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(54) POWER GROUP FOR A FUEL INJECTOR AND FUEL INJECTOR

(57) A power group (10) for a fluid injector is specified. It comprises a housing (11), a solenoid (12) including a coil (13) wound around a central axis (X) of the power group (10), a plurality of permanent magnets(15), each permanent magnet having an arched shape around the central axis, each permanent magnet extending over an angle of less than 360° around the central axis, and a ring made of plastic material (16) including a plurality of slots (17), each slot (17) accommodating one respective magnet of the permanent magnets (15) of the power group. Further, a fluid injector (100) and a method for manufacturing a fluid injector (100) are specified.

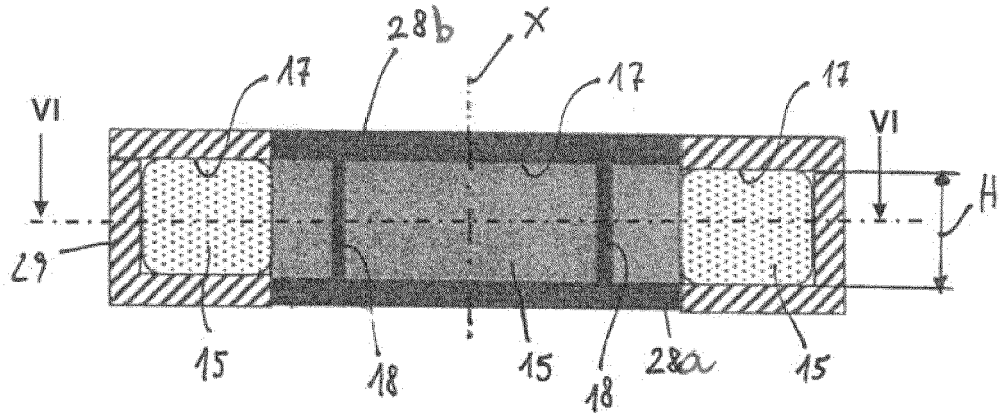

Fig. 5

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Description

Field of the invention

[0001] The present invention relates to a power group (MPG) for a fluid injector, particularly a fuel injector for injecting fuel into a combustion engine. The present invention relates also to a fluid injector including such power group.

Art Background

[0002] Fuel injectors are used in internal combustion engines, where they are arranged in order to dose fuel into a combustion chamber of a cylinder of an internal combustion engine.

[0003] A known type of fuel injector comprises:

- a valve assembly including a cavity, or fuel tube, along which an armature and a needle attached to the armature slide between a close and an open position to generate the fuel mass flow rate towards the combustion chamber;
- a power group coupled to the valve assembly and including a solenoid, which upon energization creates a magnetic path to operate the armature and the needle of the valve assembly.

[0004] In such a fuel injector, the power group may further comprise a permanent magnet with radial magnetization to support the magnetic force acting on the armature when the solenoid is actuated. The permanent magnet is typically constituted by a ring of magnetic material, which is coaxial to the solenoid. A magnetic material which is typically used in the permanent magnet is the so called plasto-neodymium (bounded neodymium).

[0005] Plasto-neodymium has limited magnetic density energy, i.e the maximum value of the magnetic field intensity is 8-10 MOe or, in SI units, 600-800 MA/m, due to the presence of not magnetic bounded media into its volume. Therefore a limited effect on actuator performances, in particular on the maximum fluid pressure (Pmax) capability, is expected for injector applications including permanent magnets made of plasto-neodymium.

Summary of the Invention

[0006] It is an object of the present invention to provide a power group for a fuel injector reaching a particularly large maximum fluid pressure (Pmax) capability, overcoming in particular the above-described inconveniences of the know power groups including plasto-neodymium permanent magnets.

[0007] Further objects of the present invention are to provide a fuel injector including such a power group and a method for manufacturing such a fuel injector.

[0008] These objects are achieved by a power group for a fluid injector, by a fluid injector and by a method according to the independent claims. Advantageous developments and modifications of the power group, the fluid injector and the methods result from the respective dependent claims, the following description and the drawings.

[0009] According to a first aspect of the present invention, a power group for a fluid injector is disclosed. The power group comprises a housing and a solenoid including a coil wound around a central axis of the power group. It further comprises a plurality of permanent magnets, each permanent magnet having an arched shape around the central axis, each permanent magnet extending over an angle of less than 360° around the central axis, and a ring made of plastic material and including a plurality of slots, each slot accommodating one respective magnet of the permanent magnets of the power group.

[0010] According to a second aspect, a fluid injector is disclosed. The injector comprises a valve body having a cavity defining a fuel path along a central axis, the valve body extending axially between a fluid inlet and a fluid outlet. It further comprises a needle which is moveable between a closing position preventing a fluid flow through the fluid outlet and at least one opening position for releasing fluid through the fluid outlet. The needle is attached to an armature so that it is axially movable together with the armature from the closing position to the at least one opening position. In addition, the fluid injector comprises the power group for creating the magnetic field to axially move the armature and the needle.

[0011] According to a third aspect, a method for manufacturing a fluid injector disclosed. The method includes a step of providing or manufacturing the valve assembly. The method further includes a step of manufacturing the power group which has the armature to be attached to the needle of the valve assembly. Manufacturing the power group comprises a step of inserting the plurality of permanent magnets into the plurality of slots. According to a further step of the method, the power group is fixed to the valve assembly.

[0012] Using permanent magnets, each having an arched shape around the central axis, but extending for an angle lower than 360° around the central axis, allows obtaining a radial magnetization, at the same time avoiding, for any material used in the manufacturing of the magnets, the stress level which may lead to the breaking of the permanent magnet ring. In this way, the power group may be capable to improve the performances of a fuel injector, for example in order to support the European Emission Standards Euro 6 and 7 for multi-streaming direct injector applications. Specifically, the power group may permit to operate the fluid injector at particularly large fluid pressures.

[0013] According to one embodiment, the arched permanent magnets comprise a Sm-Co alloy. Advantageously, this permits to reach high values of the intensity of the magnetic field generated by the power group. In order to maximize the injector performance, a different

permanent magnet material may be used, for example based Sm-Co which has a typical value of the magnetic field intensity in the range of 20-26 Moe or, in the SI, 1600-2100 MA/m.

[0014] With advantage, a ring shape made of a Sm-Co alloy is not necessary. Radially magnetized, ring shaped permanent magnets of Sm-CO alloy are not possible due to internal field strength, which would create a stress level leading easily to the breaking of the permanent magnet ring.

[0015] Using a ring of plastic material including a plurality of slots, for respectively accommodating the plurality of permanent magnets, simplifies the coupling operations between the valve assembly and the power group. For example, in a pre-assembly step, the arched permanent magnets may be accommodated in the respective positions, each in a respective slot of the plastic ring, and then the plastic ring may be included in the power group. In this way the permanent magnets will be automatically in the desired positions with respect to the other components of the power group.

[0016] According to one embodiment, the arched permanent magnets have the same dimensions. In other words, all of the arched permanent magnets have identical dimensions. Advantageously, this allows having a uniform distribution of the magnetic field around the central axis. Using permanent magnets having all the same dimensions also implies that all the slots of the ring of plastic material have the same dimensions, thus further simplifying the assembly of the power group and of the overall fluid injector.

[0017] According to further embodiments, the arched permanent magnets together cover a complete angle of 360° around the central axis of the power group. In this case, longitudinal walls of the plastic ring which may be present and separate the arched permanent magnets in circumferential direction, are in particular disregarded since they may expediently only occupy a small space compared to the permanent magnets. Advantageously, this permits the magnetic field created by permanent magnets to be uniformly distributed around central axis.

[0018] According to other embodiments, the arched permanent magnets are in the numbers of 3 or higher. To put it differently, the power group comprises three or more arched permanent magnets as said plurality of arched permanent magnets. For example, it comprises exactly three arched permanent magnets. This choice provides an optimal compromise between maximizing the power capability without breaking the permanent magnets and simplicity of assembling.

[0019] According to another embodiment, the ring of plastic material includes a bobbin and the coil of the solenoid is wounded in said bobbin, i.e. the ring of plastic material and the bobbin of the solenoid are integrated in the same plastic element. This permits to combine the solenoid with the permanent magnets into a single pre-assembly group, to be subsequently coupled to the power group and to the valve assembly of the injector.

[0020] According to further embodiments, the ring of plastic material comprises a plurality of longitudinal walls, each longitudinal wall separating two adjacent slots. This minimizes magnetic attractive forces during assembly operation. Optionally, the ring of plastic material may also comprise one or two annular walls for delimiting the slots along the axial direction, at one or both the axial end surfaces of the ring of plastic material. The annular walls are planar in one embodiment. The annular walls improve the protection of the permanent magnets from dirt or other aggressive factors on the upper and/or lower side of the ring.

[0021] An additional overmolding step may be performed to improve such protection, in particular along the inner surface of the ring of plastic material. In addition, thanks to the plastic material surrounding the permanent magnets, the ring of plastic material together with the permanent magnets can be easily mounted into the power group without magnetic interferences between the magnets and the ferromagnetic material which may constitute the housing. In particular, the longitudinal walls separating two adjacent slots and the planar annular walls may have a thickness ranging between 0,2 to 0,5 mm.

[0022] It has to be noted that embodiments of the invention have been described with reference to different aspects. In particular, some embodiments have been described with reference to the power group or to the fluid injector, whereas other embodiments have been described with reference to the method being directed to a manufacturing method for a fluid injector. However, a person skilled in the art will gather from the above and the following description that, unless other notified, in addition to any combination of features belonging to one aspect, also any combination between features relating to different aspects is considered as to be disclosed with this document.

Brief Description of the Drawings

[0023] The aspects defined above and further aspects of the power group, the fluid injector and the method are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the exemplary embodiments, to which the invention is yet not limited. Rather, it comprises any combination of elements of different embodiments. Moreover, the invention comprises any combination of claims and any combination of features disclosed by the claims.

Fig. 1 is a sectional view, taken along a plane including the central axis, of a fluid injector according to the present invention,

Fig. 2 is a top view of a portion of a power group according to the present invention,

Fig. 3 is a top view of a component of the power

group of Fig. 2,

Fig. 4 is a top view of components of the power group of Fig. 2,

Fig. 5 is a sectional view of the power group of the present invention, taken along the sectional line V-V of Fig. 2,

Fig. 6 is a sectional view of the power group of the present invention, taken along the sectional line VI-VI of Fig. 5,

Fig. 7 is a partial sectional view, taken along a plane including the central axis, of another embodiment of a power group according to the present invention.

Detailed Description

[0024] The illustrations in the figures are schematic. It is noted that in different figures, similar or identical elements or features are provided with the same reference signs. In order to avoid unnecessary repetitions elements or features which have already been elucidated with respect to a previously described embodiment are not elucidated again at a later position of the description.

[0025] **Fig. 1** shows a fluid injector 100, in particular a fuel injector for an internal combustion engine, with a central axis X. The fluid injector 100 has a valve assembly 101 and a power group 10.

[0026] The valve assembly 101 has a valve body 20, in particular of ferromagnetic material at least in some places. The valve body 20 is hollow, having a cavity 21 which extends axially between a fluid inlet 31 and a fluid outlet 32. The fluid inlet 31 is connected to a fuel supply (not shown) and the fluid outlet 32 is connected to the combustion chamber (not shown) of a cylinder of the internal combustion engine. The cavity 21 defines a fuel path along the central axis X, from the fluid inlet 31 to the fluid outlet 32.

[0027] The valve assembly 101 further has a valve needle 50, which is fixedly attached to an armature 40 of the power group 10. The valve needle 50 is axially movable together with the armature 40 between a closing position preventing a fuel flow through the fluid outlet 32 and a plurality of opening positions for releasing the a fuel mass towards the combustion chamber. The different opening positions may correspond to respective sets of different parameters of the released fuel mass, in particular mass flow rate.

[0028] The armature 40 is formed as a collar around the valve needle 50 and is axially movable in the cavity 21 along the central axis X when subject to a magnetic field created by the power group 10, as detailed below. A pole piece 14 is arranged in the cavity 21 and is fixedly coupled to the valve body 20. In operation, the electromagnetic force caused by the magnetic field created by the power group 10 magnetizes the pole piece 14 to attract the armature 14, thus also causing the armature 40, together with the valve needle 50, to move axially in the cavity 21 towards the pole piece 14, away from the closing position, i.e. towards one of the opening positions of the injector 100.

[0029] A main spring 52 is arranged in the cavity 21, mechanically coupled to the valve body 20 and the valve needle 50 at opposite axial ends. The valve needle 50, and with it the armature 40 are normally urged in the closing position by the main spring 52. A calibration tube 53 is housed inside the valve body 20 and the coupled to the pole piece 14 by a press-fit connection or by a thread. Before the injector 100 is put in operation, for example during the manufacturing process, a calibration process is carried out, during which the calibration tube 53 can be moved axially in the valve body 20 in order to preload the main spring 52 in a desired manner. In this way, a predefined force of the main spring 52 on the valve needle 50 is set to bias the valve needle 50 towards the closing position of the injector 100.

[0030] The armature 40 is axially displaceable relative to the valve needle 50 and mechanically coupled to the latter by means of an armature retainer of the valve needle 50 with which the armature is operable to engage in a form-fit connection for taking the valve needle 50 with it away from the closing position. In the present embodiment, the fluid injector 100 further comprises an armature return spring 51. The armature return spring 51 biases the armature 40 in direction towards the pole piece 14 against the armature retainer of the valve needle 50 and decelerates a movement of the armature 40 at the end of the closing transient when the valve needle 50 stops in the closing position.

[0031] **Figs. 2** to **6** show in detail one embodiment of the power group 10 of the fluid injector 100. The power group 10 provides the actuation of the injector 100 and includes:

- a housing 11, which is fixable to the valve body 20,
- a solenoid 12 including a coil 13 wound in a bobbin around the central axis X,
- the armature 40,
- the pole piece 14,
- a hollow ring 16 made of plastic material and including a plurality of arched slots 17, each slot 17 accommodating one respective arched permanent magnet 15.

[0032] During the assembly of the fluid injector 100, the solenoid 12 with the coil 13 and the hollow ring 16 with the arched permanent magnets 15 are coupled to the valve assembly 101 by fixing the housing 11 to the valve body 20. The housing 11 comprises an extension 11a, protruding from the valve body 20, for connecting, in operation, the fuel injector 100 to a control unit (not shown), which provides an operating current to energize the coil 13.

[0033] In operation, when the coil 13 is energized, a

magnetic field is developed that forms the magnetic circuit extending from the coil 13 through the valve body 20 to the pole piece 14. A magnetic attraction is thereby created which draws the armature 40 towards the pole piece 14 against the force of the main spring 52. This movement of the armature 40 causes - by means of mechanical interaction of the armature with the armature retainer of the valve needle 50 - the needle valve 50 to move from the closing position toward the opening position, allowing fuel to be discharged from the outlet end 32 of the injector 10. The permanent magnets 15 improve and strengthen the magnetic effect of the coil 13 by adding a permanent magnetic field to the electromagnetic field generated by the coil 13.

[0034] The permanent magnets 15 are made of a Sm-Co alloy. Other materials may be used according to the present invention, provided that they are able to assure a similar value of magnetic density energy, or in any case significantly higher than the magnetic density energy of known plasto-neodymium magnets.

[0035] Each permanent magnet 15 has an arched shape around an axis, which, when the magnets are installed in the injector 100, is coaxial with the central axis X. The cross-sectional shape of the permanent magnets 15, in a longitudinal plane including the central axis X, is a rectangle with rounded corners. Other cross-sectional shapes are also possible, for example circular. Each arched permanent magnet is provided with a radial magnetization H, directed towards the central axis X and schematically represented in **Figs. 2** and **3** by the arrows H.

[0036] In the embodiments of the attached figures all the three arched permanent magnets 15 have the same dimensions. In particular, they extend radially, i.e. orthogonally to the central axis X, between the same inner diameter D1 and outer diameter D2 and they have the same thickness H.

[0037] Each permanent magnet 15 extends over an angle of less than 360° around the central axis X. In other words, the outer and inner contours of each permanent magnet in top view along the central axis X is a circular arc of a circle having the central axis X as center. In a planar view parallel to the central axis X, they angularly extend for an angle α slightly lower than 120°, in such a way that, considering also the circumferential distances between any couple of adjacent permanent magnets 15, they together cover an angle of 360° around the central axis X. This geometry assures a regular and symmetrical distribution of the magnetic field generated by the permanent magnets around the central axis X.

[0038] According to the present invention, a different number of permanent magnets 15 is also possible: for example two permanent magnets 15 angularly extending for an angle α slightly lower than 180° or four permanent magnets 15 angularly extending for an angle α slightly lower than 90°.

[0039] The hollow ring 16 is made of any moldable plastic material which is able to resist to operation temperatures of 200 °C and more. The hollow ring 16 comprises two - i.e. lower and upper - planar annular walls 28a, 28b, for delimiting the slots 17 along the axial direction X, respectively on a lower side, which in the assembly of the injector 100 is closer to the fluid outlet 32, and on a upper side, which in the assembly of the injector 100 is closer to the fluid inlet 31.

[0040] The two planar annular walls 28a, 28b are connected along the external radial side by a circular wall 29. On the inner radial side the slots 17 are open in order to allow insertion of the permanent magnets 15. It is also possible that the circular wall 29 is positioned at the inner radial end of the annular walls 28a, 28b and the slots 17 are open at the outward radial side (see the second embodiment in Fig. 7). In this way, the permanent magnets 15 can easily be shifted into the slots 17 in radial inward direction.

[0041] The ring of plastic material 16 further comprises a plurality of longitudinal walls 18, each axially extending between the two planar annular walls 28a, 28b and radially projecting away from the circular wall 29. Each longitudinal wall 18 separates two adjacent slots 17. The thickness of the two planar annular walls 28a, 28b, the circular wall 29 and the longitudinal walls 18 in each case has a value between 0,2 and 0,5 mm, the limits being included. This minimizes magnetic attraction between the permanent magnets 15 when they are mounted in the hollow ring 16 and when the hollow ring 16 with the permanent magnets 15 inside is coupled to the valve body 20. The slots have the same shape as the permanent magnets 15, but dimensions slightly greater in order to assure a lash coupling between each permanent magnet 15 and the respective slot 17. This assures an easier insertion of the permanent magnets in the slots 17.

[0042] **Fig. 7** shows a further embodiment of a power group 10 according to the present invention in a longitudinal section view. The portion on the left side of the central axis X is omitted in this figure. In this embodiment, the hollow ring 16 further includes a bobbin 19, in which the coil 13 of the solenoid 12 is wound.

[0043] According to the present invention, the fluid injector 100 is manufactured according to the following manufacturing steps:

- manufacturing the components of the valve assembly 101,
- manufacturing the components of the power group 10,
- assembling the valve assembly 101 together with the armature 40 and the pole piece 14,
- inserting the plurality of permanent magnets 15 inside the plurality of slots 17,
- fixing the ring 16 and the solenoid 12 to the valve assembly 101, by directly fixing the housing 11 and/or the solenoid 12 to the valve body 20,
- optionally overmolding the ring of plastic material 16, after inserting the plurality of permanent magnets 15, to improve protection of the permanent magnets

15 from dirt or other aggressive factors coming from other parts of the injector 100, in particular towards the upper or lower or inner side of the ring.

[0044] According to the present invention, the power group 10 may be used for the production of different fuel injector configurations, for as example different from one another for the length of the valve body 20: short, standard, extended length.

Claims

1. Power group (10) for a fluid injector comprising:

   - a housing (11),
   - a solenoid (12) including a coil (13) wound around a central axis (X) of the power group (10),
   - a plurality of permanent magnets(15), each permanent magnet having an arched shape around the central axis (X), each permanent magnet extending over an angle of less than 360° around the central axis,
   - a ring (16) made of plastic material and including a plurality of slots (17), each slot (17) accommodating one respective magnet of the permanent magnets (15) of the power group.

2. The power group (10) according to the preceding claim, wherein all of the arched permanent magnets (15) have the same dimensions.

3. The power group (10) according to one of the preceding claims, wherein, disregarding walls (18) of the ring (16) between the slots (17), the arched permanent magnets (15) together cover an angle of 360° around the central axis of the power group.

4. The power group (10) according to the preceding claim, wherein the power group (10) comprises three or more arched permanent magnets (15).

5. The power group (10) according to one of the preceding claims, wherein the ring of plastic material (16) further includes a bobbin (19), the coil (13) of the solenoid being wounded in said bobbin (19).

6. The power group (10) according to one of the preceding claims, wherein the ring of plastic material (16) comprises a plurality of longitudinal walls (18), each longitudinal wall (18) separating two adjacent slots (17).

7. The power group (10) according to the preceding claim, wherein the ring of plastic material (16) comprises at least one annular wall (28a, 28b) for delimiting the slots (17), along the axial direction (X).

8. The power group (10) according to claim 6 or 7, wherein the longitudinal walls (18) separating two adjacent slots (17) and/or the annular walls (28a, 28b) have a thickness of 0,2 to 0,5 mm.

9. The power group (10) according to any of the proceeding claims, wherein the arched permanent magnets (15) comprise a Sm-Co alloy.

10. Fluid injector (100) comprising:

    - a valve body (20) having a cavity (21) defining a fuel path along a central axis (X), the valve body (20) extending axially between a fluid inlet (31) and a fluid outlet (32),
    - a needle (50) attached to an armature (40) and axially movable together with the armature from a closing position preventing a fluid flow through the fluid outlet (32) to at least one opening position for releasing fluid through the fluid outlet (32),
    - a power group (10) according to any of the preceding claims, for creating the magnetic field to axially move the armature (40) and the needle (50).

11. Method for manufacturing a fluid injector (100) comprising the steps of:

    - providing a valve assembly (101) having:

      -- a valve body (20) having a cavity (21) defining a fuel path along a central axis (X), the valve body (20) extending axially between a fluid inlet (31) and a fluid outlet (32),
      -- a needle (50) attached to an armature (40) and axially movable together with the armature (40) from a closing position preventing a fluid flow through the fluid outlet (32) to at least one opening position for releasing fluid through the fluid outlet (32),

    - manufacturing a power group (10) having:

      -- a housing (11),
      -- a solenoid (12) including a coil (13) wound around a central axis (X) of the power group (10),
      -- the armature (40),
      -- a plurality of permanent magnets(15), each permanent magnet having an arched shape around the central axis, each permanent magnet extending over an angle of less than 360° around the central axis,
      -- a ring (16) made of plastic material and including a plurality of slots (17), each slot (17) accommodating one respective magnet of the permanent magnets (15) of the

power group (10), wherein manufacturing the power group (10) comprises a step of inserting the plurality of permanent magnets(15) into the plurality of slots (17),

- fixing the power group (10) to the valve assembly (101).

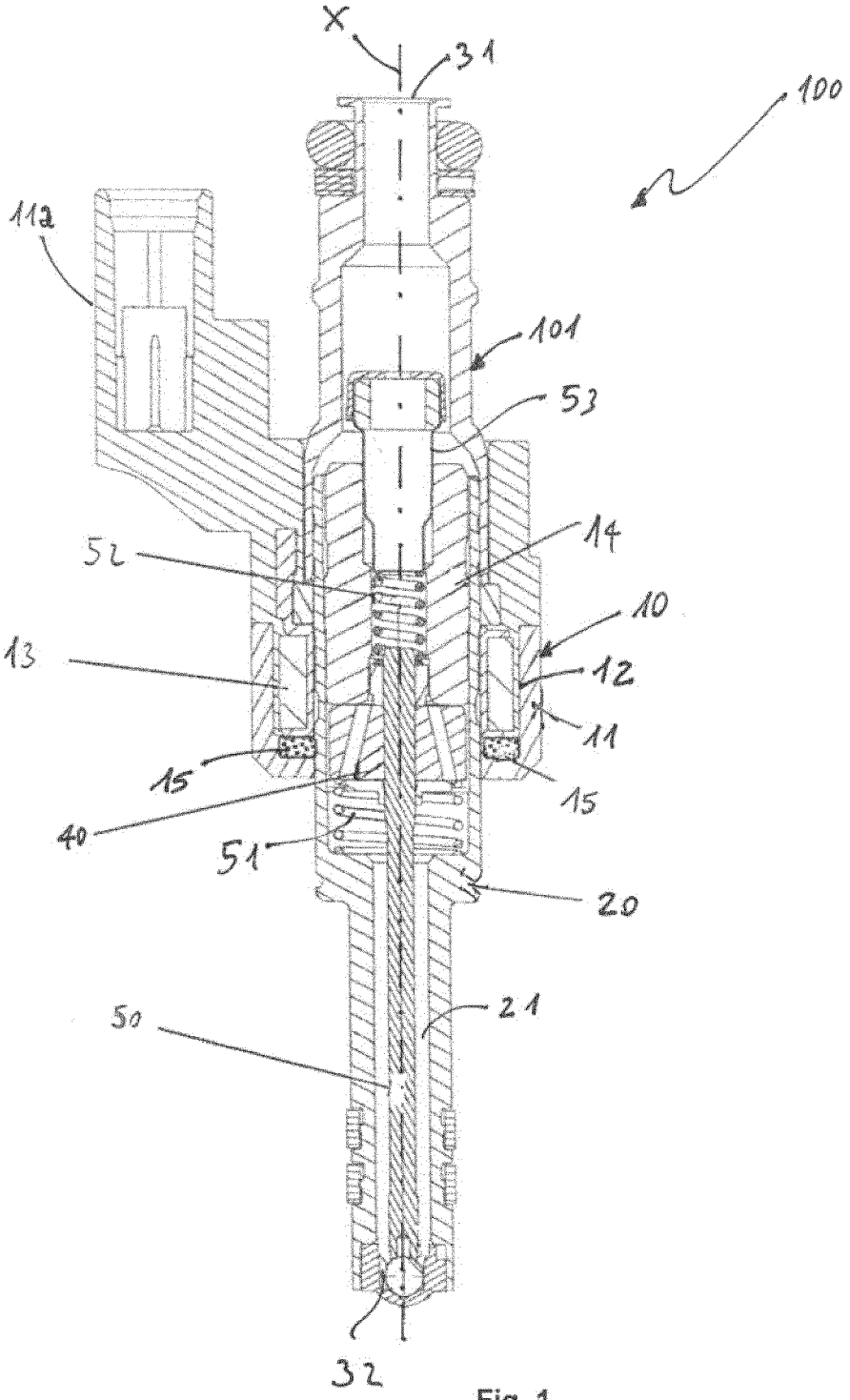

Fig. 1

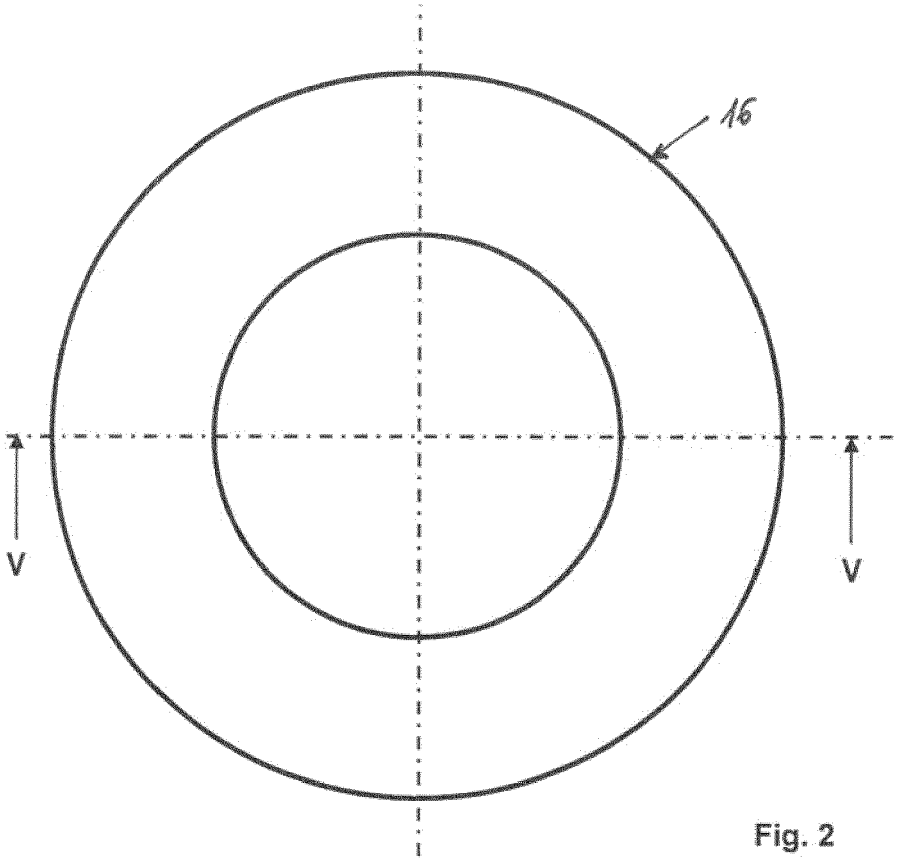

Fig. 2

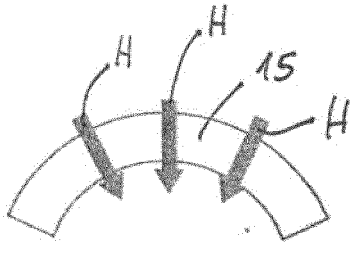

Fig. 3

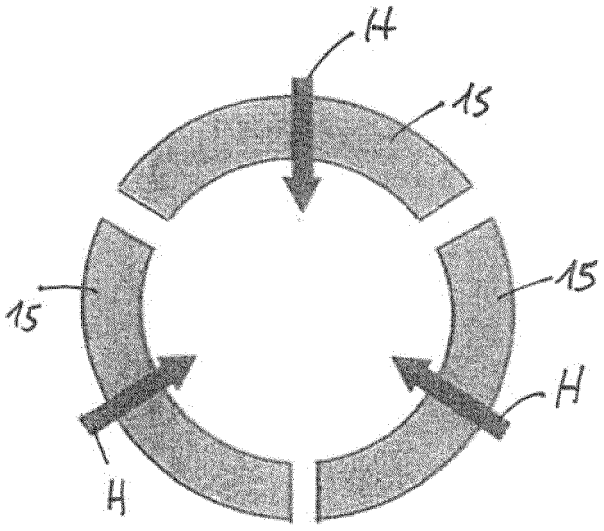

Fig. 4

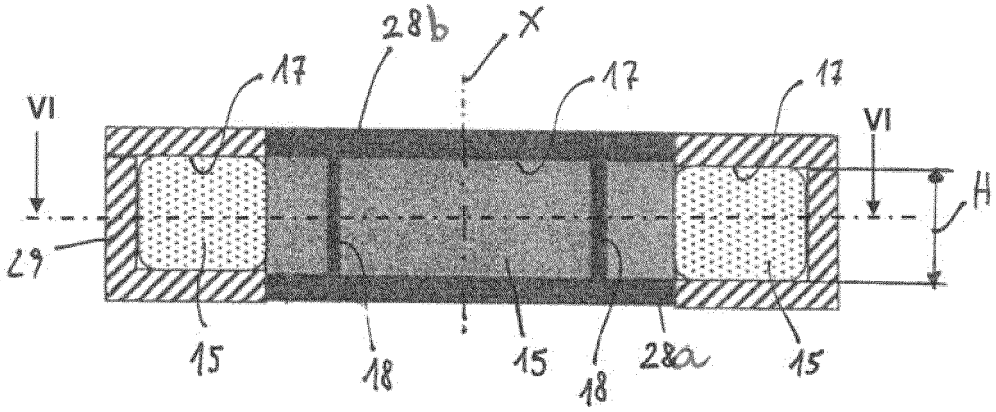

Fig. 5

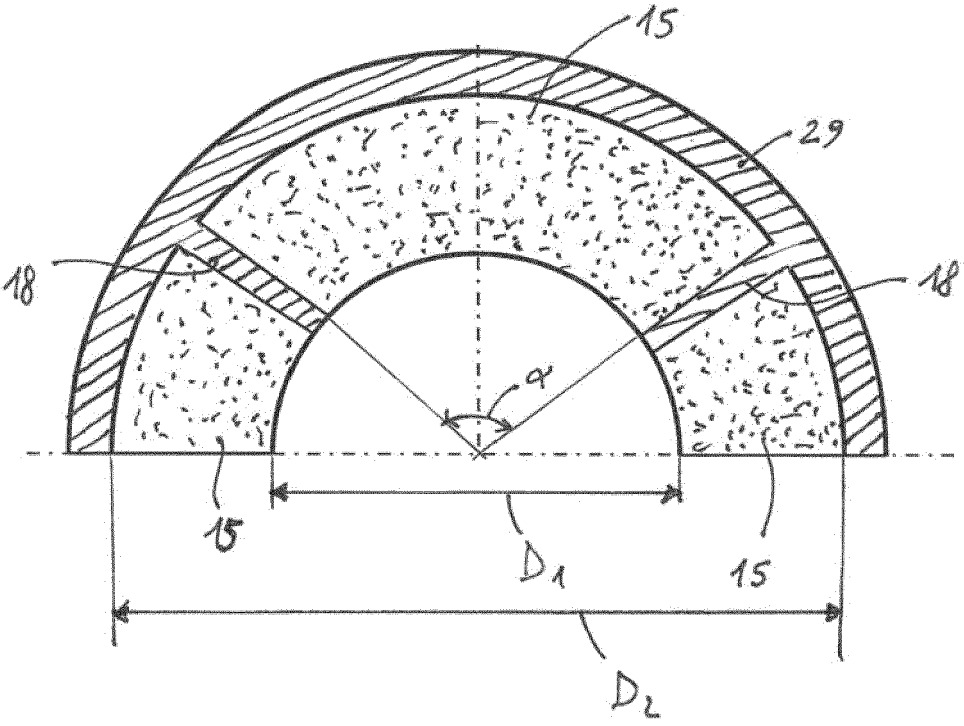

Fig. 6

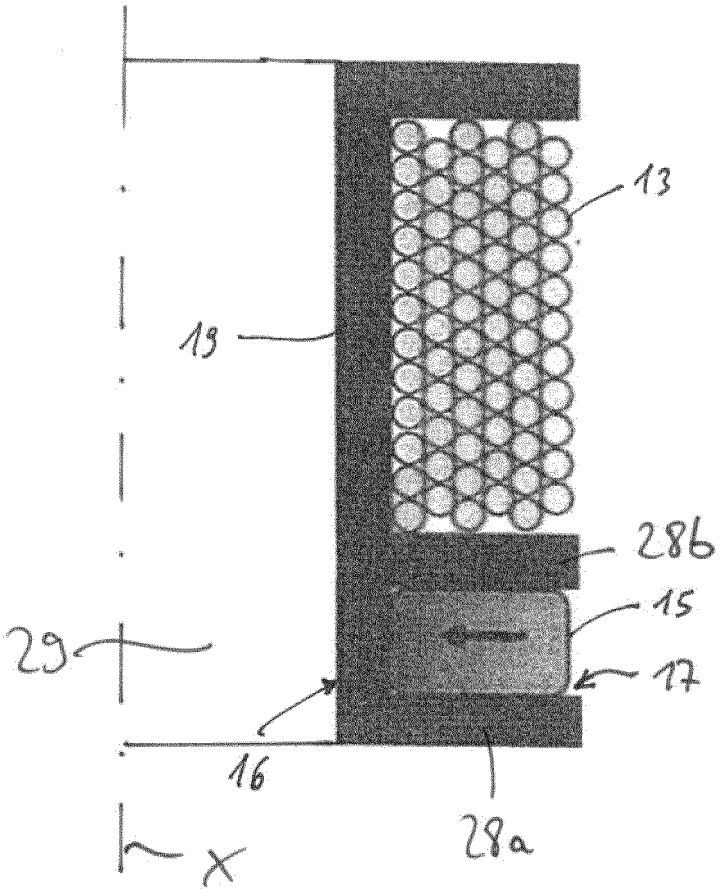

Fig. 7

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European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 4500

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 02/12713 A1 (BOSCH GMBH ROBERT [DE]; REITER FERDINAND [DE]) 14 February 2002 (2002-02-14) * page 9, line 23 - line 25; figures 2,3 *	1-4,10, 11 5-9	INV. F02M51/06 F02M61/16
Y	EP 0 952 506 A2 (SATURN ELECTRONICS & ENG INC [US]) 27 October 1999 (1999-10-27) * figures 1-4 *	5-9	
Y	EP 0 204 181 A1 (BOSCH GMBH ROBERT [DE]) 10 December 1986 (1986-12-10) * figures 1-4 *	1	
Y	US 5 127 585 A (MESENICH GERHARD [DE]) 7 July 1992 (1992-07-07) * column 13, line 16 - line 20; figure 4 *	1	
A	EP 2 320 066 A1 (DELPHI TECHNOLOGIES HOLDING [LU]) 11 May 2011 (2011-05-11) * figures 1-5 *	1	

TECHNICAL FIELDS SEARCHED (IPC)

F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 January 2016	Morales Gonzalez, M

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 18 4500

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