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ARLINGTON, VA 22203 (US)(52) **U.S. Cl.** **417/423.7; 60/282**(57) **ABSTRACT**(73) Assignee: **DENSO CORPORATION**,
Kariya-city (JP)(21) Appl. No.: **12/255,034**(22) Filed: **Oct. 21, 2008**(30) **Foreign Application Priority Data**

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An electrically powered pump includes a pump arrangement that pumps a liquid, and an electric motor arrangement that has a stator and a rotor that are installed on a passage through which the liquid pumped by the pump arrangement flows. At least one of the stator and the rotor has a winding wire that generates a magnetic field when it is energized to rotate the rotor with respect to the stator to drive the pump arrangement. The winding wire has a conductive body through which an electric current passes and an insulation body that insulates the conductive body. The conductive body is made of a material predominantly composed of carbon. Thereby, the liquid pumped by a pump arrangement is prevented from corroding the winding wire.

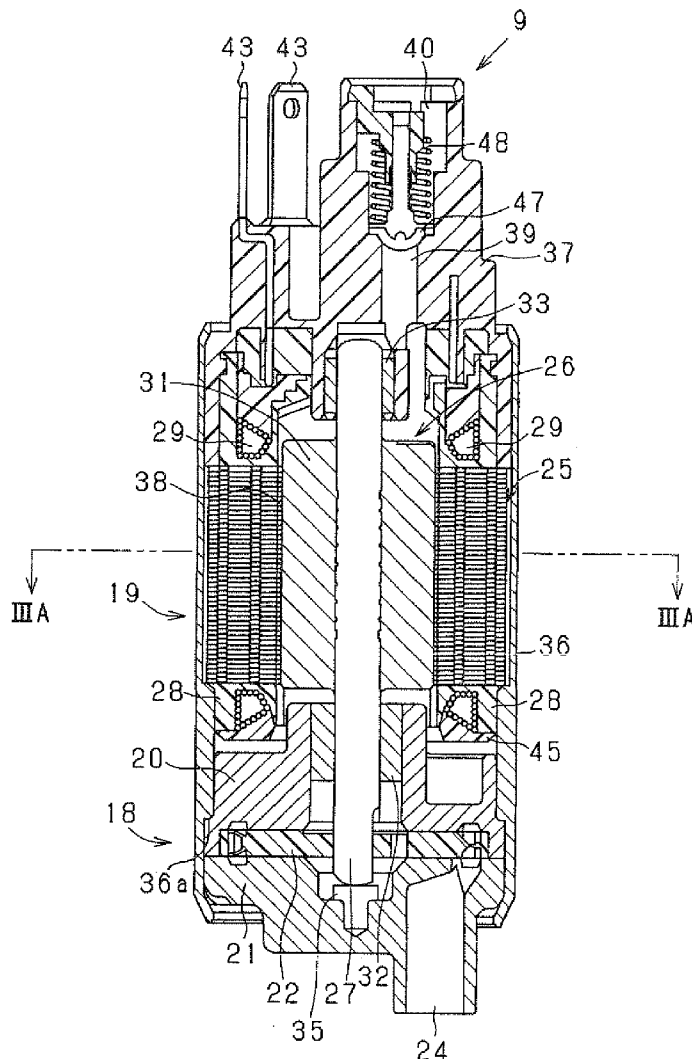


FIG. 1

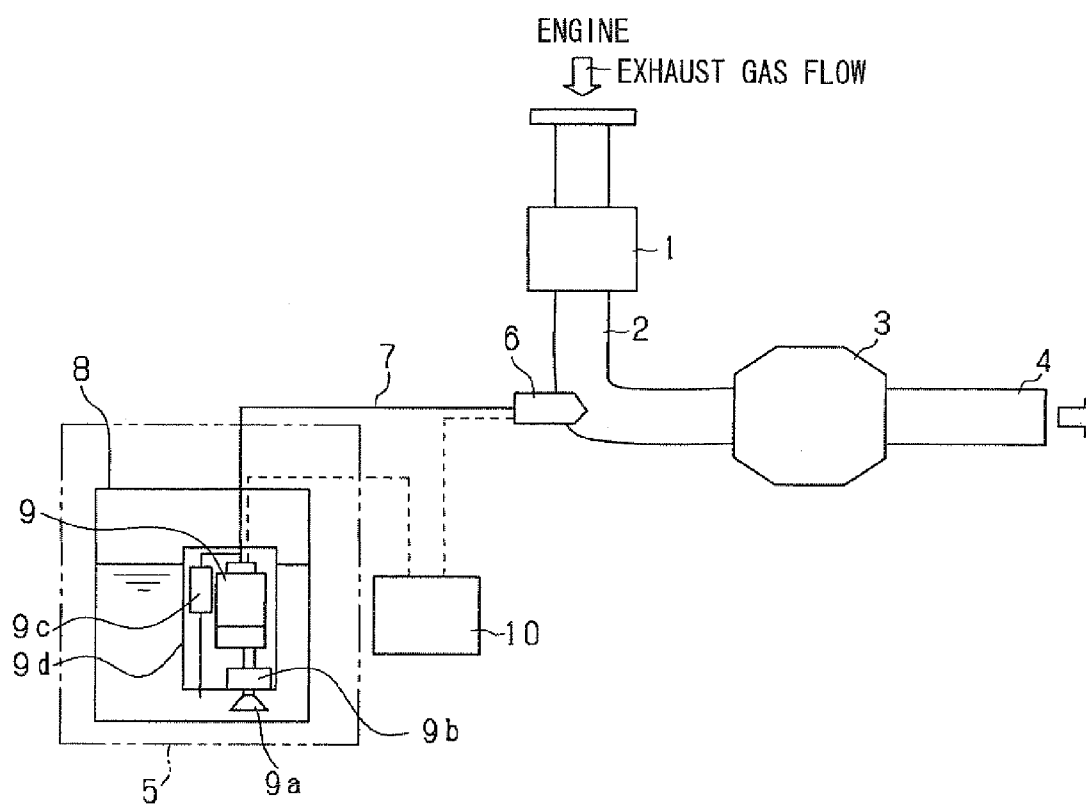


FIG. 2

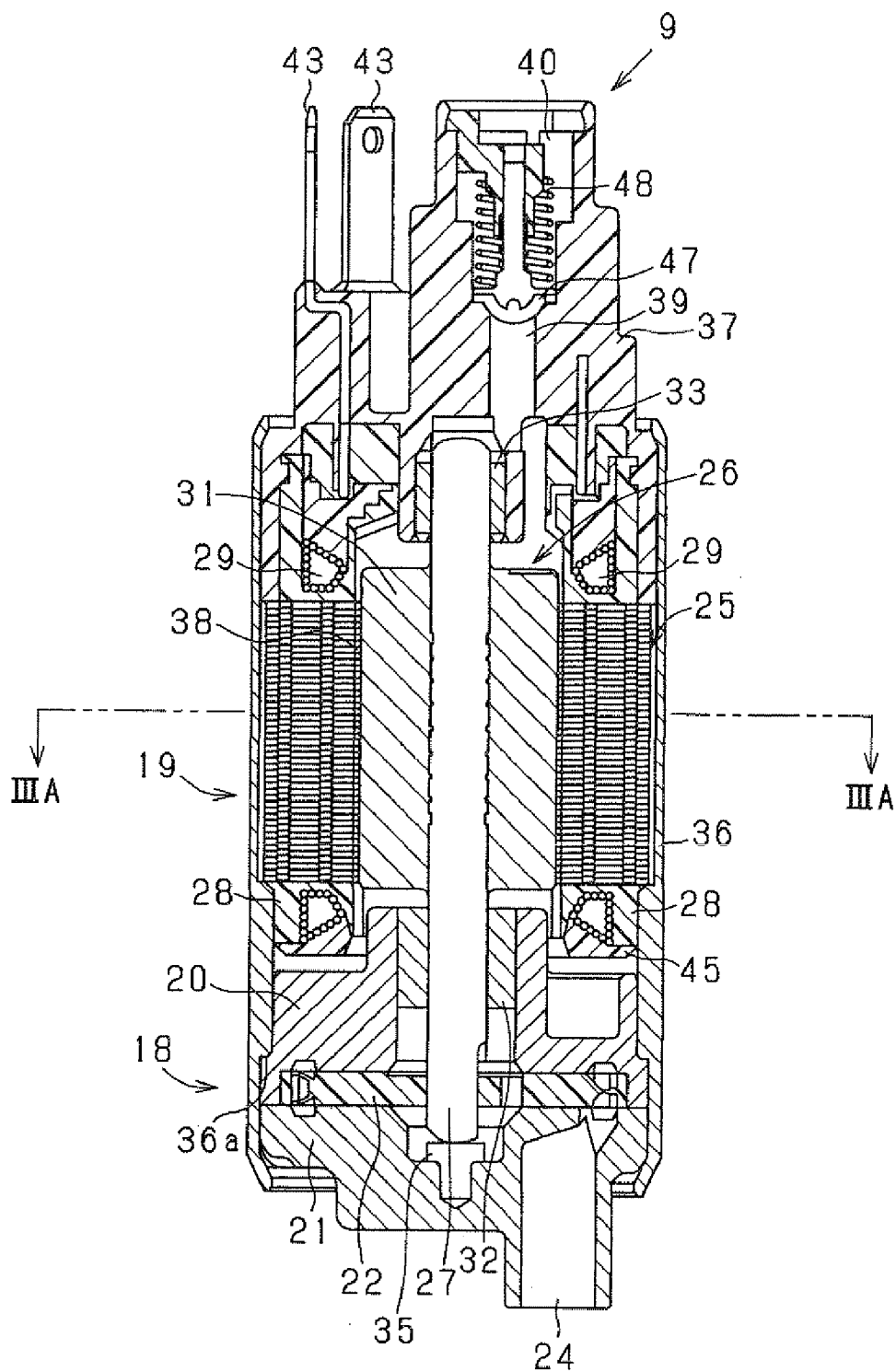


FIG. 3A

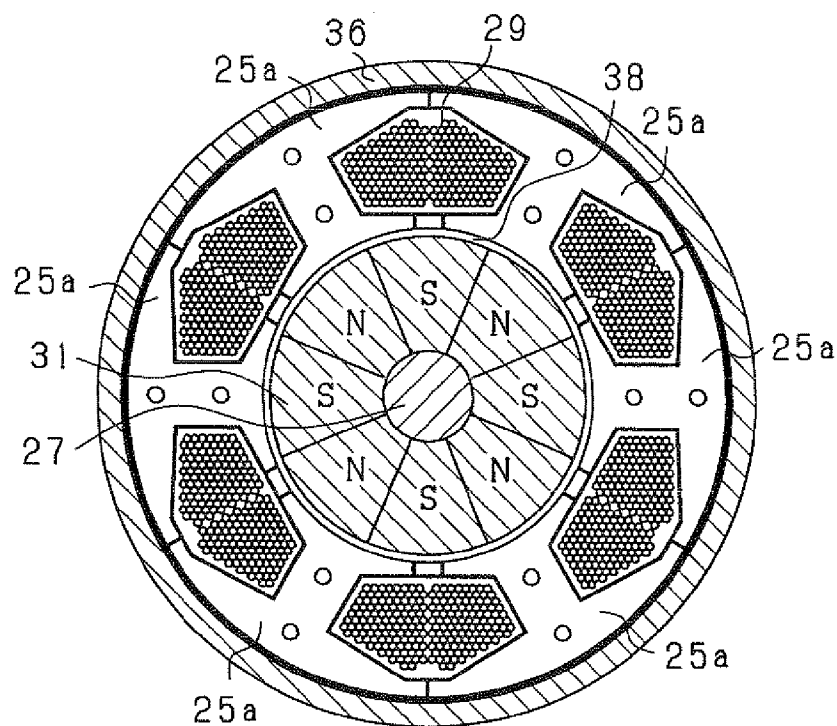
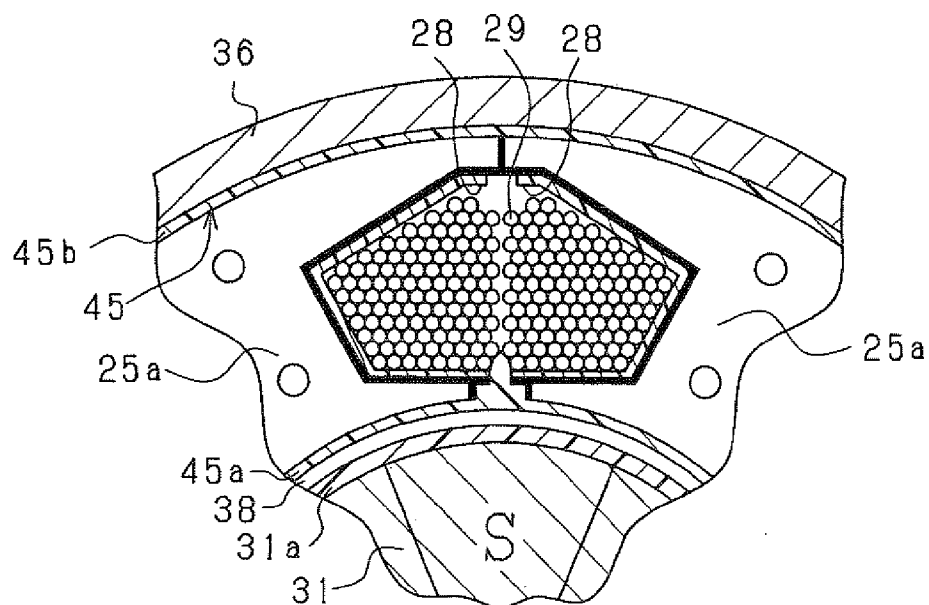


FIG. 3B



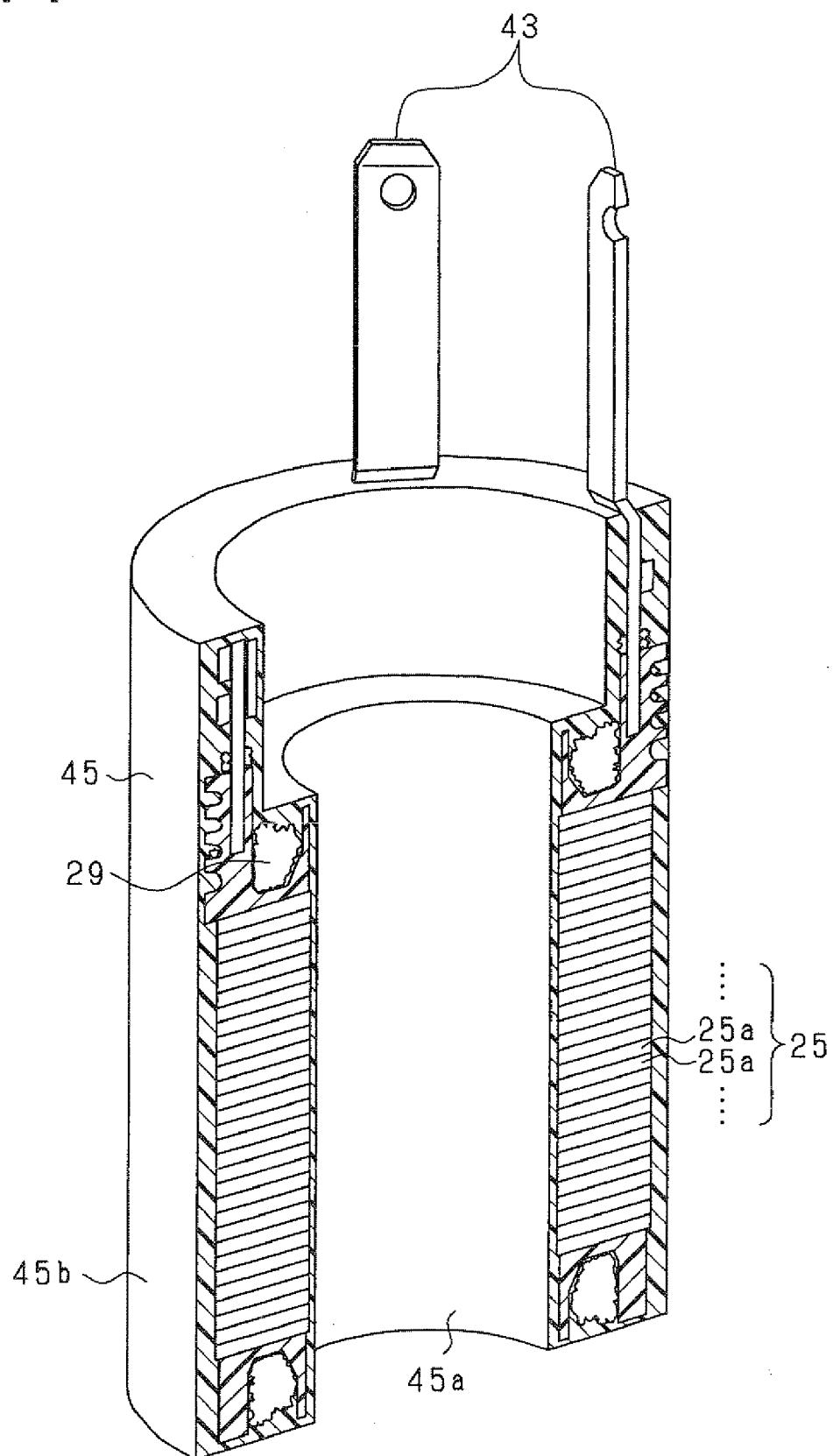


FIG. 5

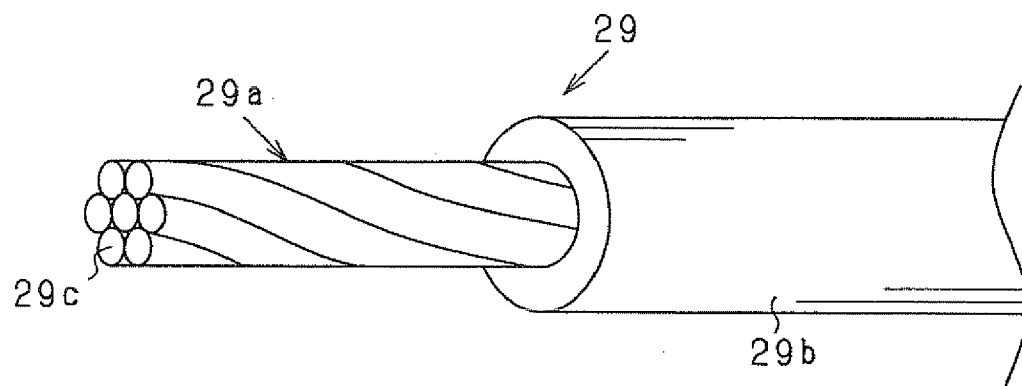
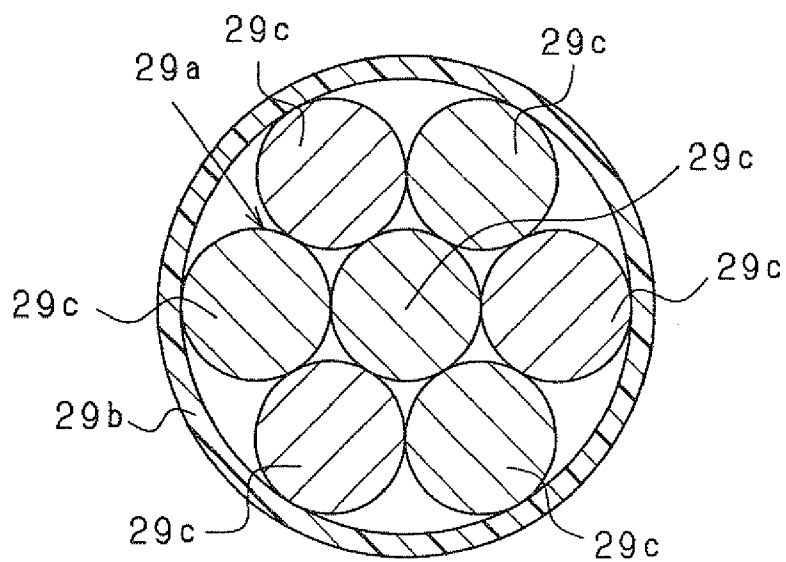


FIG. 6



ELECTRICALLY POWERED PUMP

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on and incorporates herein by reference Japanese Patent Application No. 2008-017085 filed on Jan. 29, 2008.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an electrically powered pump that has an electric motor arrangement for driving a pump arrangement.

[0004] 2. Description of Related Art

[0005] In recent years, selective reduction (SCR: Selective Catalytic Reduction) type urea SCR system is under development, and partly put into actual use. The SCR system is installed in an internal combustion engine (especially diesel engine) of a vehicle, etc., to reduce NOx (nitrogen oxides) in exhaust gas.

[0006] In the urea SCR system, a selective reduction type NOx cleaning catalyst (SCR catalyst) is installed in an exhaust pipe of an internal combustion engine, and a urea water addition valve, which adds urea water (urea water solution) as a reducing agent to the exhaust gas in the exhaust pipe, is installed on an upstream side of the NOx cleaning catalyst. In this system, the urea water addition valve adds the urea water to the exhaust gas in the exhaust pipe, and the urea water is supplied to the NOx cleaning catalyst together with the exhaust gas. Then, the exhaust gas is cleaned up by NOx reduction reaction on this NOx cleaning catalyst. In the reduction of NOx, the urea water is hydrolyzed by a heat of the exhaust gas to generate ammonia (NH₃), and NOx is selectively reduced in the NOx cleaning catalyst by the ammonia even in an atmosphere in which oxygen concentration is high, to perform a cleaning of the exhaust gas (see JP2004-510093T corresponding to US2004/0115074A1, etc.).

[0007] This kind of urea SCR system requires a urea water pump that pumps the urea water stored in a tank to the urea water addition valve. The inventor of the present invention tried to use a conventional general electrically powered pump as this urea water pump. This electrically powered pump is a pump that has a pump arrangement for pumping a liquid, and an electric motor arrangement for driving the pump arrangement.

[0008] However, when the conventional electrically powered pump was used as the urea water pump as it is, corrosion of winding wires, which are described below, became a problem.

[0009] The above-mentioned winding wires are wired on at least one of a stator and a rotor that constitute the pump arrangement to generate a magnetic field when it is energized. Conventional general winding wire has a copper conductive body and an insulation body that insulates the conductive body. Moreover, the conventional electrically powered pump has a construction in which a resin (covering resin) covers an entire body of the stator or the rotor to prevent the wiring from corroding by keeping the wiring wire away from the liquid pumped by the pump arrangement. The inventor found that it is further required to take measures against corrosion of the winding wires, since urea water easily permeates the

above-mentioned covering resin and the insulator compared with mere water, and easily corrodes the copper conductive body.

[0010] In addition, such problems as the corrosion of the winding wires are caused not only by urea water but by other liquids except water. For example, alcohol, biofuel, etc. are used in some cases as fuel of an internal combustion engine of a vehicle in recent years. Also in an electrically powered pump that pumps such fuel to fuel injection valves, there is a concern that the fuel may permeate the covering resin and the insulator to corrode the copper conductive body.

SUMMARY OF THE INVENTION

[0011] The present invention is made in view of the above-mentioned problem.

[0012] Thus, it is an objective of the present invention to provide an electrically powered pump that has an electric motor arrangement for driving a pump arrangement, in which a liquid pumped by a pump arrangement is prevented from corroding a winding wire.

[0013] To achieve the objective of the present invention, there is provided an electrically powered pump. The electrically powered pump includes a pump arrangement that pumps a liquid, and an electric motor arrangement that has a stator and a rotor that are installed on a passage through which the liquid pumped by the pump arrangement flows. At least one of the stator and the rotor has a winding wire that generates a magnetic field when it is energized to rotate the rotor with respect to the stator to drive the pump arrangement. The winding wire has a conductive body through which an electric current passes and an insulation body that insulates the conductive body. The conductive body is made of a material predominantly composed of carbon.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention, together with additional objectives, features and advantages thereof, will be best understood from the following description, the appended claims and the accompanying drawings in which:

[0015] FIG. 1 is a schematic diagram showing an entire construction of a urea SCR system in which a urea water pump (electrically powered pump) according to one embodiment of the present invention is incorporated;

[0016] FIG. 2 is a cross sectional view showing a construction of the urea water pump shown in FIG. 1 in detail;

[0017] FIG. 3A is a cross-sectional view taken along a line IIIA-III A in FIG. 2;

[0018] FIG. 3B is an enlarged view of FIG. 3A;

[0019] FIG. 4 is a fragmentary perspective view showing a stator and an insulating resin body that molds the stator therein, which are shown in FIGS. 3A, 3B;

[0020] FIG. 5 is a perspective view showing an end portion of a wiring showing the end of a winding wire shown in FIG. 4; and

[0021] FIG. 6 is a cross-sectional view of the winding wire shown in FIG. 5.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] An electrically powered pump according to one embodiment of the present invention will be described hereafter, with reference to the accompanying drawings.

[0023] The electrically powered pump according to the present embodiment is applied to a urea water pump that pumps urea water solution (hereafter referred to just as urea water) that contains urea as a reducing agent. The urea water discharged from the urea water pump is pressurized and pumped to an addition valve. The addition valve is so installed as to inject the urea water in an exhaust gas flow in an exhaust passage of a diesel engine (hereafter referred to as engine), which is an internal combustion engine.

[0024] FIG. 1 schematically shows an entire construction of a urea SCR system in which the urea water pump (electrically powered pump) according to the present embodiment is incorporated. FIG. 1 depicts an exhaust emission control device in which exhaust gas discharged from the engine of a vehicle (not shown) is cleaned up. Components of the exhaust emission control system are roughly classified into an arrangement of an exhaust gas system, an arrangement of a urea water supply system, and an arrangement of a control system.

[0025] The arrangement of the exhaust gas system includes a DPF 1 (Diesel Particulate Filter), an exhaust pipe 2 (exhaust passage on an upstream side of a catalyst), the catalyst 3, and an exhaust pipe 4 (exhaust passage on a downstream side of the catalyst) that are arranged in this order from an upstream side of the exhaust gas flow. The DPF 1 is a continuous regeneration type PM removing filter that collects PM (Particulate Matters) in exhaust gas. The DPF 1 can be continuously used by repeatedly burning and removing the collected PM by post injections subsequent to main fuel injections, which are equivalent to regeneration processes of PM removing filters, for example. The DPF 1 supports a platinum base oxidation catalyst (not shown) to remove HC and CO together with soluble organic fraction (SOF) that is one ingredient of PM.

[0026] The catalyst 3 is a part that promotes NOx reduction reaction to clean up the exhaust gas. The catalyst 3 reduces NOx in the exhaust gas by promoting reactions as follows, for example:



[0027] A water solution (hereafter referred to as urea water) that contains ammonia (NH₃), which serves as a reducing agent for NOx in these reactions, is mixed with the exhaust gas and supplied to the catalyst 3. Specifically, the urea water is injected by the addition valve that is described later, and is supplied to the exhaust gas flowing through the exhaust pipe 2 on the upstream side of the catalyst 3.

[0028] The arrangement of the urea water supply system includes a urea water supply unit 5, the addition valve 6, a distribution pipe 7, etc. The urea water supply unit 5 has a urea water tank 8, the urea water pump 9 (electrically powered pump), etc. The urea water tank 8 includes an airtight container and a supplying cap. The urea water in a predetermined concentration is stored in the urea water tank 8. In the present embodiment, the urea water pump 9 is an in-tank type one and installed in the urea water tank 8.

[0029] The urea water pump 9 is an electromotive pump that is rotationally driven by a drive signal sent from ECU (Electronic Control Unit) 10 that serves as a controller. When the urea water pump 9 is driven, the urea water in the urea water tank 8 is sucked into the urea water pump 9 via a strainer

9a and a filter 9b, and pressurized. Then, a regulator 9c adjusts a discharge pressure of the urea water pump 9, and the urea water is pumped to the addition valve 6 via the distribution pipe 7. The urea water pump 9, the filter 9b, the regulator 9c, etc. are accommodated in a unit case 9d to be unitized. When a supply pressure of the urea water pump 9 exceeds a regulation pressure of the regulator 9c, the urea water in the distribution pipe 7 is returned to the urea water tank 8 by the regulator 9c.

[0030] An injection port is formed at a tip of the addition valve 6. When an electromagnetic actuator performs a valve-opening operation of a needle valve that opens and closes the injection port, the urea water, which was supplied to the addition valve 6 by an operation of the urea water pump 9, is injected into the exhaust pipe 2 in an atomized form. When the urea water is supplied and added to the exhaust gas in this manner, the urea water is supplied to the SCR catalyst 3 together with the exhaust gas in the exhaust pipe 2. The urea SCR system is so configured as to clean up the exhaust gas by performing NOx reduction reaction at the SCR catalyst 3.

[0031] In the reduction of NOx, the urea water is hydrolyzed by a heat of the exhaust gas in accordance with a reaction as follows, for example:



[0032] Thereby, ammonia (NH₃) is generated, and this ammonia is added to NOx in the exhaust gas, which is selectively adsorbed to the SCR catalyst 3. Then, reduction reactions are performed by the ammonia in accordance with the above-mentioned chemical formulas 1 to 3, to reduce the NOx to clean up the exhaust gas.

[0033] A construction of a discrete assembly of the urea water pump 9 is described below in detail, with reference to FIGS. 2 to 4.

[0034] As shown in FIG. 2, the urea water pump 9 has a pump arrangement 18 that pumps the urea water, and an electric motor arrangement 19 that drives the pump arrangement 18. The pump arrangement 18 is a peripheral pump that has a pump case and an impeller 22. The pump case includes two components of the upper case 20 and a lower case 21 that are joined to each other. A space that serves as a pump chamber is formed radially inside of mating faces of the upper case 20 and the lower case 21. The impeller 22 is rotatably installed in the pump house. When the impeller 22 rotates, the urea water stored in the urea water tank 8 is sucked into a suction port 24 that is formed in the lower case 21, pressurized up in the pump chamber, and pumped to the electric motor arrangement 19, which is described later.

[0035] It is desirable that a component that has a portion on which urea water circulates is made of a material having corrosion resistance and oxidation resistance against urea water, among components of the urea water pumps 9. The upper case 20 and the lower case 21 are made of metal. In view of corrosion resistance and oxidation resistance, the upper case 20 and the lower case 21 are desirably made of JIS SUS304 corresponding to AISI 304, which is an austenitic stainless steel, a passivation coating regenerating material. Further, the impeller 22 is made of resin (phenol resin, for example).

[0036] The electric motor arrangement 19 is a brushless motor that has a stator 25, a rotor 26, etc., and functions to generate a driving force for pumping the urea water when it is energized. As shown in FIG. 3A that is a cross-sectional view taken along a line IIIA-III A in FIG. 2, the stator 25 includes

six split cores **25a** (core parts) that are arranged in a circular manner. Each split core **25a** is composed of magnetic steel plates, on which an insulating coating is applied, that are integrally laminated in a direction along a revolving shaft (in a vertical direction in FIG. 2). A bobbin **28** that is made of an insulating material such as resin is attached to each split core **25a** (see FIGS. 2 and 3B).

[0037] Winding wires **29** are series-wound (or shunt-wound) on an outer circumference of the bobbin **28** of each split core **25a**. The winding wires **29** are electrically connected with terminals **43** on an end cover **37** side as shown in FIG. 2. The winding wires **29** are classified into three kinds of U phase, V phase and W phase ones. A switching by the ECU **10** controls a current flow from the terminals **43** to the winding wires **29** of respective phases. Thereby, magnetic poles are generated on the winding wires **29** of the respective phases. Therefore, a clearance between an inner circumferential surface of the stator **25** and an outer circumferential surface of the rotor **26** serves as a circulation passage **38** as mentioned above, and as a gap between the stator **25** and the rotor **26** on a magnetic circuit.

[0038] A permanent magnet **31** is a plastic magnet that is formed into a cylindrical shape by kneading thermoplastic resin material such as PPS with magnetic powder. The permanent magnet **31** is formed directly on a circumference of the revolving shaft **27** by injection molding, etc. As shown in FIG. 3A, the permanent magnet **31** forms eight magnetic pole portions that are arranged around the circumference of the revolving shaft **27**. These magnetic pole portions are magnetized to form different magnetic poles in its peripheral portions by turns around the circumference of the revolving shaft **27**, to face the stator **25**.

[0039] FIG. 4 is a fragmentary perspective view showing the stator **25** and an insulating resin body **45** that molds the stator **25** therein. As shown in FIG. 4, the six split cores **25a**, the winding wires **29** of respective phases and the terminals **43** are resin molded in the insulating resin body **45** to be united. This insulating resin body **45** covers also the inner circumferential surface of the split cores **25a**. The permanent magnet **31** is also covered with an insulating resin body **31a**. That is, to be exact, the above-mentioned circulation passage **38** is formed between an inner circumferential wall portion **45a** of the insulating resin body **45** and an outer circumferential wall portion **31a** (see FIG. 3B) of the insulating resin body that covers the permanent magnet **31**. A referential numeral **45b** in FIG. 3A denotes an outer circumferential wall portion of the insulating resin body **45**.

[0040] A housing **36** serves as a housing of both of the pump arrangement **18** and the electric motor arrangement **19**. The housing **36** is made of metal. Both axial ends of the housing **36** are respectively crimped onto the lower case **21** and onto the end cover **37**. The upper case **20** butts against a step portion **36a** of the housing **36** in an axial direction of the housing **36**. Thereby, an axial position of the upper case **20** is determined. A bearing portion **32** is fixed to a radially central portion of the upper case **20** by press fitting. The lower case **21** is fixed to one end of the housing **36** by crimping. An axial force produced by the crimping provides a surface pressure that pushes the upper case **20** and the steps portion **36a** onto each other, and the lower case **21** and the upper case **20** onto each other in the axial direction, to seal the urea water.

[0041] The urea water pumped to the electric motor arrangement **19** side is sent into the circulation passage **38** between the stator **25** and the rotor **26** (see FIGS. 2 and 3A),

and then into a discharge passage **39**, and is further supplied from a discharge port **40** to the addition valve **6** side. The discharge port **40** of the discharge passage **39**, which is formed in the end cover **37** to open to an outside, is arranged to be eccentric with respect to a bearing portion **33**.

[0042] The above-mentioned insulating resin body **45** is integrally formed with the end cover **37** that covers a counter-pump arrangement **18** side end portion of the stator **25**. The bearing portion **33** that supports the revolving shaft **27**, a base portion of the terminals **43** and the discharge port **40** are united by the insulating resin body **45**, to form the end cover **37**.

[0043] A check valve **47** and a spring **48** are accommodated in the discharge port **40** that is formed in the end cover **37**. When a pressure of the urea water that is pressured up in the pump arrangement **18** reaches a predetermined value, the check valve **47** lifts up against a biasing force of the spring **48**, to discharge the urea water from the discharge port **40** to the addition valve **6** side. The check valve **47** is installed to prevent a back-flow of the urea water that is discharged from the urea water pump **9**.

[0044] Next, a construction and a material of the winding wire **29**, which are the essence of the present invention, are described below, with reference to FIGS. 5 and 6

[0045] The same winding wire is used for the respective winding wires **29** of U phase, V phase and W phase. This winding wire **29** has a conductive body **29a** through which current passes, and an insulation body **29b** that covers the conductive body **29a**. FIG. 5 is a perspective view showing an end portion of the winding wire **29**. In the end portion of the winding wire **29**, a tip end of the conductive body **29a** is exposed out of the insulation body **29b**. This exposed tip end is connected with the terminals **43**.

[0046] As shown in FIG. 6 that is a cross-sectional view of the winding wire **29**, two or more strands **29c** are twisted together into a shape of a wire, to form the conductive body **29a**. The strand **29c** is made of a material that is predominantly composed of carbon. Specifically, the strand **29c** is formed by spinning carbon nanotubes only, or by binding carbon nanotubes by a binder. The strand **29c** can be processed by manufacturing methods disclosed in JP2007-126318A, JP2007-161512A, etc.

[0047] It is desirable that the terminal **43** is also made of a material that is predominantly composed of carbon. It is desirable that a composition of the terminal **43** is substantially the same as the composition of the above-mentioned strand **29c** (a composition of carbon nanotubes or carbon fibers, for example). A material of the insulation body **29b** is resin or rubber.

[0048] The urea water pump **9** is an electrically powered pump, and there is an apprehension that the urea water corrodes electric parts and other kinds of parts in the electric motor arrangement **19** since the urea water pumped in the pump arrangement **18** circulates through the electric motor arrangement **19**. In the present embodiment, as a measure against this apprehension, the insulating resin body **45**, which molds the stator **25** therein, has an inner circumferential wall portion **45a**, and the insulating resin body, which molds the permanent magnet **31** therein, has the inner circumferential wall portion **31a**.

[0049] Thereby, in a formation of the circulation passage **38** of urea water in the clearance between the inner circumferential surface of the stator **25** and the outer circumferential surface of the rotor **26**, the inner circumferential wall portion

45a covers the electric parts of the stator **25** such as the split cores **25a** and the winding wires **29**, to prevent the electric parts from being directly exposed to the urea water in the circulation passage **38**. Further, the outer circumferential wall portion **31a** covers the parts of the rotor **26** such as the permanent magnet **31**, to prevent the parts from being directly exposed to the urea water in the circulation passage **38**. Therefore, it is possible to prevent the split cores **25a**, the winding wires **29** and the permanent magnet **31** from being corroded by the urea water.

[0050] However, the inventor found that the urea water swells the inner circumferential wall portion **45a** and the outer circumferential wall portion **31a**, which are made of resin, and that the urea water can permeate into the walls portions **45a** and **31a** due to this swelling. Further, copper is generally used as a conventional material of the conductive body **29a** of the winding wire **29**, and the inventor found that it is necessary to raise corrosion resistance of the winding wire **29**, particularly the corrosion resistance of the conductive body **29a**.

[0051] In view of this point, in the present embodiment, the conductive body **29a** is made of a material that is predominantly composed of carbon. The carbon has an electrical resistance that is approximately equal to an electrical resistance of copper, and has a corrosion resistance against ammonia (NH_3) that is higher than a corrosion resistance of copper. Further, since the urea water pump **9** is installed in an engine room of a vehicle, an environmental temperature of the urea water pump **9** is high, and a heat resistance of the winding wire **29** must be high. In this regard, a heat resistance of carbon is excellent with respect to a heat resistance of copper. Therefore, according to the present embodiment in which carbon is applied to the conductive body **29a**, the corrosion resistance of the winding wire **29** against the urea water is improved, without raising electric resistance and without reducing heat resistance, with respect to a winding wire having a conventional copper conductive body.

[0052] Further, in the present embodiment, two or more strands **29c** are twisted together into a shape of a wire, to form the conductive body **29a**. Thereby, a strength of the winding wire **29** can be improved by raising a strength of the conductive body **29a**. in a manufacturing process in which the winding wires **29** are wound on the split cores **25a**, the winding wires **29** are wound under a tension, so that the winding wire **29** must have a tensile strength that can bear the above-mentioned tension. Therefore, the manufacturing process of the stator **25** makes use of the above-mentioned advantage that the strength of the winding wire **29** is improved.

[0053] Furthermore, in the present embodiment, the strands **29c** of the conductive body **29a** are composed of carbon nanotubes, to form the conductive body **29a** having the strands **29c** that is made of a material that is predominantly composed of carbon. Thereby, the conductive body **29a** has a high conductivity and a high strength.

[0054] Furthermore, if the conductive body **29a** is composed of the strands **29c** that are formed by spinning carbon nanotubes only, the conductive body **29a** has a higher conductivity and a higher strength than those of the conductive wire **29a** that is composed of the strands **29c** that are formed by binding carbon nanotubes by binders.

Other Embodiments

[0055] The above-described embodiments may be modified and put into practice as follows. Further, the present

invention is not limited to the content of the above-described embodiment. It is possible to combine respective distinctive constructions of the above-described embodiment arbitrarily.

[0056] (1) In the above-described embodiment, carbon nanotubes are used as the material of the strands **29c** that form the conductive body **29a**. In this regard, carbon fibers can be used instead of the carbon nanotubes. That is, the strand **29c** can be formed by spinning carbon fibers only. The strand **29c** can also be formed by binding carbon fibers by binders.

[0057] (2) The strand **29c** that is composed of carbon fibers or carbon nanotubes may be so formed as to extend from one end to the other end of the winding wire **29** without having connecting portions. The strand **29c** may also be formed by connecting two or more strands on a middle of the winding wire **29** between its one end and the other end.

[0058] (3) In the above-described embodiment, the electrically powered pump according to the present invention is applied to a urea water pump. However, the present invention is not limited to such a urea water pump. For example, the electrically powered pump according to the present invention may be applied to a fuel pump that is mounted on a vehicle having an internal combustion engine to pump a fuel that was reserved in a fuel tank to fuel injection valves that injects the fuel into combustion chambers or into an intake pipe of the internal combustion engine. Further, in an internal combustion engine in which hydrocarbon (HC) is added to exhaust gas as a reducing agent instead of adding urea water as a reducing agent, the electrically powered pump according to the present invention may be applied to a pump that pumps the hydrocarbon to an addition valve.

[0059] (4) In the above-described embodiments, the present invention is applied to the electrically powered pump **9** in which the stator **25** has the winding wires **29** and the conductive bodies **29a** of the winding wires **29** on the stator **25** side are made of carbon. Alternatively, the present invention may also be applied to an electrically powered pump in which a rotor has winding wires and conductive bodies of the winding wires on the rotor side are made of carbon.

[0060] Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader terms is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described.

What is claimed is:

1. An electrically powered pump comprising: a pump arrangement that pumps a liquid; and an electric motor arrangement that has a stator and a rotor that are installed on a passage through which the liquid pumped by the pump arrangement flows, wherein: at least one of the stator and the rotor has a winding wire that generates a magnetic field when it is energized to rotate the rotor with respect to the stator to drive the pump arrangement; the winding wire has a conductive body through which an electric current passes and an insulation body that insulates the conductive body; and the conductive body is made of a material predominantly composed of carbon.
2. The electrically powered pump according to claim 1, wherein the conductive body is a strand that is formed by spinning carbon nanotubes.
3. The electrically powered pump according to claim 1, wherein the conductive body is a strand that is formed by binding carbon nanotubes by a binder.
4. The electrically powered pump according to claim 1, wherein:

the conductive body is a plurality of strands that is twisted together; and

the plurality of strands is made of a material predominantly composed of carbon.

5. The electrically powered pump according to claim 1, wherein:

the pump is adapted to be installed in an internal combustion engine of an vehicle; and

the liquid pumped by the pump arrangement is a reducing agent that reduces a nitrogen oxide contained in an exhaust gas of the internal combustion engine.

* * * * *