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# (54) GLOW PLUG

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## Description

**[0001]** The present invention relates to a glow plug.

**[0002]** A known glow plug, as disclosed in WO-A1-2014/206847 and JP-A-2014 137169 for example, includes a sheath tube extending in the axial direction, and a heat generation coil disposed in the sheath tube and whose forward end is connected to a forward end portion of the sheath tube.

**[0003]** US-A-5118921 discloses a glow plug on which the precharacterizing portion of claim 1 is based.

**[0004]** However, in the case where the distance between the forward end of the heat generation coil and the forward end of the sheath tube is short, in the event of deterioration of the forward end of the sheath tube, in some cases, the forward end of the heat generation coil is exposed from the forward end of the sheath tube, resulting in a failure to secure the durability of the glow plug. By contrast, in the case where the distance is long, due to increase in heat capacity of the forward end portion of the sheath tube, in some cases, difficulty is encountered in securing rapid heat-up performance for raising the temperature of the glow plug to a desired temperature in a relatively short time. Thus, regarding such a glow plug, demand has been rising for a technique for securing both durability and rapid heat-up performance.

**[0005]** The present invention has been conceived to solve the above problem and can be embodied in the following modes.

**[0006]** The present invention provides a glow plug as defined by claim 1.

A glow plug of such a mode can secure durability and rapid heat-up performance.

**[0007]** The forward end portion of the heat generation coil may be rectilinear. Since a glow plug of such a mode facilitates adjustment of the length of the forward end portion, while the above relational expressions (1) and (2) are met, the thickness C can be reduced. Thus, since the heat capacity of the forward end portion of the sheath tube can be reduced, a glow plug suited for rapid heat-up can be provided.

**[0008]** The forward end portion of the heat generation coil may be spiral. A glow plug of such a mode can provide stronger connection between the forward end portion of the heat generation coil and the forward end portion of the sheath tube.

**[0009]** The present invention can be embodied in various forms other than the glow plug. For example, the present invention can be embodied in a method of manufacturing a glow plug, a sheath heater, and a control unit having a glow plug.

**[0010]** The invention will be further described by way of example with reference to the accompanying drawings, in which:-

FIG. 1 is a block diagram showing a glow plug control system according to an embodiment of the present invention.

FIG. 2 is a view showing a glow plug in the glow plug control system.

FIG. 3 is a sectional view showing the structure of a sheath heater in detail.

FIG. 4 is a sectional view showing a forward end portion of a sheath tube and its periphery.

FIG. 5 is a flowchart showing a method of manufacturing the glow plug.

FIG. 6 is a set of explanatory views showing welding work in step S20.

FIG. 7 is a table showing the results of an experiment.

FIG. 8 is a sectional view showing a forward end portion of a sheath tube and its periphery of a glow plug according to a second embodiment.

FIG. 9 is a set of explanatory views showing a welding step in the second embodiment.

### A. First Embodiment

#### A1. Configuration of Glow Plug Control System

**[0011]** FIG. 1 is a block diagram showing a glow plug control system 21 according to an embodiment of the present invention. The glow plug control system 21 includes a glow plug 10, a control unit 32, and a switch 33. FIG. 1 shows only a single glow plug 10. However, an actual engine has a plurality of cylinders, and the glow plug 10 and the switch 33 are provided for each cylinder.

**[0012]** The control unit 32 is a microcomputer having a CPU, ROM, RAM, etc. The control unit 32 controls energization of the glow plug 10 by PWM (Pulse Width Modulation) control. The control unit 32 can calculate the voltage applied to the glow plug 10 on the basis of an input voltage. The switch 33 switches on/off energization of the glow plug 10 from a battery VA according to an instruction from the control unit 32. The switch 33 is configured to operate an FET (Field Effect Transistor) having a current detecting function through an NPN transistor, etc. The control unit 32 obtains resistance of the glow plug 10 from an applied voltage and current which flows to the glow plug 10 and is measured at the switch 33. Further, in the present embodiment, when the engine key is turned on, the control unit 32 can perform preglow energization for rapidly raising temperature of the glow plug 10 and, after preglow energization, afterglow energization for maintaining the glow plug 10 at a predetermined temperature for a predetermined period of time.

**[0013]** In preglow energization, the control unit 32 applies a voltage of 11 V to the glow plug 10, thereby performing rapid heat-up; specifically, raising the surface temperature of a sheath tube of the glow plug 10 at a position located 2 mm rearward in the axial direction OD from the forward end (to be described later) of the sheath tube, to 1,000°C or higher within three seconds from start of the voltage application. In preglow energization, the control unit 32 makes a curve indicative of the relation between power applied to the glow plug 10 and elapsed time coincide with a reference curve prepared in advance, thereby rapidly raising the temperature of the glow plug 10 to a target temperature. Specifically, by use of a relational expression or table indicative of the reference curve prepared in advance, the control unit 32 obtains power to be applied at individual points of elapsed time from start of energization. The control unit 32 obtains voltage to be applied to the glow plug 10 at a certain point of elapsed time from the relation between current flowing to the glow plug 10 and power to be applied at the point of elapsed time, thereby controlling voltage to be applied to the glow plug 10 by PWM control. Thus, power is applied in such a manner as to follow the reference curve, whereby the glow plug 10 generates heat according to integrated quantity of power applied up to individual points of elapsed time in the course of heating up. Therefore, upon completion of application of power along the reference curve, the glow plug 10 reaches a target temperature in a period of time indicated by the reference curve.

**[0014]** In afterglow energization, power to be supplied to the glow plug 10 is adjusted so as to maintain the surface temperature of the sheath tube of the glow plug 10 at 1,000°C or higher for a relatively long period of time (e.g., about 180 seconds). In afterglow energization, the control unit 32 controls energization of the glow plug 10 such that the resistance of the glow plug 10 becomes equal to a resistance (a target resistance) thereof at the time when the glow plug 10 is heated to a target temperature. Specifically, the control unit 32 calculates an effective voltage to be applied to the glow plug 10, from a difference between the current resistance of the glow plug 10 and the target resistance by, for example, PI (Proportional-Integral) control. On the basis of the calculated effective voltage, the control unit 32 determines a duty ratio, which is the quotient of dividing a pulse width by a pulse period, and controls energization accordingly.

A2. Structure of Glow Plug

**[0015]** FIG. 2 is a view showing the glow plug 10 in the glow plug control system 21. The glow plug 10 includes a sheath heater (heat generation device) 800 for generating heat and functions as a heat source for assisting ignition at startup of an internal combustion engine (not shown) such as a diesel engine. The glow plug 10 includes the sheath heater 800, an axial rod 200, and a metallic shell 500. These component members of the glow plug 10 are assembled together along the axial direction OD of the glow plug 10. FIG. 2 shows an external structure on the right side of an axial line O and a sectional structure on the left side of the axial line O. In the present specification, a side toward the sheath heater 800 in the glow plug 10 is called the "forward side," and a side toward an engagement member 100 is called the "rear side."

**[0016]** The metallic shell 500 is a tubular member formed of carbon steel. The metallic shell 500 holds the sheath heater 800 at a forward end portion. Also, the metallic shell 500 holds the axial rod 200 at a rear end portion through an insulation member 410 and an O-ring 460. The position along the axial line O of the insulation member 410 is fixed as a result of a ring 300 in contact with the rear end of the insulation member 410 being crimped to the axial rod 200. Further, a portion of the axial rod 200 extending from the insulation member 410 to the sheath heater 800 is disposed in an axial hole 510 of the metallic shell 500. The axial hole 510 is a through hole formed along the axial line O and is greater in diameter than the axial rod 200. In a state in which the axial rod 200 is positioned in the axial hole 510, a gap is formed between the axial rod 200 and the wall of the axial hole 510 for electrically insulating them from each other. The sheath heater 800 is press-fitted into a forward end portion of the axial hole 510 to thereby be joined to the forward end portion. The metallic shell 500 further includes a tool engagement portion 520 and an external thread portion 540. A tool (not shown) is engaged with the tool engagement portion 520 of the metallic shell 500 for attaching and detaching the glow plug 10. The external thread portion 540 meshes with an internal thread formed in an internal combustion engine (not shown).

**[0017]** The axial rod 200 is a circular columnar (rodlike) member formed of an electrically conductive material. While being inserted through the axial hole 510 of the metallic shell 500, the axial rod 200 is disposed in position along the axial line O. The axial rod 200 includes a forward end portion 210 formed at the forward end side and an external thread portion 290 provided at the rear end side. The forward end portion 210 is inserted into the sheath heater 800. The external thread portion 290 protrudes rearward from the metallic shell 500. The engagement member 100 meshes with the external thread portion 290.

**[0018]** FIG. 3 is a sectional view showing the structure of a sheath heater 800 in detail. With the forward end portion 210 of the axial rod 200 inserted into the sheath heater 800, the sheath heater 800 is press-fitted into the axial hole 510 of the metallic shell 500 to thereby be joined to the metallic shell 500. The sheath heater 800 includes a sheath tube 810, a heat generation coil 820, a rear coil 830, and an insulator 870. The heat generation coil 820 is also called the "forward end coil."

**[0019]** The sheath tube 810 is a tubular member extending in the axial direction OD and whose forward end is closed. The sheath tube 810 accommodates therein the heat generation coil 820, the rear coil 830, and the insulator 870. The sheath tube 810 includes a side portion 814 extending in the axial direction OD, a forward end portion 813 connected to the forward end of the side portion 814 and curved outward, and a rear end portion 819 opening in a direction opposite the forward end portion 813. The forward end portion 210 of the axial rod 200 is inserted into the sheath tube 810 from the rear end portion 819. The sheath tube 810 is electrically insulated from the axial rod 200 by a packing 600 and the insulator 870. Meanwhile, the sheath tube 810 is in contact with the metallic shell 500 to thereby be electrically connected to the metallic shell 500. The sheath tube 810 is formed of, for example, austenitic stainless steel which contains iron (Fe), chromium (Cr), and carbon (C), or a nickel (Ni)-based alloy such as INCONEL 601 (INCONEL is a registered trademark) or Alloy602 (corresponding to DIN2.4633 alloy specified by German Industrial Standard (DIN)).

**[0020]** The insulator 870 is formed of powder of an electrical insulation material. For example, magnesium oxide (MgO) powder is used as the insulator 870. The insulator 870 is filled into (disposed in) a gap which remains in the sheath tube 810 as a result of disposition of the axial rod 200, the heat generation coil 820, and the rear coil 830 in the sheath tube 810, thereby providing electrical insulation in the gap.

**[0021]** The heat generation coil 820 is disposed in the sheath tube 810 along the axial direction OD and generates heat by energization thereof. The heat generation coil 820 includes a forward end portion 822, which is a forward coil end portion, and a rear end portion 829, which is a rear coil end portion. The forward end portion 822 is located in the forward end portion 813 of the sheath tube 810 and electrically connected to the sheath tube 810. The rear end portion 829 is electrically connected to the rear coil 830 through a connection 840 formed as a result of welding of the heat generation coil 820 and the rear coil 830. Preferably, a main component of the heat generation coil 820 is tungsten (W) or molybdenum (Mo). Notably, the main component is a substance whose content (% by mass) is 50% by mass or higher. More preferably, the main component of the heat generation coil 820 is tungsten (W), and the tungsten (W) content of the heat generation coil 820 is 99% by mass or higher. In the present embodiment, the main component of the heat generation coil 820 is tungsten (W), and the tungsten (W) content of the heat generation coil 820 is 99% by mass or higher.

**[0022]** The rear coil 830 includes a forward end portion 831, which is a forward coil end portion, and a rear end portion 839, which is a rear coil end portion. The forward end portion 831 is welded to the rear end portion 829 of the heat generation coil 820 to thereby be electrically connected to the heat generation coil 820. The rear end portion 839 is joined to the forward end portion 210 of the axial rod 200 to thereby be electrically connected to the axial rod 200. The rear coil 830 is formed of, for example, a nickel (Ni)-chromium (Cr) alloy or an iron (Fe)-chromium (Cr)-aluminum (Al) alloy.

**[0023]** In view of secure rapid heat-up performance, preferably, resistance $R_{20}$ at 20°C of the glow plug 10 is 0.6 Ω or less. In the present embodiment, the resistance $R_{20}$ at 20°C of the glow plug 10 is the sum of a resistance at 20°C of the heat generation coil 820 and a resistance at 20°C of the rear coil 830. In the present embodiment, the resistance $R_{20}$ at 20°C of the glow plug 10 is 0.4 Ω. In the present embodiment, resistance ratio R1 of resistance $R1_{1000}$ at 1,000°C to resistance $R1_{20}$ at 20°C of the heat generation coil 820 and resistance ratio R2 of resistance $R2_{1000}$ at 1,000°C to resistance $R2_{20}$ at 20°C of the rear coil 830 are in the relation of R1 > R2.

**[0024]** FIG. 4 is a sectional view showing the forward end portion 813 of the sheath tube 810 and its periphery. FIG. 4 is a sectional view of the sheath heater 800 taken along the axial line O and shows a spiral portion 823 and the forward end portion 822 of the heat generation coil 820, the sheath tube 810, and the insulator 870. In the present embodiment, the forward end portion 822 of the heat generation coil 820 is rectilinear along and on the axial line O. As shown in FIG. 4, the forward end portion 822 of the heat generation coil 820 is located between a forward end 811 of the sheath tube 810 and a forward-end inner wall surface 812 of the sheath tube 810 and is surrounded by and embedded in the forward end portion 813 of the sheath tube 810. In the case where an alloy of a metal used to form the sheath tube 810 and a metal used to form the heat generation coil 820 is formed between the forward end portion 813 of the sheath tube 810 and the forward end portion 822 of the heat generation coil 820, the thickness of an alloy portion formed of the alloy is 10 μm or less. The thickness of the alloy portion can be calculated by detecting the alloy portion through analysis of a region in the vicinity of the boundary between the forward end portion 822 of the heat generation coil 820 and the forward end portion 813 of the sheath tube 810 by use of, for example, EPMA (Electron Probe Micro Analyzer). Notably, in the glow plug 10 of the present embodiment, the alloy portion is not formed. Accordingly, FIG. 4 does not show the alloy portion.

**[0025]** FIG. 4 further shows thickness A, distance B, and thickness C. The thickness A is the minimum thickness of the side portion 814 of the sheath tube 810 as measured in a region along the axial direction OD where the heat generation coil 820 is disposed. The distance B is the distance along the axial direction OD from the forward end 811 of the sheath tube 810 to a forward end 821 of the heat generation coil 820. The thickness C is the maximum thickness along the axial direction OD of the forward end portion 813 of the sheath tube 810. The thickness A of the side portion 814 is determined beforehand to enable usage of the glow plug 10 up to at least a desired number of cycles even when the sheath tube 810 (side portion 814) is eroded as a result of, for example, oxidation stemming from repeated energization cycles in each of which the glow plug 10 is energized and deenergized. The thickness A, the distance B, and the thickness C meet the following relational expressions (1) and (2). Hereinafter, the ratio "C/A" between the thickness C and the thickness A is called the "thickness ratio."

$$B > A \quad \ldots (1)$$

$$C/A \leq 2.5 \ldots (2)$$

**[0026]** In view of erosion of the sheath tube 810 (side portion 814) as a result of repeated energization of the glow plug 10, the thickness A is preferably 0.4 mm or more. A thickness A of 0.4 mm or more allows the glow plug 10 to be used up to a sufficient number of cycles. In view of rapid heat-up performance of the glow plug 10, the thickness A is preferably 0.7 mm or less. Through employment of a thickness A of 0.7 mm or less, the distance from the inner wall to the surface of the sheath tube 810 does not become excessively long, whereby the rapid heat-up performance of the glow plug 10 can be secured.

A3. Method of Manufacturing Glow Plug 10

**[0027]** FIG. 5 is a flowchart showing a method of manufacturing the glow plug 10. In manufacture of the glow plug 10, first, the heat generation coil 820 and the axial rod 200 are welded together (step S10). Specifically, the heat generation coil 820 and the rear coil 830 are welded together; further, the rear end portion 839 of the rear coil 830 and the forward end portion 210 of the axial rod 200 are welded together. Next, the forward end portion 822 of the heat generation coil 820 and the forward end portion 813 of the sheath tube 810 are welded together (step S20). Step S20 is also called the "welding step."

**[0028]** FIG. 6 is a set of explanatory views showing welding work in step S20. In the welding step, first, there is prepared a sheath tube 810p which includes a forward end portion 813p having an opening 815 and which is shaped such that diameter gradually reduces toward the opening 815. The forward end portion 822 of the heat generation coil 820 is inserted into the forward end portion 813p (opening 815) of the prepared sheath tube 810p (FIG. 6(a)). Next, while the forward end portion 813p is melted by, for example, arc welding from outside and then is solidified to close the opening 815, the forward end portion 822 of the heat generation coil 820 and the forward end portion 813 of the sheath tube 810 are welded together (FIG. 6(b)). By this procedure, the forward end portion 822 of the heat generation coil 820 is surrounded by and embedded in the forward end portion 813 of the sheath tube 810. In the welding step, the volume of the forward end portion 813p of the sheath tube 810p to be prepared, the length (length of the forward end portion 822) of the heat generation coil 820 to be disposed in the opening 815, output of a welding machine, welding time, etc. are adjusted such that the thickness A, the distance B, and the thickness C meet the relational expressions (1) and (2). Also, in the welding step, output of the welding machine, welding time, etc. are adjusted such that the heat generation coil 820 and the sheath tube 810 are welded together at a temperature lower than the melting point of the heat generation coil 820 and higher than the melting point of the sheath tube 810, so as to attain a thickness of the alloy portion of 10 μm or less.

**[0029]** When welding work in step S20 is completed, the insulator 870 is filled into the sheath tube 810 (step S30). The insulator 870 covers the heat generation coil 820, the rear coil 830, and the axial rod 200 to thereby fill a gap formed in the sheath tube 810, whereby assembly of the sheath heater 800 is completed.

**[0030]** When the sheath heater 800 is assembled, swaging is performed on the sheath heater 800 (step S40). Swaging is performed such that striking force is applied to the sheath heater 800 to thereby reduce the diameter of the sheath heater 800, so as to densify the insulator 870 filled into the sheath tube 810. When striking force is applied to the sheath heater 800 as a result of swaging, the striking force is transmitted into the sheath heater 800, thereby densifying the insulator 870.

**[0031]** After swaging is performed on the sheath heater 800, the sheath heater 800 and the metallic shell 500 are assembled together to thereby assemble the glow plug 10 (step S50), whereby the glow plug 10 is completed. Specifically, the sheath heater 800 assembled with the axial rod 200 is fixedly press-fitted into the axial hole 510 of the metallic shell 500; the O-ring 460 and the insulation member 410 are fitted to the axial rod 200 at a rear end portion of the metallic shell 500; and the engagement member 100 is meshed with the external thread portion 290 of the axial rod 200 located rearward of the rear end of the metallic shell 500. Also, in step S50, aging is performed on the glow plug 10. Specifically, the assembled glow plug 10 is energized so that the sheath heater 800 generates heat, thereby forming an oxide film on the outer surface of the sheath heater 800.

**[0032]** According to the thus-configured glow plug 10 of the present embodiment, since the thickness A and the distance B meet the relational expression (1), even when the glow plug 10 is used up to a desired number of cycles, exposure of the forward end 821 of the heat generation coil 820 from the forward end portion 813 of the sheath tube 810 can be restrained; thus, the durability of the glow plug 10 can be secured.

**[0033]** Also, since the thickness A and the thickness C meet the relational expression (2), the rapid heat-up performance of the glow plug 10 can be secured.

**[0034]** Also, since the thickness of the alloy portion is 10 μm or less, there can be restrained the shortening of the distance B which could otherwise result from formation of a thick alloy portion. Thus, deterioration of durability of the glow plug 10 can be restrained.

**[0035]** Further, since the forward end portion 822 of the heat generation coil 820 is rectilinear, the length of the heat generation coil 820 in the forward end portion 813 of the sheath tube 810 (length of the forward end portion 822) can be reduced; thus, the thickness C can be reduced while the relational expressions (1) and (2) are met. Thus, since the heat capacity of the forward end portion 813 of the sheath tube 810 can be reduced, the glow plug 10 suited for rapid heat-up can be provided.

**[0036]** Grounds for validity of the relational expression (2) for securing the rapid heat-up performance of the glow plug 10 will be described below on the basis of experimental results.

B. Description and Results of Experiment

**[0037]** FIG. 7 is a table showing the results of an experiment conducted for obtaining the optimum range of the thickness ratio. FIG. 7 shows the thickness A, the thickness C, the thickness ratio (C/A), and judgment on rapid heat-up performance. The present experiment prepared samples 1 to 9 which differ in a combination of the thickness A and the thickness C. The sheath heaters 800 of the samples were manufactured such that the thickness A and the distance B meet the relational expression (1) and such that the thickness of the alloy portion was 10 $\mu$m or less. The present experiment used the heat generation coils 820 formed of tungsten (W) and the rear coils 830 formed of an iron (Fe)-chromium (Cr)-aluminum (Al) alloy.

**[0038]** In the present experiment, in order to evaluate rapid heat-up performance in relation to the thickness ratio, a voltage of 11 V was applied to the samples 1 to 9, and the samples were measured for time until the surface temperature of the sheath tube 810 at a position located 2 mm rearward in the axial direction OD from the forward end 811 of the sheath tube 810 reached 1,000°C from start of the voltage application. The surface temperature of the sheath tube 810 was measured by means of a thermocouple. The rapid heat-up performance was judged by the following criteria. Application of voltage was started at room temperature (about 20°C). Samples which reached 1,000°C in three seconds or less from start of voltage application (samples judged "A" or "B") can be said to have sufficient rapid heat-up performance.

Rapid heat-up performance A:
1,000°C is reached in a time of 2 seconds or less from start of voltage application.
Rapid heat-up performance B:
1,000°C is reached in a time of longer than 2 seconds, and 3 seconds or less from start of voltage application.
Rapid heat-up performance C:
1,000°C is reached in a time of longer than 3 seconds, and 3.5 seconds or less from start of voltage application.
Rapid heat-up performance F:
1,000°C is reached in a time of longer than 3.5 seconds from start of voltage application.

**[0039]** According to the results of the experiment, in the samples 1 to 6 having a thickness ratio of 2.5 or less, the rapid heat-up performance was judged "B" or "A," indicating that sufficient rapid heat-up performance is secured. Particularly, in the samples 1 and 2 having a thickness ratio of 1.9 or less, the rapid heat-up performance is judged "A," indicating that more rapid heat-up is possible.

**[0040]** The experimental results indicate that the rapid heat-up performance of the glow plug 10 can be secured by means of the relational expression (2) being met. Deterioration of durability resulting from exposure of the forward end 821 of the heat generation coil 820 from the forward end portion 813 of the sheath tube 810 can be restrained by increasing the distance B; however, increasing the distance B deteriorates the rapid heat-up performance of the glow plug 10 due to an increase in the heat capacity of the forward end portion 813 of the sheath tube 810. However, by means of the thickness C and the thickness A meeting the relational expression (2); i.e., by means of the upper limit of the thickness C being 2.5 times the thickness A, durability and rapid heat-up performance can be secured.

C. Second Embodiment

C1. Structure of Glow Plug 10a

**[0041]** FIG. 8 is a sectional view showing the forward end portion 813 of the sheath tube 810 and its periphery of a glow plug 10a according to a second embodiment. FIG. 8 is a sectional view of the sheath heater 800 taken along the axial line O and shows a spiral portion 823a and a forward end portion 822a of a heat generation coil 820a, the sheath tube 810, and the insulator 870. In the present embodiment, the forward end portion 822a of the heat generation coil 820a is spiral. A cut bounded by the broken line S in FIG. 8 schematically shows, on an enlarged scale, a portion of the forward end portion 822a of the heat generation coil 820a in the case where an alloy portion 860 is formed between the forward end portion 813 of the sheath tube 810 and the forward end portion 822a of the heat generation coil 820a. FIG. 8 further shows the thickness A, the distance B, and the thickness C. The thickness A is the minimum thickness of the side portion 814 of the sheath tube 810 as measured in a region along the axial direction OD where the heat generation coil 820a is disposed. The distance B is the distance along the axial direction OD from the forward end 811 of the sheath tube 810 to a forward end 821a of the heat generation coil 820a. The thickness C is the maximum thickness along the axial direction OD of the forward end portion 813 of the sheath tube 810. In the present embodiment also, the thickness A and the distance B meet the relational expression (1), and the thickness A and the thickness C meet the relational expression (2). Other structural features of the glow plug 10a of the present embodiment are similar to those of the glow plug 10 of the first embodiment; thus, repeated description thereof is omitted.

C2. Method of Manufacturing Glow Plug 10a

**[0042]** In the method of manufacturing the glow plug 10a of the present embodiment, first, the heat generation coil 820 having the spiral forward end portion 822a is prepared, and the heat generation coil 820a and the axial rod 200 are welded together (step S10 in FIG. 5). Next, similarly to the case of the first embodiment, the welding step is performed for welding the heat generation coil 820a and the sheath tube 810a together (step S20 in FIG. 5).

**[0043]** FIG. 9 is a set of explanatory views showing the welding step in the second embodiment. In the welding step, the spiral forward end portion 822a of the heat generation coil 820a is inserted into the forward end portion 813p (opening 815) of the sheath tube 810p (FIG. 9(a)). Next, while the forward end portion 813p is melted by, for example, arc welding from outside and then is solidified to close the opening 815, the spiral forward end portion 822a of the heat generation coil 820a and the forward end portion 813 of the sheath tube 810 are welded together (FIG. 9(b)). By this procedure, the forward end portion 822a of the heat generation coil 820a is surrounded by and embedded in the forward end portion 813 of the sheath tube 810. Other features of the method of manufacturing the glow plug 10a in the present embodiment are similar to those of the method of manufacturing the glow plug 10 in the first embodiment; thus, repeated description thereof is omitted.

**[0044]** According to the thus-configured glow plug 10a of the present embodiment, the thickness D of the alloy portion 860 is 10 $\mu$m or less; the thickness A and the distance B meet the relational expression (1); and the thickness A and the thickness C meet the relational expression (2); therefore, the present embodiment yields effects similar to those of the first embodiment.

**[0045]** Further, since the forward end portion 822a of the heat generation coil 820a is spiral, as compared with the rectilinear forward end portion 822 of the heat generation coil 820, the forward end portion 822a of the heat generation coil 820a surrounded by and embedded in the forward portion 813 of the sheath tube 810 has a larger surface area (volume). Thus, the forward end portion 813 of the sheath tube 810 and the forward end portion 822a of the heat generation coil 820a can be connected together more firmly.

D. Modifications

• Modification 1

**[0046]** In the first embodiment, the forward end portion 822 of the heat generation coil 820 is rectilinear on and along the axial line O. However, the rectilinear forward end portion 822 may not be located on the axial line O, but may intersect with the axial line O. Further, the forward end portions 822 and 822a of the heat generation coil may have a shape other than rectilinear and spiral shapes.

• Modification 2

**[0047]** In the above embodiments, the glow plug 10 or 10a includes the heat generation coil 820 or 820a and the rear coil 830. However, the glow plug 10 or 10a may be configured to have a single coil such that the rear end portion 829 of the heat generation coil 820 or 820a is connected to the forward end portion 210 of the axial rod 200. Also, the rear coil 830 of the glow plug 10 or 10a may be configured such that a plurality of coils are connected together.

• Modification 3

**[0048]** In the above embodiments, arc welding is used in the welding step for welding the forward end portion 813p of the sheath tube and the forward end portion 822 or 822a of the heat generation coil together. However, other welding methods such as laser welding may be used in the welding step.

• Modification 4

**[0049]** In the above embodiments, the glow plug control system 21 includes the glow plug 10, the control unit 32, and the switch 33. However, the glow plug control system 21 may be configured to include the glow plug 10 and the control unit 32.

**[0050]** The present invention is not limited to the above embodiments and modifications, but may be embodied in various other forms without departing from the scope of the invention. For example, in order to solve, partially or entirely, the above-mentioned problem or yield, partially or entirely, the above-mentioned effects, technical features of the embodiments and modifications corresponding to technical features can be replaced or combined as appropriate. Also, the technical feature(s) may be eliminated as appropriate unless the present specification mentions that the technical feature(s) is mandatory.

[Description of Reference Numerals]

**[0051]**

10, 10a: glow plug
21: glow plug control system
32: control unit
33: switch
100: engagement member
200: axial rod
210: forward end portion
290: external thread portion
300: ring
410: insulation member
460: O-ring
500: metallic shell
510: axial hole
520: tool engagement portion
540: external thread portion
600: packing
800: sheath heater

810, 810a: sheath tube
810p: sheath tube
811: forward end
812: forward-end inner wall surface
813, 813a: forward end portion
813p: forward end portion
814: side portion
815: opening
819: rear end portion
820, 820a: heat generation coil
821, 821a: forward end
822, 822a: forward end portion
823, 823a: spiral portion
829: rear end portion
830: rear coil
831: forward end portion
839: rear end portion
840: connection
860: alloy portion
870: insulator
O: axial line
OD: axial direction
VA: battery

**Claims**

1. A glow plug (10, 10a) comprising:

a sheath tube (810) having a side portion (814) extending in an axial direction (OD) and a forward end portion (813) connected to a forward end of the side portion (814) and closing the forward end of the side portion (814), and
a heat generation coil (820, 820a) disposed in the sheath tube (810) in such a manner as to extend in the axial direction (OD) and whose forward end portion (822, 822a) is connected to the forward end portion (813) of the sheath tube (810),
wherein the forward end portion (822, 822a) of the heat generation coil (820, 820a) is surrounded by and embedded in the forward end portion (813) of the sheath tube (810);
**characterized by**:

an alloy portion (860) located between the heat generation coil (820, 820a) and the forward end portion (813) of the sheath tube (810) and formed of an alloy of a metal used to form the sheath tube (810) and a metal used to form the heat generation coil (820, 820a) has a thickness of 10 $\mu$m or less; and by
a minimum thickness A of the side portion (814) of the sheath tube (810) as measured in a region along the axial direction (OD) where the heat generation coil (820, 820a) is disposed,
a distance B along the axial direction (OD) from a forward end (811) of the sheath tube (810) to a forward end (821, 821a) of the heat generation coil (820, 820a), and
a maximum thickness C of the forward end portion (813) of the sheath tube (810) along the axial direction (OD) satisfying the relational expressions:

$$B > A$$

and

$$C/A \leq 2.5.$$

2. A glow plug (10) according to claim 1, wherein the forward end portion (822) of the heat generation coil (820) is rectilinear.

3. A glow plug (10a) according to claim 1, wherein the forward end portion (822a) of the heat generation coil (820a) is spiral.

**Patentansprüche**

1. Glühkerze (10, 10a), umfassend:

ein Mantelrohr (810) mit einem Seitenabschnitt (814), der sich in einer axialen Richtung (OD) erstreckt, und einem vorderen Endabschnitt (813), der mit einem vorderen Ende des Seitenabschnitts (814) verbunden ist und das vordere Ende des Seitenabschnitts (814) verschließt, und
eine Wärmeerzeugungsspule (820, 820a), die in dem Mantelrohr (810) auf eine solche Weise angeordnet ist, dass sie sich in der axialen Richtung (OD) erstreckt, und deren vorderer Endabschnitt (822, 822a) mit dem vorderen Endabschnitt (813) des Mantelrohrs (810) verbunden ist,
wobei der vordere Endabschnitt (822, 822a) der Wärmeerzeugungsspule (820, 820a) von dem vorderen Endabschnitt (813) des Mantelrohrs (810) umgeben ist und darin eingebettet ist;
**gekennzeichnet dadurch, dass**:

ein Legierungsabschnitt (860), der sich zwischen der Wärmeerzeugungsspule (820, 820a) und dem vorderen Endabschnitt (813) des Mantelrohrs (810) befindet und aus einer Legierung eines Metalls, das verwendet wird, um das Mantelrohr (810) zu

bilden, und eines Metalls, das verwendet wird, um die Wärmeerzeugungsspule (820, 820a) zu bilden, gebildet ist, eine Dicke von 10 μm oder weniger aufweist; und durch
eine Mindestdicke A des Seitenabschnitts (814) des Mantelrohrs (810), gemessen in einem Bereich entlang der axialen Richtung (OD), in dem die Wärmeerzeugungsspule (820, 820a) angeordnet ist,
einen Abstand B entlang der axialen Richtung (OD) von einem vorderen Ende (811) des Mantelrohrs (810) zu einem vorderen Ende (821, 821a) der Wärmeerzeugungsspule (820, 820a) und
eine maximale Dicke C des vorderen Endabschnitts (813) des Mantelrohrs (810) entlang der axialen Richtung (OD), die die relationalen Ausdrücke erfüllen:

$$B > A$$

und

$$C/A \leq 2{,}5.$$

2. Glühkerze (10) nach Anspruch 1, wobei der vordere Endabschnitt (822) der Wärmeerzeugungsspule (820) geradlinig ist.

3. Glühkerze (10a) nach Anspruch 1, wobei der vordere Endabschnitt (822a) der Wärmeerzeugungsspule (820a) spiralförmig ist.

## Revendications

1. Bougie de préchauffage (10, 10a) comprenant :

un tube de gainage (810) comportant une partie latérale (814) s'étendant dans une direction axiale (OD) et une partie d'extrémité avant (813) reliée à une extrémité avant de la partie latérale (814) et refermant l'extrémité avant de la partie latérale (814), et
une bobine de génération de chaleur (820, 820a) disposée dans le tube de gainage (810) de manière à s'étendre dans la direction axiale (OD) et dont la partie d'extrémité avant (822, 822a) est reliée à la partie d'extrémité avant (813) du tube de gainage (810),
la partie d'extrémité avant (822, 822a) de la bobine de génération de chaleur (820, 820a) étant entourée par la partie d'extrémité avant (813) du tube de gainage (810) et incorporée dans celle-ci ;

**caractérisée par** :

une partie d'alliage (860) située entre la bobine de génération de chaleur (820, 820a) et la partie d'extrémité avant (813) du tube de gainage (810) et formée d'un alliage d'un métal utilisé pour former le tube de gainage (810) et un métal utilisé pour former la bobine de génération de chaleur (820, 820a) présente une épaisseur de 10 μm ou moins ; et par
une épaisseur minimale A de la partie latérale (814) du tube de gainage (810) telle que mesurée dans une région dans la direction axiale (OD) où la bobine de génération de chaleur (820, 820a) est disposée,
une distance B dans la direction axiale (OD) depuis une extrémité avant (811) du tube de gainage (810) vers une extrémité avant (821, 821a) de la bobine de génération de chaleur (820, 820a), et
une épaisseur maximale C de la partie d'extrémité avant (813) du tube de gainage (810) dans la direction axiale (OD) satisfaisant aux expressions de relation :

$$B > A$$

et

$$C/A \leq 2{,}5.$$

2. Bougie de préchauffage (10) selon la revendication 1, dans laquelle la partie d'extrémité avant (822) de la bobine de génération de chaleur (820) est rectiligne.

3. Bougie de préchauffage (10a) selon la revendication 1, dans laquelle la partie d'extrémité avant (822a) de la bobine de génération de chaleur (820a) est hélicoïdale.

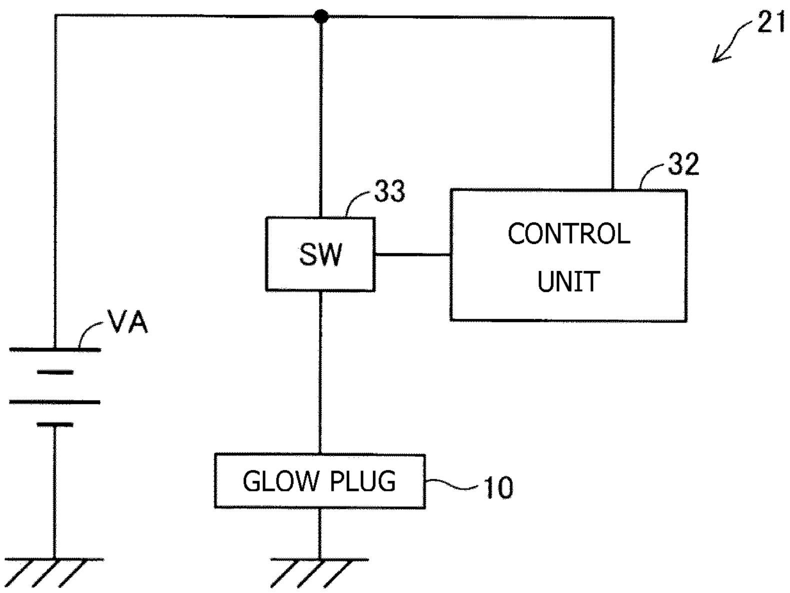


FIG. 1

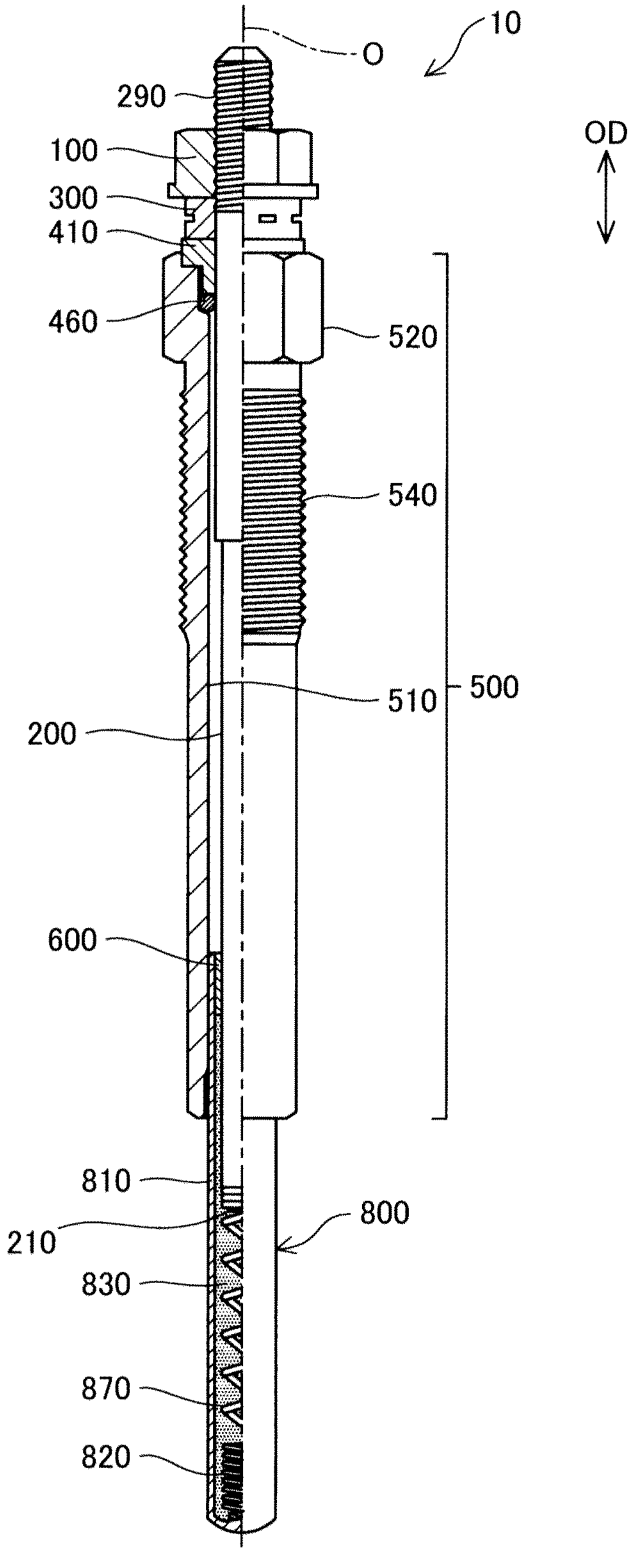
10
O
290
100
300
410
460
520
540
510
500
200
600
810
210
800
830
870
820
OD

FIG. 2

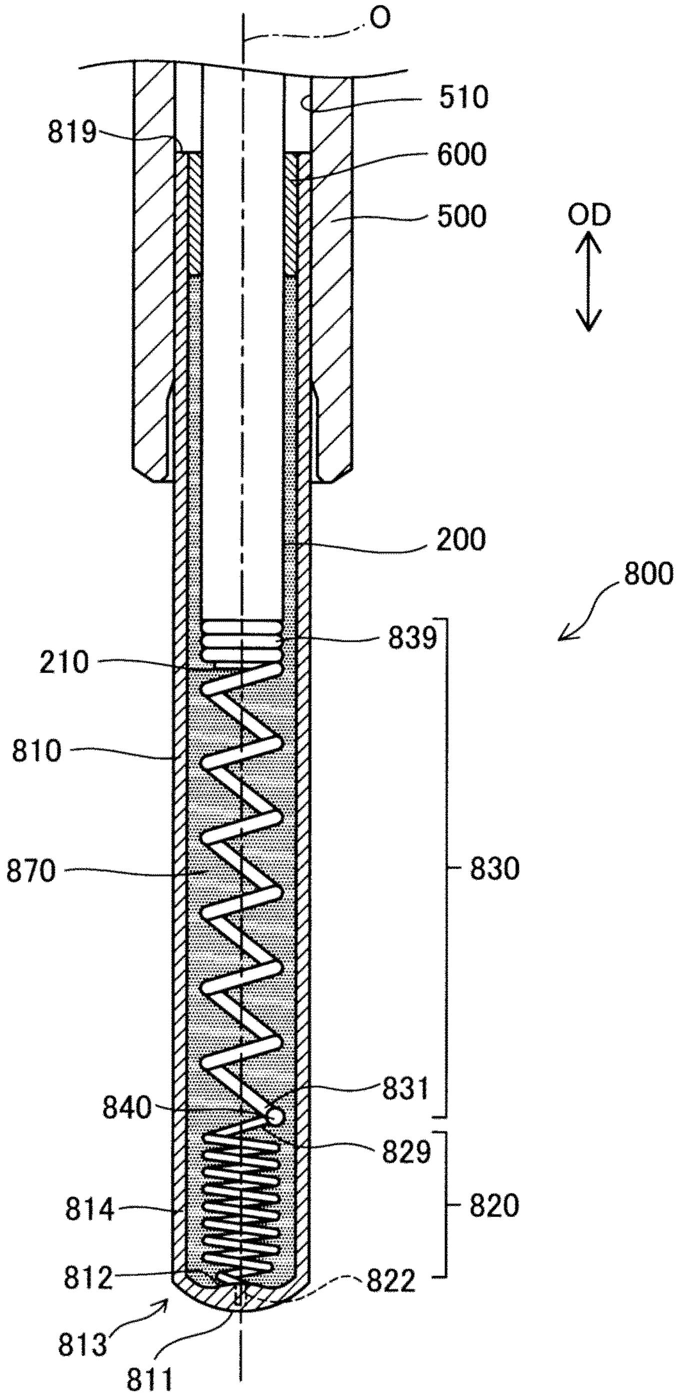
O
510
819
600
500
OD
200
800
839
210
810
870
830
831
840
829
814
820
812
822
813
811

FIG. 3

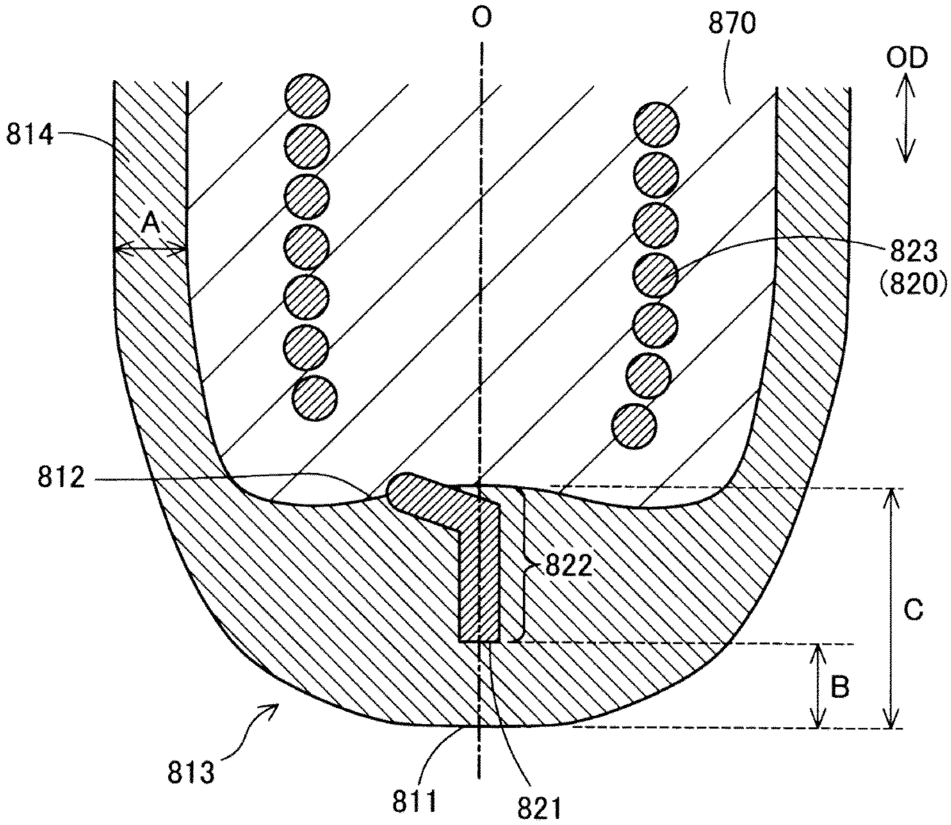


FIG. 4

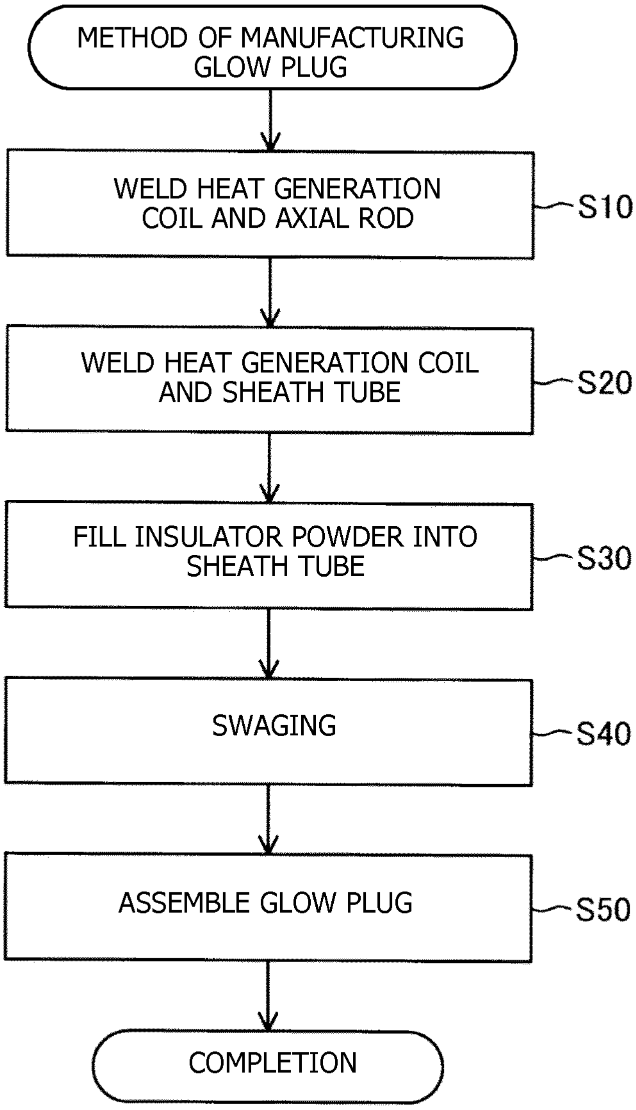
METHOD OF MANUFACTURING GLOW PLUG
WELD HEAT GENERATION COIL AND AXIAL ROD
S10
WELD HEAT GENERATION COIL AND SHEATH TUBE
S20
FILL INSULATOR POWDER INTO SHEATH TUBE
S30
SWAGING
S40
ASSEMBLE GLOW PLUG
S50
COMPLETION

FIG. 5

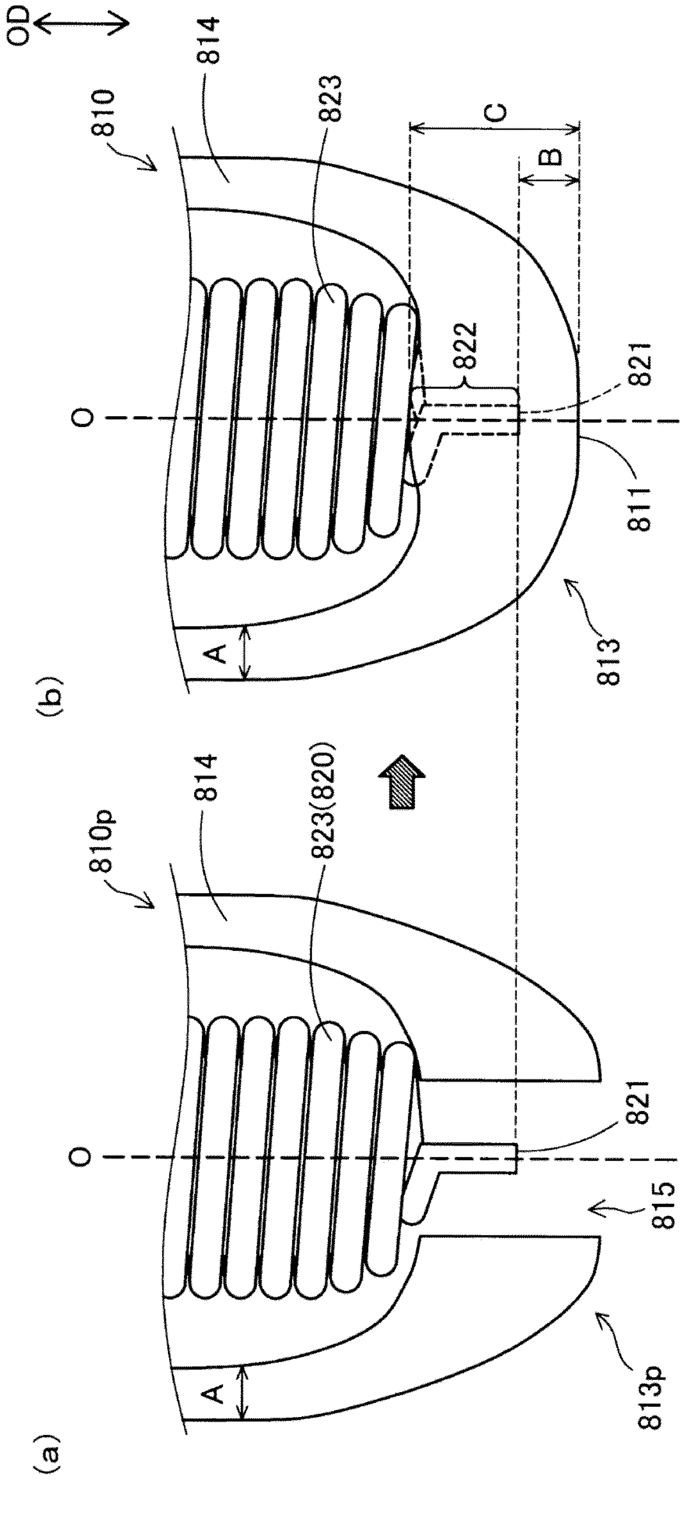
OD
810
814
823
C
B
822
O
821
811
813
A
(b)
810p
814
823(820)
821
815
813p
(a)

FIG. 6

| Sample | A (mm) | C (mm) | C/A | Judgment (rapid heat-up performance) |
|---|---|---|---|---|
| 1 | 0.41 | 0.74 | 1.8 | A |
| 2 | 0.41 | 0.78 | 1.9 | A |
| 3 | 0.41 | 0.80 | 2.0 | B |
| 4 | 0.41 | 0.92 | 2.2 | B |
| 5 | 0.41 | 0.95 | 2.3 | B |
| 6 | 0.41 | 1.04 | 2.5 | B |
| 7 | 0.41 | 1.05 | 2.6 | C |
| 8 | 0.41 | 1.20 | 2.9 | C |
| 9 | 0.41 | 1.40 | 3.4 | F |

FIG. 7

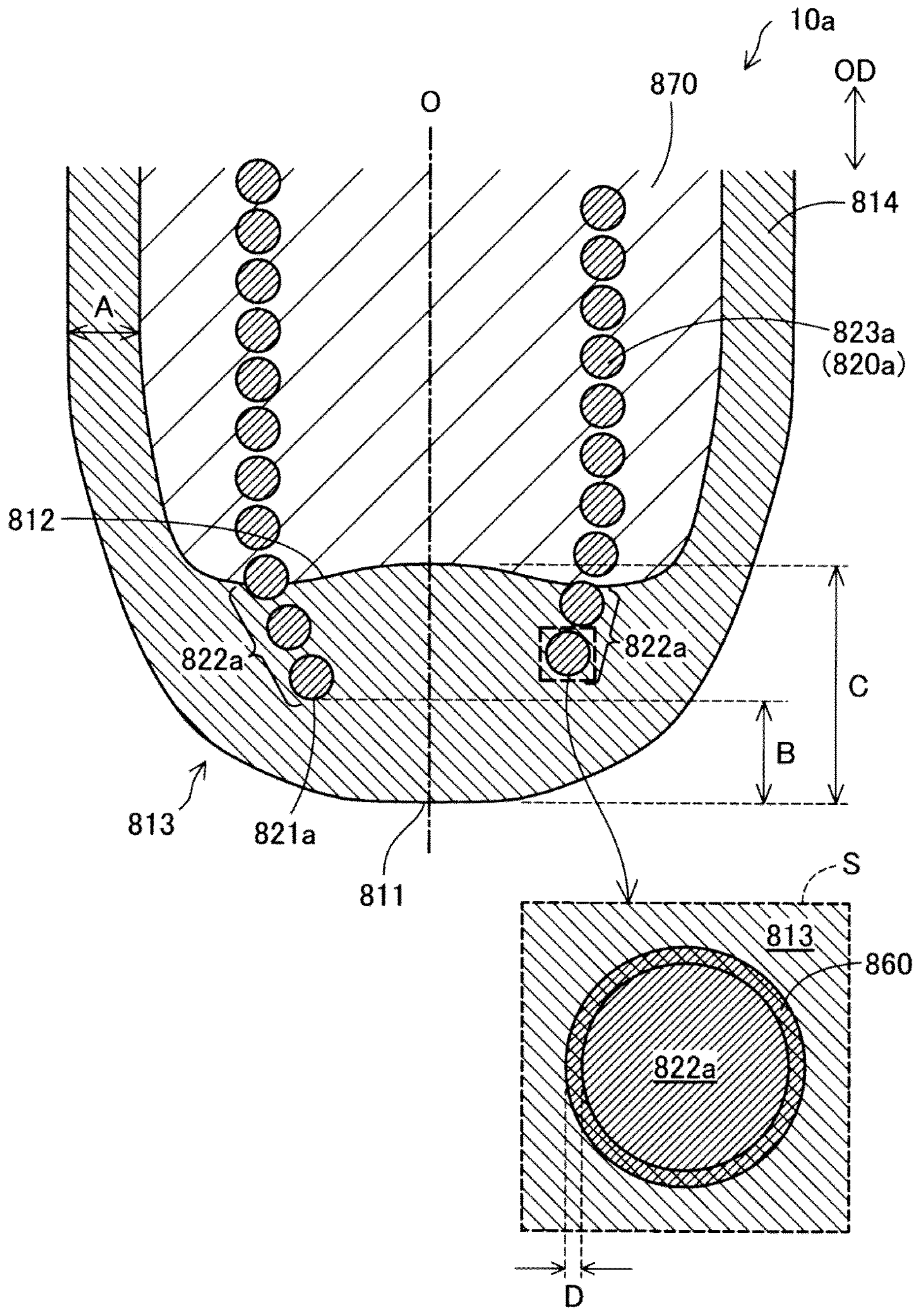
10a
OD
870
O
814
A
823a
(820a)
812
822a
822a
C
B
813
821a
811
S
813
860
822a
D

FIG. 8

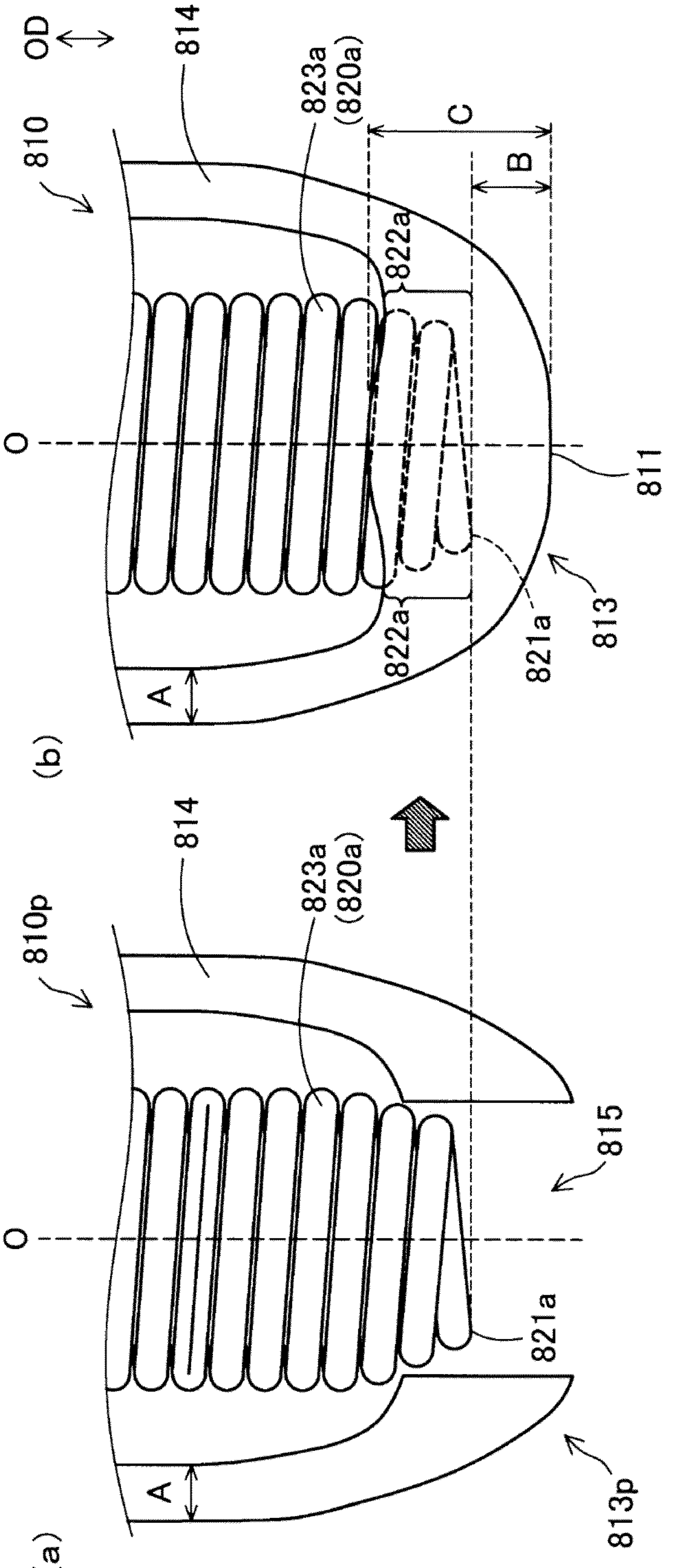
OD
810
814
823a
(820a)
C
B
822a
O
811
813
821a
822a
A
(b)
810p
814
823a
(820a)
815
O
821a
813p
A
(a)

FIG. 9

## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description

- WO 2014206847 A1 **[0002]**
- JP 2014137169 A **[0002]**
- US 5118921 A **[0003]**