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(54) Electromagnetic coil for a fluid injector and fluid injector

(57) Disclosed is an electromagnetic coil for actuating a fluid injector, the coil comprising a first electrical terminal (105), a second electrical terminal (110) and a coiled conductor (115) that is electrically connected between the first (115) and second (110) terminals. The conductor comprises at least two sections (120), each section coiling around a longitudinal axis (125), wherein the sections (120) are electrically connected in parallel.

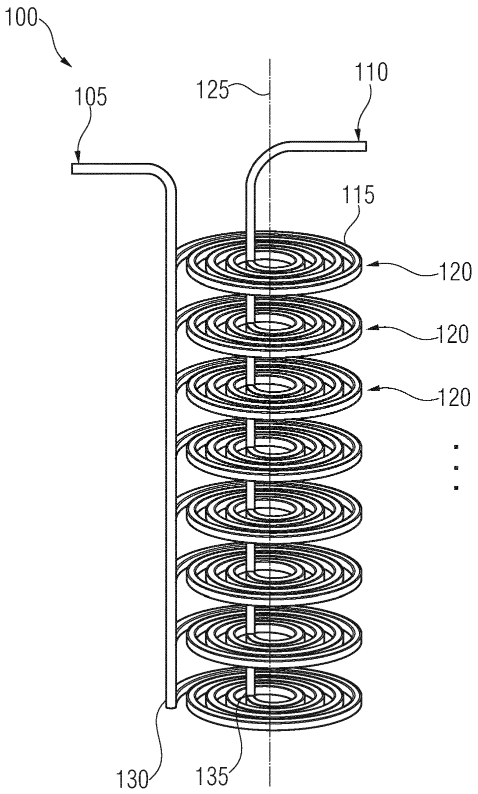

FIG 1

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Description

[0001] The present disclosure relates to an electromagnetic coil for a fluid injector. According to one aspect, the present disclosure relates to the layout of a coiled conductor that is part of the coil. The present disclosure further relates to a fluid injector, e.g. a fuel injector.

[0002] A fuel injector for injecting a liquid fluid into the comustion chamber of a combustion engine may comprise an electrically activated valve. For activating the valve, an electrical current or voltage must be converted into a longitudinal movement. In known fuel injectors, this can either be done through a stack of piezoelectric elements or an electromagnet comprising a solenoid and a core. When a current flows through the solenoid, a magnetic field around the core is generated and the core is magnetically attracted or repelled from the solenoid. This force is used to create a longitudinal movement of the core and the core operates the valve.

[0003] The solenoid comprises a coiled conductor that is coiled around the longitudinal axis. In order to allow for precise control of the valve, the magnetic field generated by the solenoid must be strong. The force of the magnetic field is dependent on the number of coils and the current that flows through the conductor. As the number of coils increases the length of the conductor also increases and an electrical resistance of the conductor rises. This limits the current that can flow through the conductor at a given voltage.

[0004] It is an object of present invention to provide an electromagnetic coil with a particularly small electrical resistance.

[0005] This object is achieved by an electromagnetic coil with the features of claim 1. Advantageous or preferred embodiments and developments of the coil and of a fluid injector are specified in the dependent claims.

[0006] According to one aspect, an electromagnetic coil is specified. According to a further aspect, a fluid injector is specified. The fluid injector expediently comprises the coil. The coil is in particular a solenoid. The coil is preferably configured for activating the fluid injector. The fluid injector may be a fuel injector for injecting fuel into a combustion engine.

[0007] The coil comprises a first electrical terminal, a second electrical terminal and a coiled conductor that is electrically connected between the first and second terminals. The conductor comprises at least two sections, each section coiling around a longitudinal axis, wherein the sections are electrically connected in parallel.

[0008] By connecting the sections in parallel, the overall resistance of the conductor is reduced to a value lower than the resistance of any single section. By lowering the overall resistance, the current through the coil at a given voltage increases and the magnetic field gets stronger. This allows for a fast acceleration of a core, resulting in a faster and more precise operation of a valve. Used in a fuel injector for injecting fuel into a combustion engine, combustion can be controlled more precisely and the injected fuel can be used more effectively. This allows for less fuel waste and reduced emission of noxious gases.

[0009] In one embodiment, one of the sections comprises at least two sub-sections, each sub-section coiling around the longitudinal axis where the sub-sections of the one section are electrically connected in series.

[0010] More specifically, it is possible to create a nested arrangement of sections of the conductor that are connected either in series or in parallel. Each parallel connection reduces the electrical resistance of the connected sections and each serial connection increases the overall resistance. This way, the conductor can be tailored to have a desired overall electrical resistance and electrical resistances of sections of the conductor can be adjusted in the same way. This way the force of the magnetic field that is created when current flows through the conductor may vary along the longitudinal axis. This allows for exercising a more precisely defined force upon a core in the region of the longitudinal axis.

[0011] In one embodiment, one of the sections extends as a spiral in top view along the longitudinal axis. A plurality of such sections may be stacked along the longitudinal axis to form the coil. Electrical connections between adjacent spirals can be made easily. Through this, the layout of the connector along the spiral can be controlled more precisely and with less effort. In a preferred environment, the conductor of one of the sections is embedded in a bulk of silicone material, for example of silicone resin. Since silicone materials have a high electrical resistance, only small distances between individual windings of the coiled conductor are necessary. Thus, a high filling factor is achievable so that the coil may produce a particularly large magnetic field relative to its size.

[0012] In one embodiment, the conductor comprises aluminium or copper. Both metals or alloys of them may be used in conjunction with a silicone bulk. The low electrical resistance of those metals may be used advantageously for the solenoid.

[0013] The conductor in one of the sections may have a rectangular profile, the rectangular profile may also be denoted as a rectangular cross-section. The rectangular profile may use the available space better so that a conductor with a particularly large cross-sectional area can be used, thus reducing the electrical resistance and allowing for a higher current. Generally, any profile can be used for the conductor, including circular, oval, triangular or polygonal profiles.

[0014] According to another embodiment, the profile of the conductor - i.e. in particular the cross-sectional area and/or the cross-sectional shape - varies over its length. In one example, the profile may be smaller where the conductor lies closer to the longitudinal axis where the magnetic field is stronger and bigger where it lies further away from the strongest portion of the magnetic field. In other words, the cross-sectional area of the conductor may increase with increasing distance from the longitudinal axis. That way, optimal use can be made of the space available, potentially allowing for more coils for producing a stronger magnetic field. Alternatively, outer dimensions of the solenoid may be reduced.

[0015] According to another embodiment, an inner portion, with respect to the longitudinal axis, of the conductor in one of the sections may comprise a different material than an outer portion of the conductor in the same section. A first material with a low specific resistance may thus be saved for the portion where it is most effective, while a less expensive material with a higher specific resistance may be used where the effect of its increased resistance is smaller.

[0016] Further advantages and advantageous embodiments and developments of the coil and the fluid injector will become apparent from the exemplary embodiments which are described below in connection with schematic figures, in which:

Figure 1 shows a schematic perspective view of a coil for a fluid injector according to one embodiment;

Figure 2 shows a perspective section view of the coil of figure 1;

Figure 3 shows different variants of electrical connections between sections of the coiled conductor of one figures 1 and 2;

Figure 4 shows a plan view on a section of the coil of one of the preceding figures according one embodiment, and

Figure 5 shows a longitudinal sectional view of a fuel injector for use with the coil of figures 1 and 2.

[0017] In the exemplary embodiments and figures, identical, similar or similarly acting constituent parts are provided with the same reference symbols. The elements illustrated in the figures and their size relationships among one another should not be regarded as true to scale. Rather, individual elements may be represented with an exaggerated size for the sake of better representability and/or for the sake of better understanding.

[0018] Figure 1 shows a coil, specifically a solenoid 100, for activating a fuel injector for injecting fuel into a combustion engine. Figure 2 shows a longitudinal section of the solenoid 100 of figure 1.

[0019] The solenoid 100 comprises a first electrical terminal 105, a second electrical terminal 110 and an electrical conductor 115 that is connected between the first and second terminals 105 and 110. The conductor 115 comprises a plurality of sections 120, wherein each section 120 coils around a longitudinal axis 125. "Coiled around the longitudinal axis" 125 in particular means that the conductor 115 is wound around the longitudinal axis 125 so that a plurality of turns are produced. The sections 120 follow one another in direction along the longitudinal axis 125.

[0020] It is generally sufficient that the conductor 115 is wound around the longitudinal axis 125 in any way. However, it is preferred that the conductor 115 of each section 120 has the longitudinal axis 125 as the centre of a spiral along which the conductor 115 extends inside the section 120. A main plane of extension of the spiral is preferably perpendicular to the longitudinal axis 125.

[0021] Generally, the winding direction of the conductor 115 in each of the sections 120 must be the same, that is, a current flowing from the first terminal 105 to the second terminal 110 should flow either clockwise in each section 120 or counter clockwise in each section 120. This is necessary to maximize the force of the magnetic field that is created in the vicinity of the longitudinal axis 125.

[0022] The conductor 115 has to ends per section 120 by means of which the individual sections 120 are electrically connected in parallel. For this, a first power rail 130 and a second power rail 135 run in parallel to the longitudinal axis 125. One end of each section 120 is electrically connected to the first power rail 130, the second end of each section 120 is electrically connected to the second power rail 135.

[0023] The power rails 130 and 135 can be made of the same material as the conductor 115 inside the sections 120. However, a different material can also be used. Also, the profile of the power rails 130 and 135 may be increased with respect to the profile of the conductor 115 inside the power rails 130 and 135In other words, the cross-sectional area of the power rails 130, 135 may be larger than the cross-sectional area of the conductor 115.

[0024] In an alternative embodiment, no power rails 130 or 135 are used and ends of the conductor 115 of adjacent sections 120 make electrical contact by making direct physical contact with one another. Besides this, portions of the conductor 115 in different sections 120 are preferably electrically insulated.

[0025] Figure 3 shows different variants of electrical connections between sections 120 of the coiled conductor 115 of figures 1 or 2. Although all sections 120 in figures 1 and 2 are shown connected electrically in parallel, the variants discussed with respect to figure 3 may be used interchangeably.

[0026] Figure 3a shows a parallel configuration of sections 120 like in the embodiments of figures 1 and 2. The number of sections 120 is not limited apart from the ampacity of the power rails 130, 135; generally any number of sections 120 can be used.

[0027] Figure 3b shows a mixed serial and parallel configuration of sections 120. Here, a first section 120 and a second section 120 are connected in serial and each of the sections 120 comprise two sub-sections 305, which are connected in parallel. As the sub-sections 305 each comprise a portion of the conductor 115 that is electrically connected between the first and second terminals 105 and 110, the sub-sections 305 may also be considered as sections 120.

[0028] Figure 3c shows a mixed mode serial and parallel configuration of sections 120 of the solenoid 100. Here the hierarchy of the embodiment of Figure 3b is reversed and the two sections 120 that are electrically connected in parallel each comprise two sub-sections 305 that are connected in serial. Again, the sub-sections 305 can also be considered as sections 120 as they form part of the conductor 115 that is electrically connected between the first and second electrical terminals 105 and 110.

[0029] The number of sections 120 and sub-sections 305 in each of the figures 3a-3c are only exemplary; generally any number of sections 120 and sub-sections 305 can be used. Also, the serial and parallel configurations of figures 3b and 3c can be nested to the desired level, for example in a serial/parallel/serial configuration.

[0030] In one embodiment, sections 120 that are connected together in serial or in parallel have the same resistance. It is preferred that such sections 120 have the same number of coils along the longitudinal axis 125. However, sections 120 that differ in size, resistance or number of coils can also be connected together in the way described above.

[0031] Figure 4 shows a plan view of a section 120 of the solenoid 100 of figures 1 or 2 in one embodiment. Here, the conductor 115 is embedded in abulk of silicone material 405. The silicone material 405 expediently covers the conductor 115 on all sides. Preferably, the silicone material 405 encapsulates the conductor 115. The silicone bulk 405 provides insulation between adjacent coils of the conductor 115.

[0032] The conductor 115 preferably comprises a metal with low electrical resistance, such as aluminium or copper. In one embodiment, the material of conductor 115 changes along its length in section 120. For instance, turns adjacent to the longitudinal axis 125 may be made out of copper, while coils further away from the axis 125 may be made of aluminium. This may also be considered as a serial connection of sub-sections of different materials.

[0033] The profile of the conductor 115 inside the section 120 may be circular. Figure 4 also shows other possible profiles 410, 415 and 420 of conductor 115. Other profiles are also possible, especially general polygonal profiles and curved profiles such as circular or elliptical profiles. The profile may change along the conductor 115.

[0034] Ends of the conductor 115 inside section 120 are shown connected with the power rails 130 and 135. In a different embodiment, the ends of conductor 115 may be uncovered, i.e. not insulated by the silicone bulk 405 and configured such that they may make contact in axial or radial direction with the power rails 130, 135 or ends of an adjacent section 120 of similar configuration. However, preferably, the silicone material 405 is cast or molded over the coil 100 after the electrical connection of the sections 120 to the power rails 130, 135.

[0035] Figure 5 shows a longitudinal section of an exemplary fuel injector 500 for injecting fuel into a combustion engine, wherein the fuel injector 500 is configured to be used with the solenoid 100 of one of the preceding figures.

[0036] Injector 500 comprises a valve 505 for controlling flow of fuel from an inlet 510 to a nozzle 515. The valve 505 comprises the solenoid 100 according one of figures 1 to 4 and a moveable core 520 that extends along longitudinal axis 125. The moveable core 520 preferably extends partly into the solenoid 100 and may be made out of metal or a magnetic material. A spring 530 is provided to push the core 520 partially out of the solenoid 100 along longitudinal axis 125 when the solenoid 100 is not energized.

[0037] An electric connector 525 is electrically connected with electrical terminals 105 and 110 of the solenoid 100. If a voltage is applied to connector 525, current flows through the conductor 115 of solenoid 100, thereby creating a magnetic field that causes the core 520 to be moved along longitudinal axis 125 in opposition to the force of spring 530, i.e. upwards in Fig. 1. Through this motion, the valve 505 is opened and fuel is allowed to pass from inlet 510 to the nozzle 515 and into a combustion engine in which the injector 500 may be installed.

[0038] Solenoid 100 has roughly the shape of a hollow right circular cylinder with longitudinal axis 125. The inner recess of the cylinder has enough clearance for core 520 to be moved at least partially into the recess. For protecting the solenoid 100 against possible corrosive or conductive effects of the fuel, a separator between the inner radial surface of solenoid 100 and the longitudinal axis 125 is provided. In the preferred embodiment of Fig. 1 the separator comes as a reel 535 onto which the conductor is wound. The reel 535 may preferably be manufactured from a nonconductive material that withstands corrosion from the fuel, like certain types of plastics. In the shown embodiment, a body 540 of injector 500 extends in a radial space between the reel 535 and the core 520 so that the fuel is held back by the body 540 and the reel 535 need not be fuel resistive. The reel 535 may also be shifted over a metallic valve body of the injector 500.

Claims

1. An electromagnetic coil (100) for actuating a fluid injector (500), the coil (100) comprising:

   - a first electrical terminal (105);
   - a second electrical terminal (110);
   - a coiled conductor (115) that is electrically connected between the first (105) and second (110) terminals,
   - wherein the conductor (115) comprises at least two sections (120), each section (120) coiling around a longitudinal axis (125),

   characterized in that

   - the sections (120) are electrically connected in parallel.

2. Coil (100) according to claim 1, wherein one of the sections (120) comprises at least two sub-sections (305), each sub-section (305) coiling around the longitudinal axis (125) and the sub-sections (305) of the one section (120) being electrically connected in series.

3. Coil (100) according to claim 1 or 2, wherein at least one of the sections (120) extends as a spiral in top view along the longitudinal axis (125).

4. Coil (100) according to one of the preceding claims, wherein the conductor (115) of at least one of the sections (120) is embedded in a silicone bulk (405).

5. Coil (100) according to claim 4, wherein the conductor (115) comprises aluminium or copper.

6. Coil (100) according to claim 4 or 5, wherein the conductor (115) at least in one of the sections (120) has a rectangular profile (410-420).

7. Coil (100) according to one of claims 4 to 6, wherein the profile (410-420) of the conductor (115) varies over its length.

8. Coil (100) according to one of claims 4 to 7, wherein an inner portion of the conductor (115) in one of the sections (120) comprises a different material than an outer portion of the conductor (115) in the same section (120).

9. Fluid injector (500) comprising a coil (100) according to one of the preceding claims.

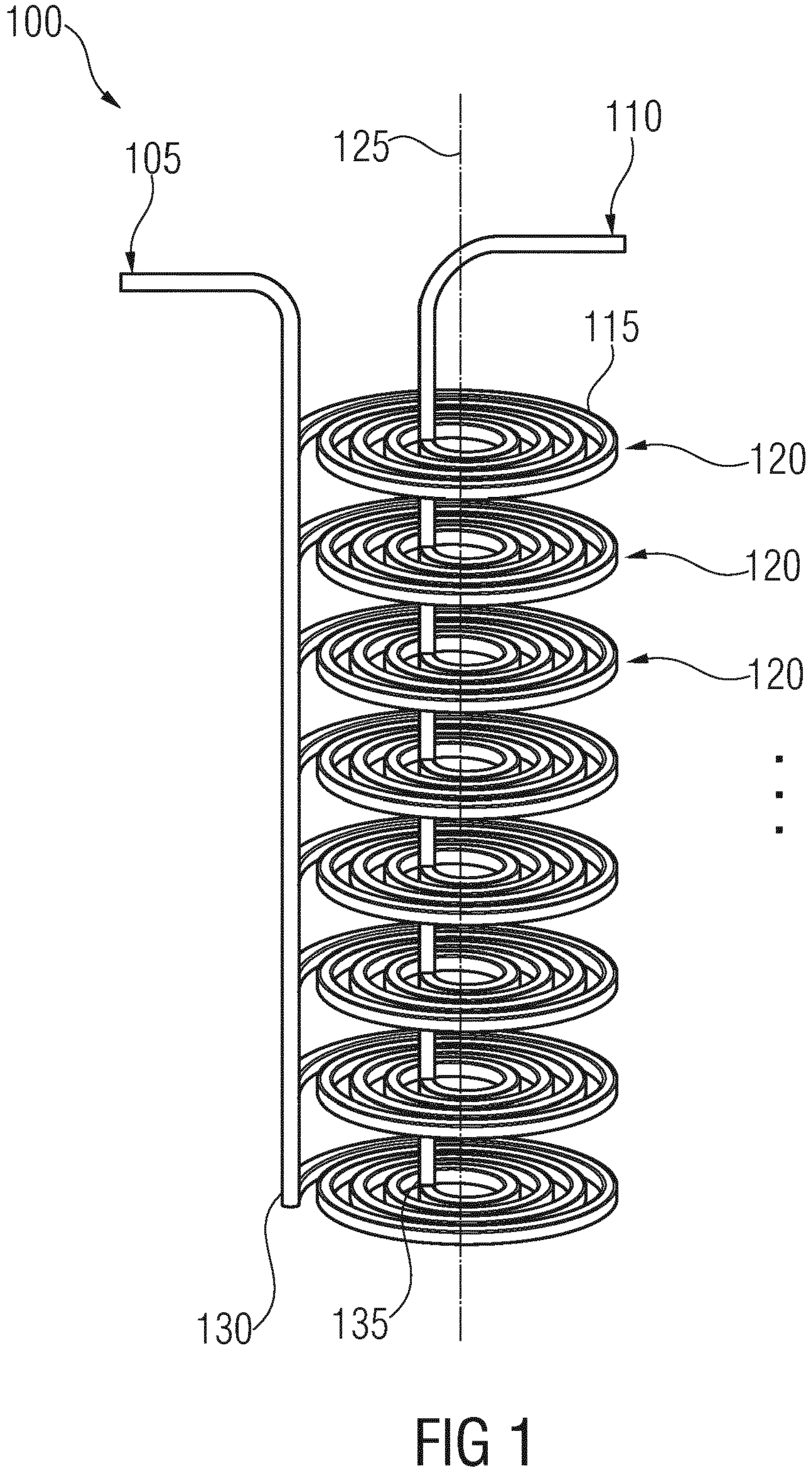

FIG 1

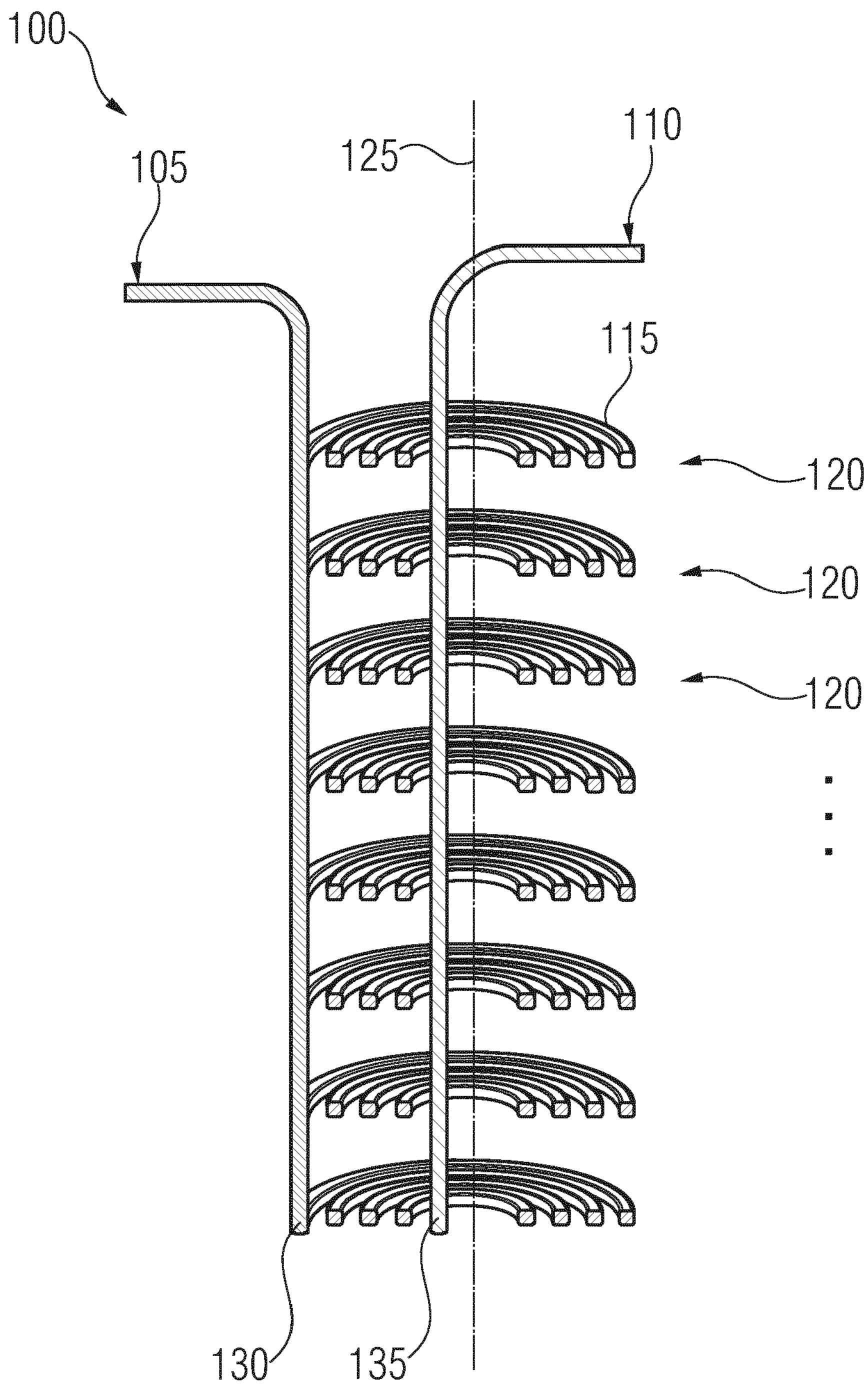

FIG 2

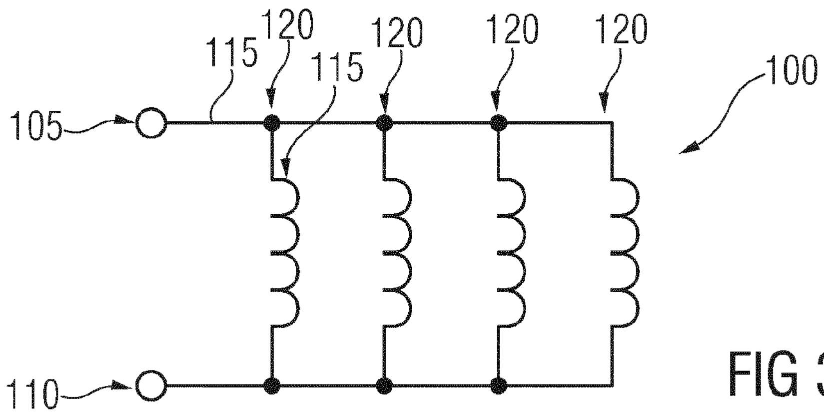

FIG 3a

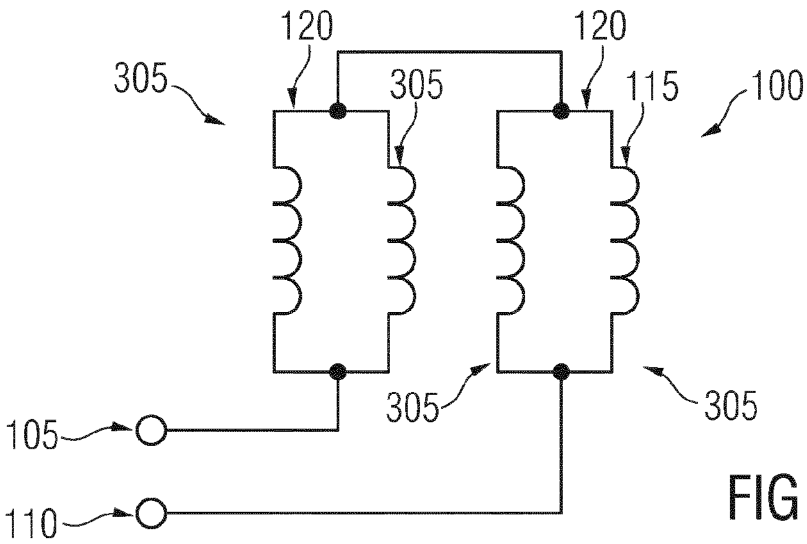

FIG 3b

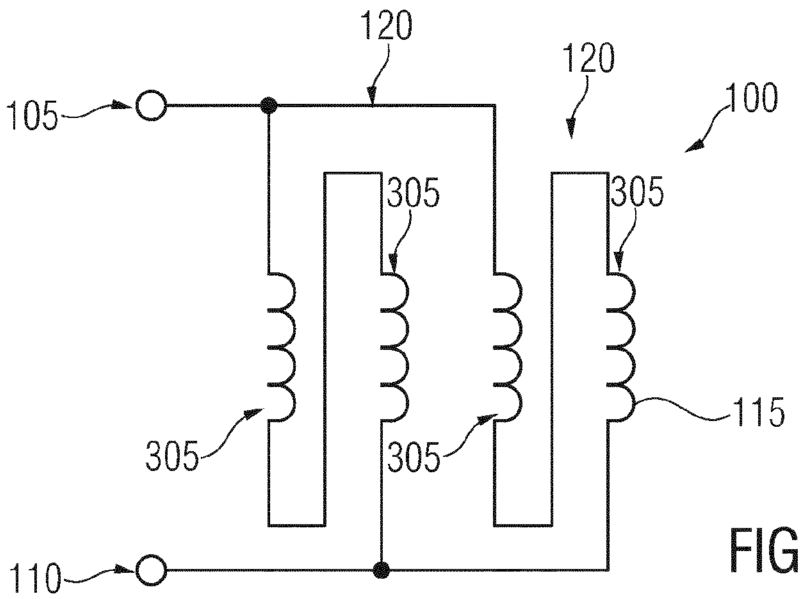

FIG 3c

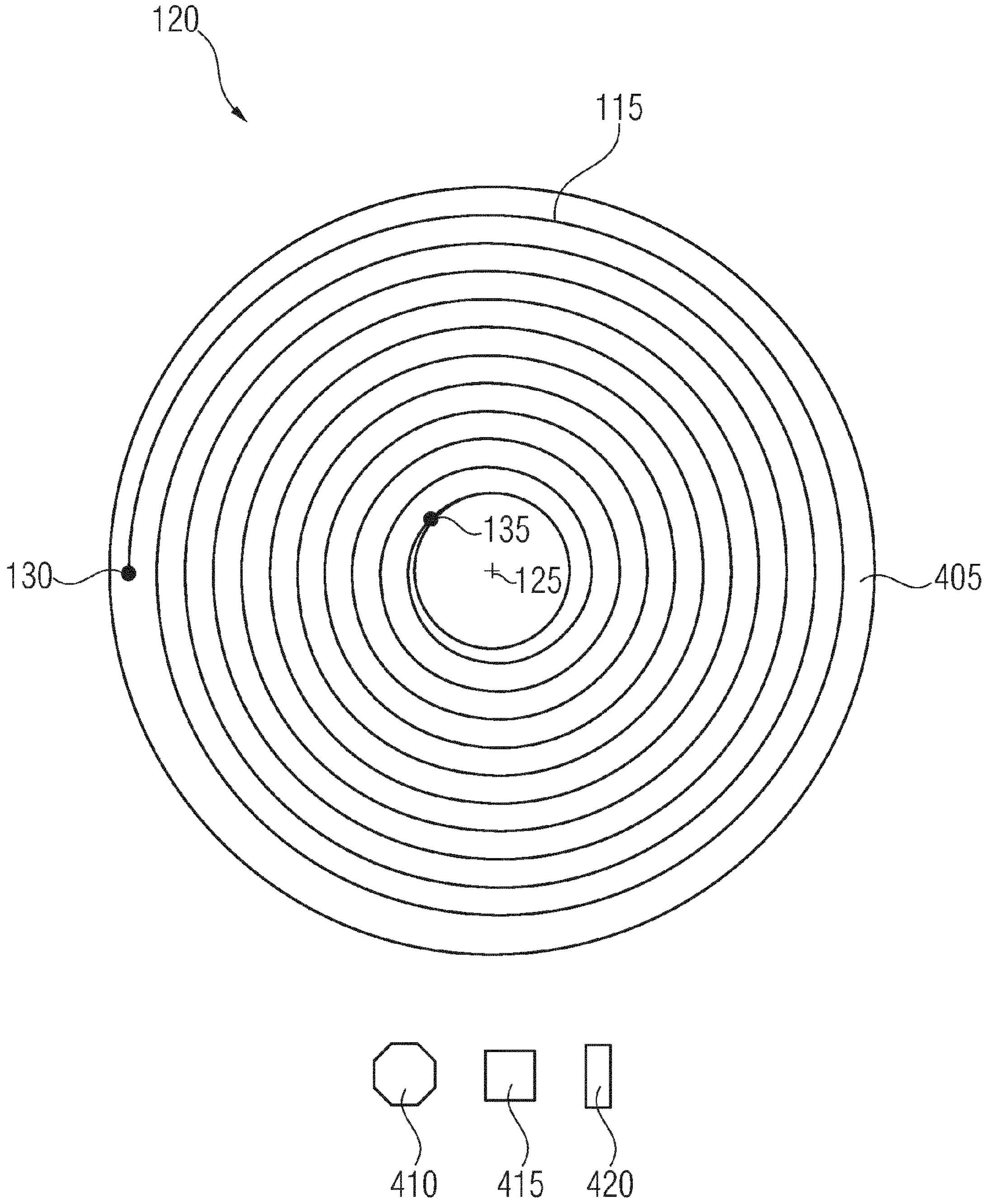

FIG 4

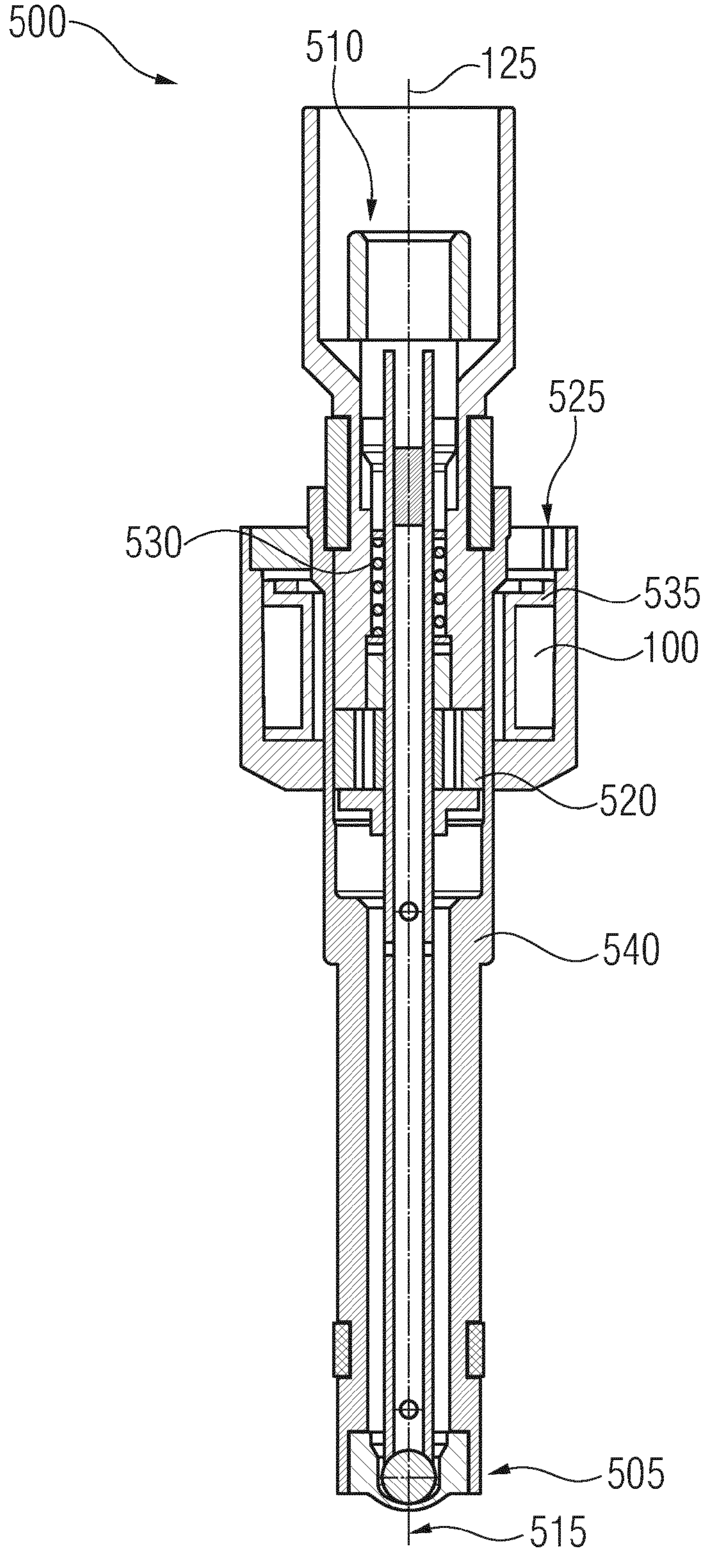

FIG 5

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EUROPEAN SEARCH REPORT

Application Number
EP 13 18 3275

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	21 January 2014	Barunovic, Robert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

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