fluid injection valve is disclosed. It comprises a valve assembly with a needle for mating with the valve seat and a first spring for pressing said needle towards the valve seat.

[0009] The fluid injection valve further comprises an electromagnetic actuator assembly comprising a solenoid, an armature and a pole piece for magnetically attracting the armature when the solenoid is energized. The armature is slidably positioned on said needle. Preferably, the armature is a one-pieced part.

[0010] The fluid injection valve, in particular the valve assembly, further comprises a stopper which is rigidly attached to said needle or comprised by said needle. In particular it is attached to a shaft of the valve needle or in one piece with the shaft. In

[0011] The stopper is configured to engage with the armature when the armature moves towards the pole piece. In other words, the armature is operable to take the valve needle with during its travel towards the pole piece by means of mechanical interaction - in particular by means of a form fit connection - with the stopper. Preferably, the armature is spaced apart from the stopper in a closed configuration of the fluid injection valve and the engagement between the stopper and the armature is in particular established only after the armature has travelled a given distance - the free lift - towards the pole piece. In case of an inward opening valve, the stopper is thus in particular configured to engage with said armature when the armature exceeds a predetermined distance to the valve seat.

[0012] The fluid injection valve further comprises a second spring for biasing the armature away from the stopper. In case of an inward opening valve, the second spring is thus operable to bias the armature towards the valve seat.

[0013] In one embodiment, the second spring comprises a wave spring. The wave spring can apply a very high load with very compact dimensions. Construction and assembly of the valve assembly may thus be simplified. The wave spring may also apply very little or virtually no lateral forces on any adjacent member upon compression. Guidance of the armature and of the needle may thus have improved precision.

[0014] According to an alternative embodiment, the second spring comprises a Belleville spring. The Belleville spring is also known as Belleville washer, coned-disc spring, conical spring washer, disc spring or cupped spring washer. The Belleville spring can apply a high load with compact dimensions. It may also have low side loads upon compression. The valve assembly may thus be simple in construction and assembly and the second spring may show good performance in resetting the armature on the needle.

[0015] In an expedient embodiment, the pole piece comprises a longitudinal recess with a shoulder against which an axial end of the second spring rests. The longitudinal recess is in particular a central opening of the pole piece which extends completely through the pole piece along a longitudinal axis of the fluid injection valve.

[0016] In an alternative embodiment, the second spring is received in a stepped longitudinal recess of the armature such that a first end of the second spring is seated against the step of the longitudinal recess of the armature and the opposite, second end of the second spring is seated against the stopper.

[0017] The second spring may thus be at least partly received by the recess in the pole piece or the armature. This design may be space saving. As both the wave spring and the Belleville spring are compact in size, only a small portion of the pole piece or the armature must be removed to make room for the second spring. Mechanical and electromagnetic properties of the pole piece may thus be preserved. In particular, good axial guidance of the valve needle and/or the armature may thus be achievable.

[0018] It is furthermore preferred that the first spring and/or the stopper is received by the recess of the pole piece or the armature.

[0019] In case of the recess being comprised by the pole piece, the second spring may preferably lie radially outside the first spring and/or the stopper. In other words, the second spring preferably exposes the first spring and/or the stopper in top view along the longitudinal axis in this case. In particular, the stopper and/or a portion of the first spring may be arranged in a central opening of the second spring. A recess in the pole piece may thus need only slide adaption for accommodating for the second spring as described above. A known valve assembly may thus be easily adaptable to the invention.

[0020] In one embodiment, the second spring comprises at least a first Belleville spring and a second Belleville spring which are arranged subsequently along a longitudinal axis of the fluid injection valve. Each of the first and second Bellville springs may extend obliquely to the longitudinal axis from an outer circumferential edge to an inner circumferential edge. In particular, the outer circumferential edge and the inner circumferential edge each extend circumferentially around the longitudinal axis. The outer circumferential edge is at a larger radial distance from the longitudinal axis than the inner circumferential edge. The inner circumferential edge in particular defines an opening of the respective Belleville spring through which preferably the valve needle extends. The outer circumferential edge in particular defines an outer contour of the respective Belleville spring in top view along the longitudinal axis. The first and second Belleville spring is preferably in the shape of a truncated cone shell extending from the outer circumferential edge to the inner circumferential edge. The, imaginary, apex of the cone shape is preferably positioned on the longitudinal axis.

[0021] In one development, the inner circumferential edges of the first and second Belleville springs are positioned axially between the outer circumferential edge of the first Belleville spring the outer circumferential edge of the second Belleville spring. Preferably, the inner circumferential edges contact one another and the outer circumferential edges are spaced apart from one another. For example, the cone shapes of the first and second Belleville springs are directed in opposite directions of the longitudinal axis.

[0022] In another development, the inner circumferential edge of the first Belleville spring is axially displaced relative to the outer circumferential edge of the first Belleville spring in the same direction as the inner circumferential edge of the second Belleville spring relative to the outer circumferential edge of the second Belleville spring. Preferably, the outer circumferential edges contact one another and the inner circumferential edges contact one another. For example, the cone shapes of the first and second Belleville springs are directed in the same direction of the longitudinal axis. In a further development, the second spring additionally comprises at least a third Belleville spring and a fourth Belleville spring which are arranged subsequently along a longitudinal axis of the fluid injection valve wherein each of the third and fourth Bellville springs extend obliquely to the longitudinal axis from an outer circumferential edge to an inner circumferential edge and the inner circumferential edges of the third and fourth Belleville springs are positioned axially between the outer circumferential edge of the third Belleville spring the outer circumferential edge of the fourth Belleville spring.

[0023] By such arrangement of Belleville springs, length and spring constant of the second spring may be easily adaptable to requirements of different valve types.

[0024] The second spring may comprise steel. If made from steel, the second spring may be very stable over temperature and its suspension weight may be very reproducible. The second spring may comprise a standard element as offered by a spring manufacturer. Production costs for the valve assembly may thus be kept low.

[0025] The invention will now be described with more detail making reference to the enclosed figures, in which:

Fig. 1	shows a longitudinal section of a fuel injection valve according to an exemplary embodiment;
Fig. 2	shows an exploded view of elements of the valve assembly according to a variant of the fuel injection valve of Fig. 1;
Figs. 3 to 5	show embodiments of a wave spring for the fuel injection valve of Fig. 1 and
Figs. 6 to 9	show arrangements of Belleville springs for the fuel injection valve of Fig. 1.

[0026] Fig. 1 shows a longitudinal section of a fluid injection valve 100 which is a fuel injector in the present exemplary embodiment. The fuel injector may especially be adapted for injecting fuel in a combustion engine. The combustion engine may be adapted for propelling a motor vehicle. Only a lower part of the injection valve 100 comprising the valve assembly is shown. For reasons of display proportions in the lower part of the valve assembly 100 may be distorted.

[0027] The injection valve 100 extends along a longitudinal axis 105. The valve 100 comprises a valve assembly 110 with a needle 115 that is adapted for mating with a valve seat 120 of the valve assembly 110. The valve seat 120 is comprised by a housing 160 of the valve assembly 110. The valve needle 115 is positioned in a cavity of the housing 160. In the shown exemplary embodiment, the tip of the valve needle 115 is represented by a sealing ball 125 which is located between and attached to a shaft of the needle 115 and the valve seat 120. The valve 110 is closed as long as the needle 115 is pressed in a direction of the valve seat 120. When the needle 115 is lifted from the valve seat 120, the valve 110 opens and permits a flow of fuel through an nozzle 130.

[0028] The valve assembly 100 further comprises a first spring 135 for pressing the needle 115 towards the valve seat 120. It is preferred that one axial end of the first spring 135 rests against an axial end of the needle 115. In the shown embodiment there is provided a pole piece 140 with an axial recess 145 in which at least a portion of first spring 135 and at least a portion of the needle 115 is received. The recess 145 may comprise different diameters consecutively. Where sections of different diameters lie adjacent, a shoulder 150 with an axial surface may be formed. It is preferred that the axial surface of the shoulder 150 lies in a plane perpendicular to longitudinal axis 105.

[0029] The pole piece 140 is positionally fix relative to the housing 160 and preferably received in its cavity. It is part of an electromagnetic actuator assembly of the fuel injection valve 100. The electromagnetic actuator assembly also comprises a solenoid 155 extending circumferentially around the pole piece 140 and the housing 160. In other words, the housing 160 may extend radially between the solenoid 155 and the pole piece 140, thereby isolating the solenoid 155 from fuel flowing through an inside of the injection valve 100.

[0030] A one-pieced armature 165 is positioned on the needle 115 such that it may slide along longitudinal axis 105 with respect to the needle 115 and also with respect to the housing 160 and the pole piece 140. The sliding motion of the armature 165 relative to the needle 115 is determined by a first stopper 170 in longitudinal direction towards the pole piece 140 and preferably in direction away from the pole piece 140 by a second stopper 175. Both stoppers 170, 175 are rigidly attached to the needle 115.

[0031] From a configuration where it is in contact with the second stopper 175, the armature 165 may travel in a first direction along longitudinal axis 105 until it engages with the first stopper 170. When the armature 165 is in engagement with the first stopper 170, it is operable to take the needle 115 with it in the first direction by means of the form fit connection with the first stopper 170.

[0032] The second stopper 175 limits displacement of the armature 165 relative to the needle 115 in a second direction opposite to the first direction. When the armature 165 rests against the second stopper 175, e.g. when the armature 165 is in a position closest to the valve seat 120 in the present embodiment, and the solenoid 155 is energised, a magnetic force pulls the armature 165 in the first direction, away from the valve seat 120. The armature 165 accelerates in a sliding motion with respect to the needle 115 and the pole piece 140 until it engages with the first stopper 170. Upon engaging, the momentum of the armature 165 accelerates the needle 115 and the armature 165 carries the needle 115 with it on its further travel towards the pole piece 140, thus quickly lifting the needle 115 from the valve seat 120 and opening the valve 110. The lifting motion of the armature 165 is stopped when axial ends of the armature 165 and the pole piece 140 meet. The meeting may be hydraulically cushioned by fuel in the space between the pole piece 140 and the armature 165. It is also conceivable that the needle 115 hits the pole piece 140 for stopping the movement of the armature 165 and the needle 115.

[0033] When the solenoid 155 is de-energised, the first spring 135 presses the needle 115 in the second direction, back towards the valve seat 120. The first stopper 170 forces the armature 165 in the same direction, separating it axially from the pole piece 140. After the valve 110 is closed - i.e. the sealing ball 125 of the valve needle 115 is in contact with the valve seat 120 - the armature 165 needs to be brought some distance further towards the valve seat 120 and retained out of engagement with the first stopper 170 in order to enable repetition of the above described procedure when the solenoid 155 is energised for the next injection event. To this end, a second spring 180 is provided that presses the armature 165 away from the first stopper 170, i.e. towards the valve seat 120 and the second stopper 175 in the present exemplary embodiment. It is preferred that the second spring 180 engages axially with the armature 165. A second axial end of the second spring 180 is preferred to rest against the shoulder 150 of the recess 145. It is preferred that the diameter of the recess 145 is large enough to accommodate for the second spring 180 at an axial end of the pole piece 140 that faces the armature 165 as in the embodiment shown in Fig. 1.

[0034] The second spring 180 is preferred to have compact dimensions and a high stiffness. It is also preferred that the second spring 180 exerts very small or no lateral forces upon axial compression. A preferred choice for the second spring 180 is a wave spring or a Belleville spring. Both types of springs are preferred to comprise steel and will be explained in more detail with reference to Figs. 5 to 9.

[0035] Fig. 2 shows an exploded view of some elements of the valve assembly 110 of the fuel injection valve 100 of Fig 1. The elements are exploded along longitudinal axis 105.

[0036] The pole piece 140 shows radial protrusions that extend in an axial direction. To put it differently, it has axially elongated fins at its outer circumferential surface. The protrusions are adapted to engage with the housing 160 and provide a predetermined friction to maintain the axial position of the pole piece 140 relative to the housing 160.

[0037] As a variant of the exemplary embodiment, the first stopper 170 is shown mounted on the shaft of the needle 115, in contrast to Fig. 1, where the shaft of the needle 115 and the first stopper 170 are in one piece. The second stopper 175 (not visible in Fig. 2) may also be mounted on the shaft of the needle 115 like in Fig. 1 or the second stopper 175 may be made from one piece with the shaft of the needle 115. The shown elements are adapted to be received in the housing 160.

[0038] Figs. 3 to 5 show embodiments of a wave spring for use as the second spring 180 in the valve assembly 100 of Fig. 1 or Fig. 2.

[0039] In the embodiment of Fig. 3 the wave spring is made from one single flattened wire which essentially extends along a helix with respect to a longitudinal axis. In this, the helical wire is bent axially, preferably according to a sinusoidal shape. In other words, the helical basic shape of the flattened wire is modulated by a curved shape such as a sinusoidal shape, in particular such that portions on axially adjacent turns of the helix contact one another. Where portions of the wire meet axially, they may be affixed to one another, for instance by welding or soldering.

[0040] The wave spring 180 shown in Fig. 4 complements the embodiment of Fig. 3 with a so-called shim 185 on each axial end. The shim is a portion of the flattened wire that runs circularly around the longitudinal axis 105 to provide an axial end that lies in one plane.

[0041] The wave spring 180 shown in Fig. 5 is of the interlaced type and comprises at least two flattened wires that lie axially adjacent over their lengths. In another embodiment, the interlaced wave spring 180 may comprise shims as discussed above with respect to Fig. 4.

[0042] Fig. 6 shows a single Belleville spring for use in or as the second spring 180 in the valve assembly 100 of Fig. 1 or 2. The Belleville spring 180 is shaped like a washer deformed axially so that it comprises frusto-conical surfaces. The Bellville springs extends obliquely to the longitudinal axis 105 from an outer circumferential edge 190 which defines an outer contour of the Belleville spring in top view along the longitudinal axis 105 to an inner circumferential edge 195 which defines an opening of the Belleville spring through which the valve needle 115 extends (not shown in Fig 6). The circumferential edges 190, 195 extend circumferentially around the longitudinal axis 105 such that the outer circumferential edge 190 is at a larger radial distance from the longitudinal axis 105 than the inner circumferential edge 195.

[0043] Fig. 7 shows a second spring 180 of the Belleville type that comprises a parallel arrangement of several single Belleville springs.

[0044] The inner circumferential edges 195 of each of the Belleville springs are axially displaced relative to the outer circumferential edge 190 of the respective Belleville spring in the same direction. The outer circumferential edges 190 contact one another and the inner circumferential edges 195 contact one another.

[0045] Fig. 8 shows another embodiment of the second spring 180 comprising the serial arrangement of single Belleville springs according to Fig. 6.

[0046] In this embodiment, the inner circumferential edges of a first and a second Belleville springs are positioned axially between the outer circumferential edge of the first Belleville spring the outer circumferential edge of the second Belleville spring so that the inner circumferential edges contact one another and the outer circumferential edges are spaced apart from one another. The second spring 180 according to the present exemplary embodiment comprises two axially subsequent pairs of such first and second Belleville springs. It may alternatively comprise only one or more than two such pairs.

[0047] Finally, Fig. 9 shows a serial-parallel arrangement of single Belleville springs according to Fig. 6 comprised by another embodiment of the second spring 180. The arrangement is a combination of those discussed above in connection with Figures 7 and 8.

[0048] Other combinations of Belleville springs in serial, parallel or mixed arrangements may also be used. The resulting second spring 180 of the Belleville type may show a high stiffness and compact dimensions. Due to the construction, the second spring 180 may have very low side loads upon axial compression.

Claims

1. A fluid injection valve (100), comprising:

   - a valve assembly with a valve seat (120), a needle (115) for mating with the valve seat (120) and a first spring (135) for pressing said needle (115) towards the valve seat (120);
   - an electromagnetic actuator assembly comprising a solenoid (155), an armature (165), and a pole piece (140) for magnetically attracting the armature (165) when the solenoid (155) is energized, the armature (165) being slidably positioned on said needle (115);
   - a stopper (170) rigidly attached to said needle (115) or comprised by said needle (115) and configured to engage with said armature (165) when the armature (165) moves towards the pole piece (140);
   - a second spring (180) for biasing said armature (165) away from the stopper (170),
   - wherein the second spring (180) comprises a wave spring or a Belleville spring.

2. Fluid injection valve (100) according to the preceding claim, wherein the pole piece (140) comprises a lon-

gitudinal recess (145) with a shoulder (150) against which an axial end of the second spring (180) rests.

3. Fluid injection valve (100) according to the preceding claim, wherein the first spring (135) and/or the stopper (170) is received in the recess (145).

4. Fluid injection valve (100) according to the preceding claim, wherein the second spring (180) is arranged radially outside of the stopper (170).

5. Fluid injection valve (100) according claim 1, wherein the armature (165) comprises a longitudinal recess with a shoulder against which an axial end of the second spring (180) rests.

6. Fluid injection valve (100) according to the preceding claim, wherein the first spring (135) and/or the stopper (170) is received in the recess.

7. Fluid injection valve (100) according to one of the preceding claims wherein the second spring (180) comprises at least a first Belleville spring and a second Belleville spring which are arranged subsequently along a longitudinal axis (105) of the fluid injection valve (100).

8. Fluid injection valve (100) according to the preceding claim, wherein each of the first and second Bellville springs extend obliquely to the longitudinal axis (105) from an outer circumferential edge (190) to an inner circumferential edge (195) and the inner circumferential edges (195) of the first and second Belleville springs are positioned axially between the outer circumferential edge (190) of the first Belleville spring the outer circumferential edge (190) of the second Belleville spring.

9. Fluid injection valve (100) according to claim 7, wherein each of the first and second Bellville springs extend obliquely to the longitudinal axis (105) from an outer circumferential edge (190) to an inner circumferential edge (195) and the inner circumferential edge (195) of the first Belleville spring is axially displaced relative to the outer circumferential edge (190) of the first Belleville spring in the same direction as the inner circumferential edge (195) of the second Belleville spring relative to the outer circumferential edge (190) of the second Belleville spring.

10. Fluid injection valve (100) according to the preceding claim, wherein the second spring (180) additionally comprises at least a third Belleville spring and a fourth Belleville spring which are arranged subsequently along the longitudinal axis (105) of the fluid injection valve (100) wherein each of the third and fourth Bellville springs extend obliquely to the longitudinal axis (105) from an outer circumferential edge (190) to an inner circumferential edge (195) and the inner circumferential edges (195) of the third and fourth Belleville springs are positioned axially between the outer circumferential edge (190) of the third Belleville spring the outer circumferential edge (190) of the fourth Belleville spring.

11. Fluid injection valve (100) according to one of the preceding claims, wherein the second spring (180) comprises steel.

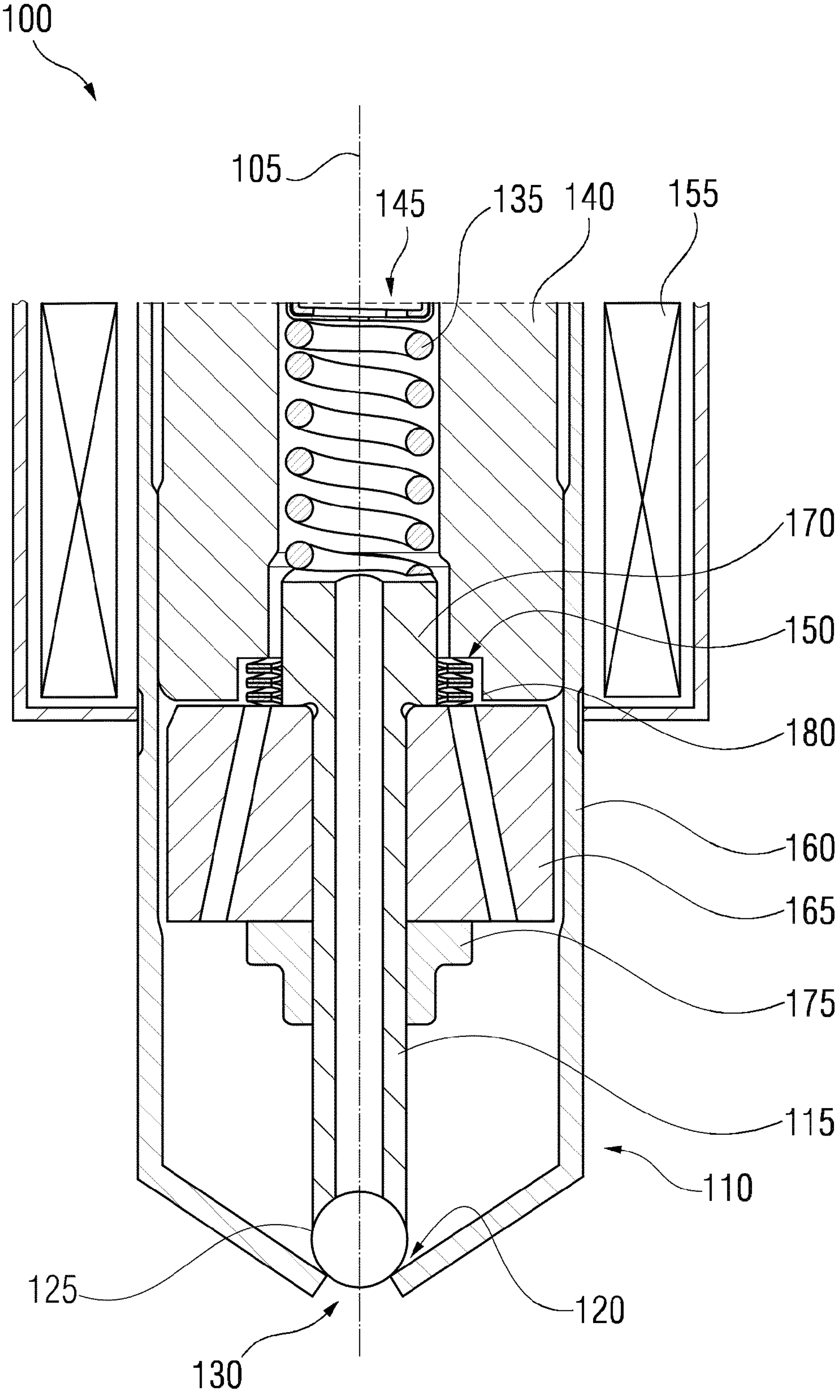
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FIG 1

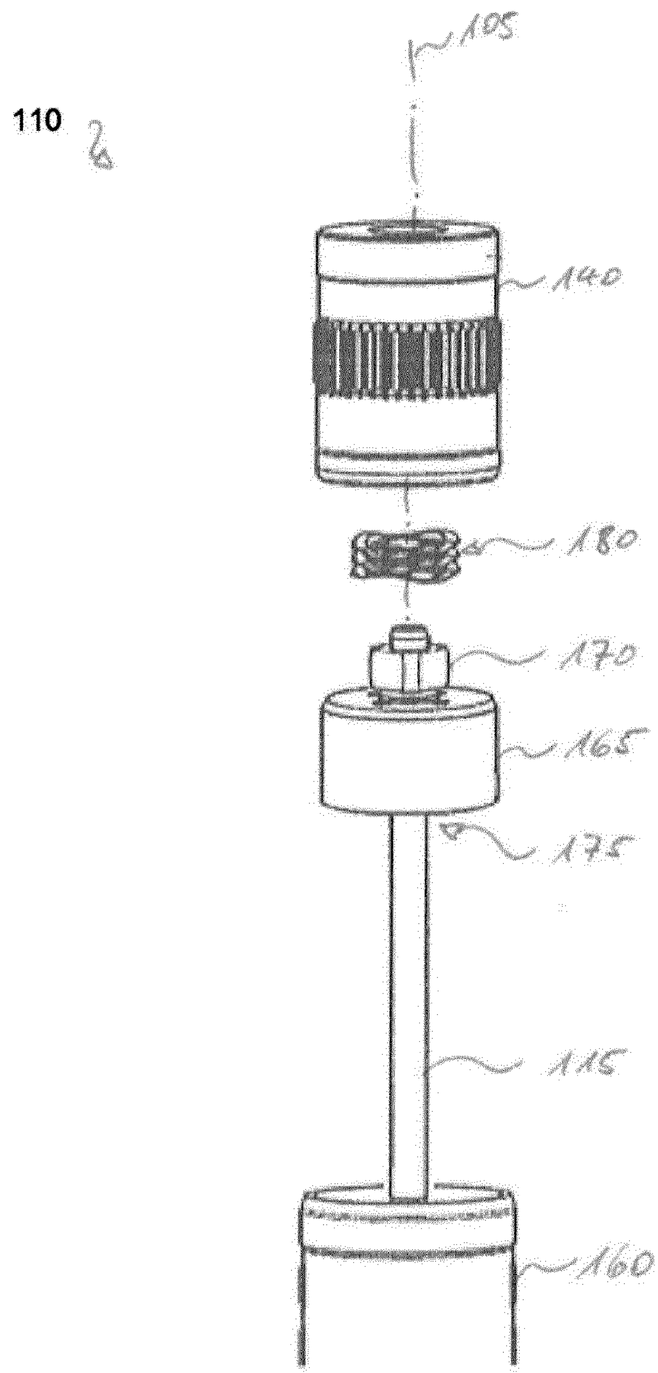

Fig. 2

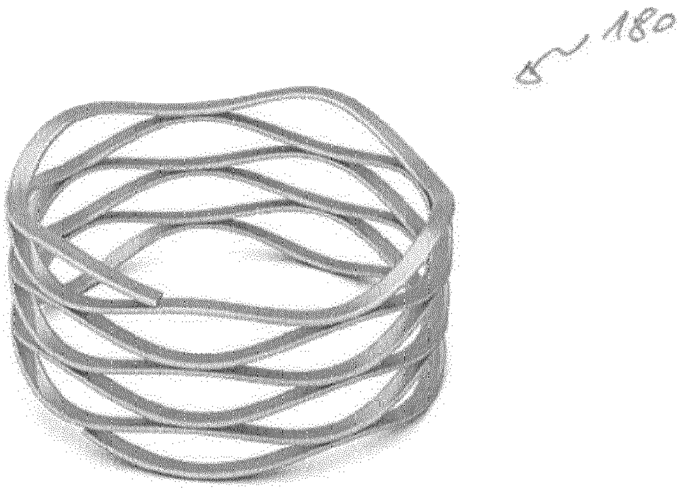

Fig. 3

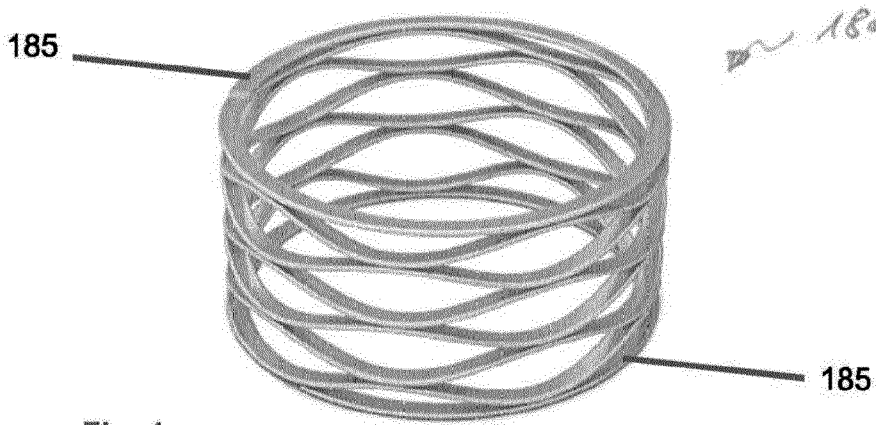

Fig. 4

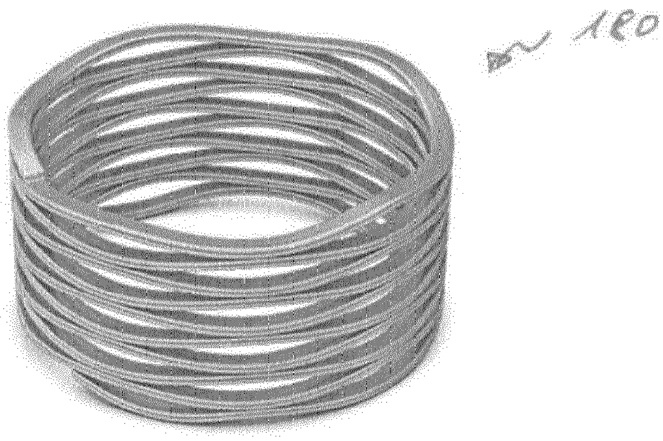

Fig. 5

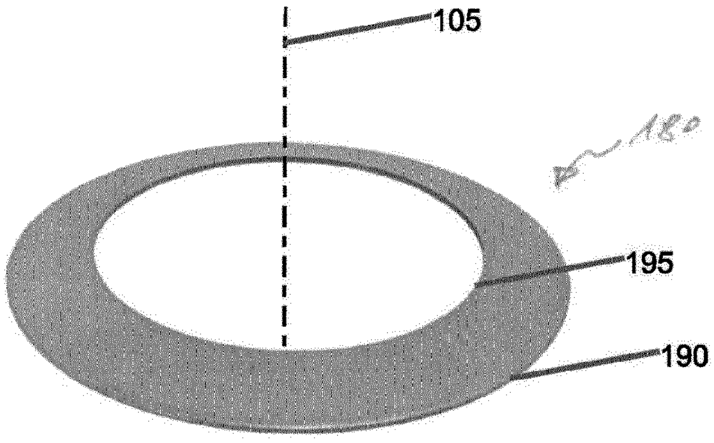

Fig. 6

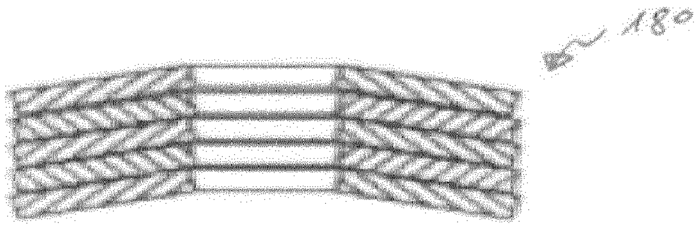

Fig. 7

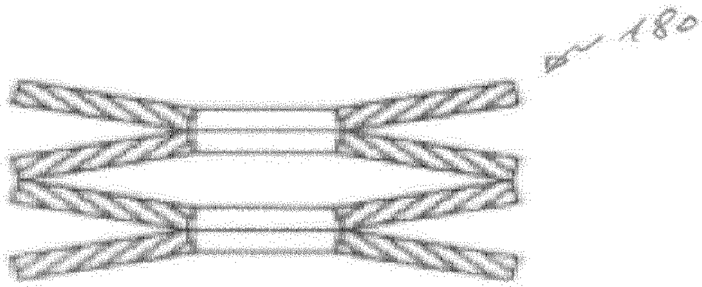

Fig. 8

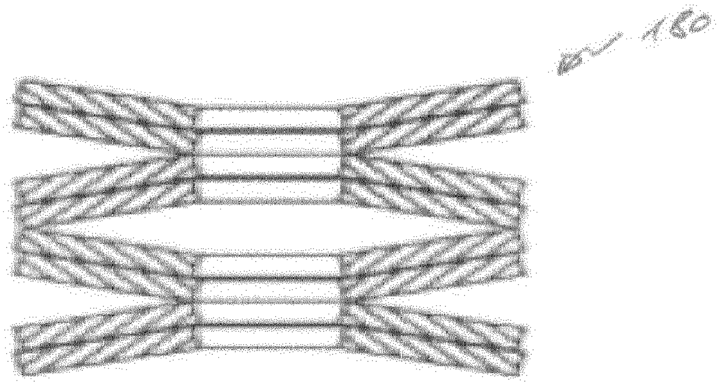

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 14 18 1077

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 January 2015	Landriscina, V

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 18 1077

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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19-01-2015

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