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(54) **GLOW PLUG**

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a glow plug used as an auxiliary heat source of an internal combustion engine, such as a diesel engine.

2. Description of the Related Art

[0002] Glow plugs are used as auxiliary heat sources of compression ignition internal combustion engines, such as diesel engines. A typical glow plug includes a sheath tube having a tubular shape with a bottom including a closed front end portion and an open back end portion, and a heating coil that is disposed in the sheath tube and generates heat when electricity is applied thereto. A front end portion of the heating coil is joined to the front end portion of the sheath tube, and a back end portion of the heating coil is electrically connected to a center rod that extends toward the back end of the sheath tube. The heating coil generates heat when electricity is applied thereto through the center rod. The sheath tube is filled with insulating powder, such as magnesia powder, so that the outer peripheral surface of the heating coil and the inner peripheral surface of the sheath tube are insulated from each other.

[0003] The sheath tube of the glow plug is generally made of a conductive material that is highly resistant to heat and oxidation. In recent years, there has been a demand to increase the temperature in combustion chambers of internal combustion engines to reduce emissions and increase fuel efficiency, and accordingly, glow plugs operable in environments at higher temperatures have also been in demand. As the operation temperature increases, the oxidation reaction more easily progresses. Therefore, the sheath tube needs to be made of a material resistant to oxidation to delay the progress of the oxidation reaction. Accordingly, PTL 1 discloses a sheath tube made of an alloy containing Ni as the main component and predetermined amounts of Cr, Al, and Y.

Citation List

Patent Literature

[0004] PTL 1: Japanese Unexamined Patent Application Publication No. 2016-148506
Document JP 2015-078784A and document EP 2 863 126 A1 describe further glow plugs which comprise a sheath tube with a heating coil.

[0005] However, when the sheath tube is made of a specific material as described above, tensile stress is applied to a melted portion formed in a joining section between the sheath tube and the heating coil when the sheath tube and the heating coil are joined together, and there is a risk that cracks will be formed in the melted portion. More specifically, cracks may be formed in the melted portion so as to extend from surfaces (outer and inner surfaces) of the sheath tube to an inner region of the sheath tube. When the melted portion is formed in a heating process and is then cooled and solidified, heat is dissipated through the sheath tube. Accordingly, a section of the melted portion that is near the sheath tube is cooled and solidified first. As a result, tensile stress is applied to the central section of the melted portion that is not yet cooled and solidified, and cracks are formed accordingly. Such a crack allows entrance of air (oxygen) into the gap thereof, and leads to a reduction in the oxidation resistance.

SUMMARY OF THE INVENTION

[0006] The present invention has been made to solve the above-described problem of the related art, and its object is to provide a glow plug including a sheath tube whose resistance to oxidation can be maintained by reducing the occurrence of cracks in a melted portion of the sheath tube when the sheath tube is formed of a specific material.

[0007] A glow plug according to an aspect of the present invention extends along an axial line and includes a sheath tube and a heating coil. The sheath tube has a tubular shape with a closed front end, and is made of an alloy containing 50% or more by weight of nickel (Ni), 18 to 30% by weight of chromium (Cr), 1% or less by weight of aluminum (Al), and 0.01 to 0.3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr). The heating coil is disposed in the sheath tube and includes a front end portion connected to a front end portion of the sheath tube. The heating coil generates heat when electricity is applied thereto.

[0008] A main component of the heating coil is tungsten (W) or molybdenum (Mo). The front end portion of the heating coil is embedded in a melted portion provided in the front end portion of the sheath tube and is not exposed at an outer surface of the sheath tube. In a sectional view including the axial line, the melted portion satisfies $0.46 \leq a/b$, where a is a maximum value of a length of the melted portion in an axial line direction and b is a maximum value of a length of the melted portion in a direction perpendicular to the axial line direction.

[0009] According to the glow plug of this aspect, the heating coil contains tungsten (W) or molybdenum (Mo) as the main component, and the front end portion of the heating coil is embedded in the melted portion provided in the front end portion of the sheath tube. Since the heating coil is made of the specific material whose main component is tungsten or molybdenum, which have melting points higher than that of the specific material of the sheath tube, the heating coil is hardly melted when it is embedded in the melted portion formed in the sheath tube to join the sheath tube and the heating coil together. As a result, when the melted portion is cooled and solidified, heat can be dissipated through the heating coil, so that the central section of the melted portion is cooled and solidified and contracts in an early stage. Accordingly, the tensile stress applied to the central section of the melted portion can be distributed over the entirety of the melted portion.

[0010] In the glow plug according to this aspect, in the sectional view including the axial line, the melted portion satisfies $0.46 \leq a/b$, where a is the maximum value of the length of the melted portion in the axial line direction and b is the maximum value of the length of the melted portion in the direction perpendicular to the axial line direction. When the melted portion has such a specific shape, the tensile stress applied to the melted portion can be reduced. This effect cannot be obtained when the melted portion satisfies $a/b < 0.46$.

[0011] By embedding the heating coil made of the specific material in the melted portion having the specific shape, the tensile stress applied to the melted portion can be distributed over the entirety of the melted portion, and can also be reduced. Therefore, the occurrence of cracks in the melted portion of the sheath tube can be reduced. As a result, the oxidation resistance of the sheath tube can be maintained.

[0012] The front end portion of the heating coil is embedded in the melted portion and is not exposed at the outer surface of the sheath tube. Accordingly, even when the heating coil made of a material containing tungsten or molybdenum as the main component is directly embedded in the melted portion, oxidation of the heating coil can be suppressed.

[0013] In the glow plug according to the present invention, in the sectional view including the axial line, the melted portion preferably satisfies $a/b < 0.74$. In this case, the risk that the heating coil will be displaced backward away from the front end of the sheath tube due to an increase in the volume of the melted portion and that the maximum heating temperature position of the sheath tube will accordingly be displaced backward can be reduced. As a result, heat can be intensively generated in the front end section of the sheath tube.

[0014] In the glow plug according to the present invention, in the sectional view including the axial line, the melted portion preferably satisfies $0.54 \leq a/b \leq 0.66$. In this case, the oxidation resistance of the sheath tube can be more reliably maintained, and heat can be more intensively generated in the front end section of the sheath tube.

[0015] In the glow plug according to the present invention, the melted portion is preferably convex toward an inner region of the sheath tube. In this case, the front end portion of the heating coil can be embedded in the melted portion so as not to be exposed at the outer surface of the sheath tube, and the sheath tube and the heating coil can be strongly fixed together.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

- Fig. 1 is a half sectional view of a glow plug.
- Fig. 2 is a sectional view illustrating the detailed structure of a sheath heater.
- Fig. 3 is a sectional view of the region around a front end portion of a sheath tube.
- Fig. 4 is a flowchart of a method for manufacturing the glow plug.
- Figs. 5A and 5B illustrate a welding process performed in step S20.
- Fig. 6 is a sectional view of the region around a front end portion of a glow plug according to a modification.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Fig. 1 is a half sectional view of a glow plug 10. The glow plug 10 includes a sheath heater 800 and serves as a heat source that assists ignition at the start of an internal combustion engine, such as a diesel engine (not shown). The glow plug 10 mainly includes a center rod 200 and a metal shell 500 in addition to the sheath heater 800. These components of the glow plug 10 are assembled along the direction of an axial line O of the glow plug 10 (hereinafter referred to also as an axial line direction OD). In Fig. 1, the external structure is shown on the right side of the axial line O, and the cross-sectional structure is shown on the left side of the axial line O. In this specification, the end of the glow plug 10 at which the sheath heater 800 is provided is referred to as "front end", and the end of the glow plug 10 at which an engagement member 100 is provided is referred to as "back end".

[0018] The metal shell 500 is a tubular member formed of carbon steel. A front end portion of the metal shell 500 holds the sheath heater 800. A back end portion of the metal shell 500 holds the center rod 200 with an insulating member 410 and an O-ring 460 interposed therebetween. A ring 300, which is in contact with the back end of the insulating member 410, is crimped onto the center rod 200, so that the insulating member 410 is fixed to the metal shell 500. A portion of the center rod 200 that extends from the insulating member 410 to the sheath heater 800 is disposed in an axial hole 510 formed in the metal shell 500. The axial hole 510 is a through hole that extends along the axial line O, and has a diameter greater than that of the center rod 200. When the center rod 200 is positioned with respect to the axial hole 510, an air gap that electrically insulates the axial hole 510 and the center rod 200 from each other is provided between the axial hole 510 and the center rod 200. The sheath heater 800 is joined to a front end portion of the axial hole 510 by being press-fitted thereto. The metal shell 500 also includes a tool engagement portion 520 and an externally threaded portion 540. The tool engagement portion 520 of the metal shell 500 engages with a tool (not shown) used to attach and detach the glow plug 10. The externally threaded portion 540 is screwed into an internal thread formed in the internal combustion engine (not shown).

[0019] The center rod 200 is a columnar (rod-shaped) member made of a conductive material. The center rod 200 is inserted into the axial hole 510 in the metal shell 500 so as to extend in the axial line direction OD. The center rod 200 includes a front end portion 210 formed at the front end thereof and an externally threaded portion 290 provided at the back end thereof. The front end portion 210 is inserted in the sheath heater 800. The externally threaded portion 290 projects backward from the metal shell 500. The engagement member 100 is fastened to the externally threaded portion 290.

[0020] Fig. 2 is a sectional view illustrating the detailed structure of the sheath heater 800. The sheath heater 800 is press-fitted to the axial hole 510 in the metal shell 500 while the front end portion 210 of the center rod 200 is disposed in the sheath heater 800. The sheath heater 800 mainly includes a sheath tube 810, a heating coil 820, a back end coil 830, and an insulator 870.

[0021] The sheath tube 810 is a tubular member that extends in the axial line direction OD and has a closed front end. The sheath tube 810 contains the heating coil 820, the back end coil 830, and the insulator 870. The sheath tube 810 includes a side portion 814 that extends in the axial line direction OD, a front end portion 813 that is connected to the front end of the side portion 814 and that is outwardly rounded, and a back end portion 819 that opens at the end opposite the front end portion 813. The front end portion 210 of the center rod 200 is inserted into the sheath tube 810 through the back end portion 819. The sheath tube 810 is electrically insulated from the center rod 200 by a packing 600 and the insulator 870. The sheath tube 810 is in contact with and electrically connected to the metal shell 500.

[0022] The sheath tube 810 is made of a Ni-based alloy that contains 50% or more by weight of nickel (Ni). This alloy contains, as additives, 18 to 30% by weight of chromium (Cr); 1% or less by weight of aluminum (Al); and 0.01 to 0.3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr). The sheath tube 810 is formed of this alloy so that the sheath tube 810 of the glow plug 10 is resistant to oxidation in high temperature environments.

[0023] The alloy of the sheath tube 810 preferably contains 0.2 to 1.5% by weight of at least one component selected from silicon (Si), titanium (Ti), and manganese (Mn). The alloy preferably further contains 5 to 20% by weight of iron (Fe).

[0024] In the present embodiment, the sheath tube 810 is made of an alloy containing nickel (Ni) as the main component, 23% by weight of chromium (Cr), 0.5% by weight of aluminum (Al), 0.14% by weight of yttrium (Y), 0.9% by weight of silicon (Si), and 10% by weight of iron (Fe).

[0025] The insulator 870 is made of powder of an insulating material that is electrically insulative. For example, the insulator 870 may be made of magnesium oxide (MgO) powder. The insulator 870 fills (is disposed in) the gap formed in the sheath tube 810 when the center rod 200, the heating coil 820, and the back end coil 830 are disposed in sheath tube 810, and electrically insulates the gap.

[0026] The heating coil 820 is disposed in the sheath tube 810 so as to extend in the axial line direction OD, and generates heat when electricity is applied thereto. The heating coil 820 includes a front end portion 822 at the front end thereof, a back end portion 829 at the back end thereof, and a helical portion 823 that connects the front end portion 822 and the back end portion 829. The front end portion 822 is disposed in the front end portion 813 of the sheath tube 810, and is electrically connected to the sheath tube 810. The back end portion 829 is electrically connected to the back end coil 830 at a connecting portion 840 formed by welding the heating coil 820 and the back end coil 830 together.

[0027] The heating coil 820 contains tungsten (W) or molybdenum (Mo) as the main component thereof. The main component is a material whose content (% by weight) is 50% or more by weight. In the present embodiment, the heating coil 820 contains 99% or more by weight of tungsten (W).

[0028] The back end coil 830 includes a front end portion 831 at the front end thereof, and a back end portion 839 at the back end thereof. The front end portion 831 is electrically connected to the heating coil 820 by being welded to the back end portion 829 of the heating coil 820. The back end portion 839 is electrically connected to the center rod 200 by being joined to the front end portion 210 of the center rod 200. The back end coil 830 is made of, for example, a nickel-chromium (Ni-Cr) alloy or an iron-chromium-aluminum (Fe-Cr-Al) alloy.

[0029] Fig. 3 is a sectional view of the region around the front end portion 813 of the sheath tube 810. The sectional view of Fig. 3 shows a cross section of the sheath heater 800 taken along the axial line O, and illustrates the helical portion 823 and the front end portion 822 of the heating coil 820, the sheath tube 810, and the insulator 870 sectioned along the axial line O. In the present embodiment, the front end portion 822 of the heating coil 820 linearly extends along the axial line O. As illustrated in Fig. 3, the front end portion 822 of the heating coil 820 is located between a front end 811 of the sheath tube 810 and a front inner wall surface 812 of the sheath tube 810. The front end portion 822 of the heating coil 820 is embedded in a melted portion 816 provided in the front end portion 813 of the sheath tube 810. A front end 821 of the front end portion 822 of the heating coil 820 is disposed in the melted portion 816 and is not exposed at the outer surface of the front end portion 813 of the sheath tube 810 (outer surface of the melted portion 816). In the present embodiment, the melted portion 816 has a substantially elliptical shape that is convex toward the front end and toward the back end (toward the inner region of the sheath tube 810). The shape of the melted portion 816 is not limited to an elliptical shape.

[0030] As described above, the sheath tube 810 is made of a Ni-based alloy containing nickel (Ni) as the main component, and the heating coil 820 is made of a metal containing tungsten (W) or molybdenum (Mo) as the main component. Accordingly, the material of the sheath tube 810 (metal containing nickel (Ni) as the main component) has a melting point of about 1400°C, and the material of the heating coil 820 (metal containing tungsten (W) as the main component) has a melting point of 3000°C or higher. Thus, there is a large difference between the melting points of the materials. Therefore, when the heating coil 820 and the sheath tube 810 are welded together, the heating coil 820 is hardly melted, and only the sheath tube 810 is melted. Thus, the melted portion 816 in which the front end portion 822 of the heating coil 820 is embedded is formed.

[0031] Even if the heating coil 820 is somewhat melted, the thickness of an alloy portion made of an alloy of the metal of the sheath tube 810 and the metal of the heating coil 820 is smaller than or equal to 10 (μm). The alloy portion can be detected and the thickness thereof can be calculated by analyzing the region around the boundary between the front end portion 822 of the heating coil 820 and the front end portion 813 of the sheath tube 810 with, for example, an electron probe micro analyzer (EPMA). The alloy portion is not formed in the glow plug 10 according to the present embodiment, and is therefore not illustrated in Fig. 3.

[0032] Fig. 3 also illustrates lengths a and b. The length a is the maximum length of the melted portion 816 in the axial line direction OD (maximum value of the length in the vertical direction in Fig. 3). The length b is the maximum length of the melted portion 816 in a direction perpendicular to the axial line direction OD (maximum value of the length in the horizontal direction in Fig. 3). In the present embodiment, the melted portion 816 satisfies $0.46 \leq a/b$ (more specifically, $a/b = 0.60$).

[0033] In the glow plug 10 of the present embodiment having the above-described structure, the heating coil 820 contains tungsten (W) or molybdenum (Mo) as the main component, and the front end portion 822 of the heating coil 820 is embedded in the melted portion 816 provided in the front end portion 813 of the sheath tube 810. Since the heating coil 820 is made of the specific material whose main component is tungsten or molybdenum, which have melting points higher than that of the specific material of the sheath tube 810, the heating coil 820 is hardly melted when it is embedded in the melted portion 816 formed in the sheath tube 810 to join the sheath tube 810 and the heating coil 820 together. As a result, when the melted portion 816 is cooled and solidified, heat can be dissipated through the heating coil 820, so that the central section of the melted portion 816 is cooled and solidified and contracts in an early stage. Accordingly, the tensile stress applied to the central section of the melted portion 816 can be distributed over the entirety of the melted portion 816.

[0034] In addition, in the sectional view of the glow plug 10 according to the present embodiment including the axial line O, the melted portion 816 satisfies $0.46 \leq a/b$, where a is the maximum value of the length of the melted portion 816 in the axial line direction OD and b is the maximum value of the length of the melted portion 816 in the direction perpendicular to the axial line direction OD. When the melted portion 816 has such a specific shape, the tensile stress applied to the melted portion 816 can be reduced.

[0035] By embedding the heating coil 820 made of the specific material in the melted portion 816 having the specific shape, the tensile stress applied to the melted portion 816 can be distributed over the entirety of the melted portion 816, and can also be reduced. Therefore, the occurrence of cracks in the melted portion 816 of the sheath tube 810 can be reduced. As a result, the oxidation resistance of the sheath tube 810 can be maintained.

[0036] The front end portion 822 of the heating coil 820 is embedded in the melted portion 816 and is not exposed at the outer surface of the sheath tube. Accordingly, even when the heating coil 820 made of a material containing tungsten or molybdenum as the main component is directly embedded in the melted portion 816, oxidation of the heating coil 820 can be suppressed.

[0037] In the sectional view of the glow plug 10 according to the present embodiment including the axial line, the melted portion 816 satisfies $a/b < 0.74$. In this case, the risk that the heating coil 820 will be displaced backward away from the front end 811 of the sheath tube 810 due to an increase in the volume of the melted portion 816 and that the maximum heating temperature position of the sheath tube 810 will accordingly be displaced backward can be reduced. As a result, heat can be intensively generated in the front end section of the sheath tube 810.

[0038] In the sectional view of the glow plug 10 according to the present embodiment including the axial line, the melted portion 816 satisfies $0.54 \leq a/b \leq 0.66$. In this case, the oxidation resistance of the sheath tube 810 can be more reliably maintained, and heat can be more intensively generated in the front end section of the sheath tube 810.

[0039] The melted portion 816 of the glow plug 10 according to the present embodiment is preferably convex toward the inner region of the sheath tube 810. In this case, the front end portion 822 of the heating coil 820 can be embedded in the melted portion 816 so as not to be exposed at the outer surface of the sheath tube 810, and the sheath tube 810 and the heating coil 820 can be strongly fixed together.

[0040] A method for manufacturing the glow plug 10 will now be described. Fig. 4 is a flowchart of the method for manufacturing the glow plug 10. According to the method for manufacturing the glow plug 10, first, the heating coil 820, the back end coil 830, and the center rod 200 are welded together (step S10). More specifically, the heating coil 820 and the back end coil 830 are welded together, and the back end portion 839 of the back end coil 830 and the front end portion 210 of the center rod 200 are welded together.

[0041] Next, the front end portion 822 of the heating coil 820 and the front end portion 813 of the sheath tube 810 are welded together (step S20). Figs. 5A and 5B illustrate the welding process performed in step S20. To facilitate description of the welding process, Figs. 5A and 5B illustrate the heating coil 820 in perspective and the sheath tube 810 (810p) in cross section. In this process, first, a sheath tube 810p that includes a front end portion 813p having an opening 815 and whose diameter decreases toward the opening 815 is prepared. The front end portion 822 of the heating coil 820, to which the center rod 200, for example, is joined, is inserted into the front end portion 813p (into the opening 815) of the prepared sheath tube 810p, as illustrated in Fig. 5A. Next, the opening 815 is closed by melting and solidifying the front end portion 813p. The front end portion 813p is externally melted by, for example, arc welding. Thus, the front end portion 822 of the heating coil 820 and the sheath tube 810 are welded together while the front end portion 822 of the heating coil 820 is embedded in the melted portion 816 provided in the front end portion 813 of the sheath tube 810, as illustrated in Fig. 5B. In other words, the front end portion 822 of the heating coil 820 is embedded in the melted portion 816 of the sheath tube 810.

[0042] In the welding process, the output of the welding device, welding time, etc., are adjusted so that the heating coil 820 and the sheath tube 810 are welded together at a temperature lower than the melting point of the heating coil 820 and higher than the melting point of the sheath tube 810 (tubular sheath tube 810p). Accordingly, the heating coil 820 and the sheath tube 810 are welded together while the heating coil 820 is hardly melted and the tubular sheath tube 810p is melted. Even if the heating coil 820 is melted, the thickness of the alloy portion containing the metal of the heating coil 820 and the metal of the sheath tube 810 is preferably 10 (μm) or less. The heating coil 820 and the sheath tube 810 are not necessarily welded together by arc welding, and may instead be welded together by, for example, laser welding. In the case where laser welding is performed, preferably, the welding temperature is reduced and the melting area is increased.

[0043] After the welding process of step S20 is completed, the sheath tube 810 is filled with the insulator 870 (step S30). When the gap formed in the sheath tube 810 containing the heating coil 820, the back end coil 830, and the center rod 200 is filled with the insulator 870, the assembly of the sheath heater 800 is completed.

[0044] After the sheath heater 800 is assembled, the sheath heater 800 is subjected to swaging (step S40). Swaging is a process in which striking force is applied to the sheath heater 800 to reduce the diameter of the sheath heater 800 and densify the insulator 870 with which the sheath tube 810 is filled. When the striking force is applied to the sheath heater 800 during swaging, the striking force is transmitted to the inner region of the sheath heater 800, and the insulator 870 is densified.

[0045] After the sheath heater 800 is subjected to swaging, the glow plug 10 is assembled by attaching the sheath heater 800 and the metal shell 500 together (step S50). Thus, the glow plug 10 is completed. More specifically, the sheath heater 800, with which the center rod 200 is integrated, is press-fitted into the axial hole 510 in the metal shell 500 so that the sheath heater 800 is fixed. Also, the O-ring 460 and the insulating member 410 are fitted to the center rod 200 in the back end section of the metal shell 500, and the engagement member 100 is fastened to the externally threaded portion 290 of the center rod 200 that is provided behind the metal shell 500.

[0046] The relationship between the shape of the melted portion 816 of the glow plug 10 and oxidation resistance was evaluated. Ten samples of glow plugs were prepared by the above-described manufacturing method for each of Test Examples 1 to 9, which have structures similar to that of the glow plug 10. For each test example, the sheath tube 810 and the heating coil 820 were welded together while adjusting the output of the welding device and the welding time so that the lengths a and b of the melted portion 816 satisfied the relationship shown in Table 1. The sheath tube 810 contained nickel (Ni) as the main component, and also contained 23% by weight of chromium (Cr), 0.5% by weight of aluminum (Al), 0.14% by weight of yttrium (Y), 0.9% by weight of silicon (Si), and 10% by weight of iron (Fe). The thickness of the side portion 814 of the sheath tube 810 was 0.60 mm, and the thickness of the front end portion 813 of the sheath tube 810 was 1.24 mm. The heating coil 820 contained 99% or more by weight of tungsten (W), and had a wire diameter of 0.27 mm. The linear length of the front end portion 822 of the heating coil 820 was 0.44 mm.

[0047] The samples of each of the test examples prepared as described above were observed to determine whether cracks were formed in the melted portion 816. More specifically, the front end 811 of the sheath tube 810 was ground in a direction perpendicular to the axial line direction OD, and a ground surface was exposed at every predetermined distance from the front end 811 of the sheath tube 810 in the axial line direction OD. Then, it was determined whether or not cracks were formed in each ground surface of the melted portion 816 by visual observation. Test examples for which no cracks were found in any ground surface of any of the ten samples were rated "Good". Test examples for which one or more of the samples had cracks in any of the ground surfaces were rated "Poor" or "Fair". More specifically, assuming that cracks formed in the ground surfaces at the same position were connected in the axial line direction, test samples having a crack longer than "(thickness of the front end portion 813 - thickness of the side portion 814)/3" in the axial line direction were rated "Poor". Test samples in which all of the cracks were shorter than or equal to "(thickness of the front end portion 813 - thickness of the side portion 814)/3" in the axial line direction were rated "Fair". Table 1 shows the result of the evaluation.

[0048] Each of the above-described test examples was also evaluated for durability. More specifically, a cycle test described below was performed for 500 hours for each test example. After the cycle test, it was determined whether or not a through hole that extended through the sheath tube 810 was formed in the melted portion 816 of the sheath tube 810 for each test example. The cycle test was a test in which "a voltage was applied to the glow plug 10 so that the temperature increased to 1000°C in 2 seconds after the start of application of the voltage, and subsequently the temperature was maintained at 1100°C for 180 seconds and then returned to normal temperature by blowing cold air against the glow plug 10 for 120 seconds". The temperature was measured by a radiation thermometer at a location 2 mm away from the front end 811 of the sheath tube 810. Test examples in which no through holes were formed in the melted portion 816 of the sheath tube 810 were rated "Good", and test examples in which through holes were formed in the melted portion 816 of the sheath tube 810 were rated "Poor". Table 1 shows the result of the evaluation.

Table 1

Test Example	a/b	Crack	Durability
1	0.74	Good	Good
2	0.73	Good	Good
3	0.67	Good	Good
4	0.66	Good	Good
5	0.54	Good	Good
6	0.53	Fair	Good
7	0.46	Fair	Good
8	0.45	Poor	Poor
9	0.40	Poor	Poor

[0049] Table 1 shows that in Test Examples 1 to 7, in which the melted portion 816 satisfied $0.46 \leq a/b$, the occurrence of cracks in the melted portion 816 was suppressed, and therefore the samples were highly durable. In contrast, in Test Examples 8 and 9, in which the melted portion 816 satisfied $a/b < 0.46$, cracks were formed in the melted portion 816, and as a result, the samples were not sufficiently durable. In Test Examples 1 to 5, in which the melted portion 816 satisfied $0.54 \leq a/b$, no cracks were formed in the melted portion 816 at all.

[0050] The relationship between the shape of the melted portion 816 of the glow plug 10 and intense heat generation at the front end section of the sheath tube 810 was also evaluated. More specifically, a voltage of 11 V was applied to the glow plug 10 of each of the above-described test examples. The temperature at the front end section of the sheath tube 810 was measured with a radiation thermometer, and the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position, at which the temperature measured by the radiation thermometer was at a maximum, was determined. Test examples in which the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was less than or equal to 3 mm were rated "Good". Test examples in which the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was more than 3 mm and was less than or equal to 5 mm were rated "Fair". Test examples in which the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was more than 5 mm were rated "Poor". Table 2 shows the result of the evaluation.

Table 2

Test Example	a/b	Heat Generation at Front End
1	0.74	Poor
2	0.73	Fair
3	0.67	Fair
4	0.66	Good
5	0.54	Good
6	0.53	Good
7	0.46	Good
8	0.45	Good
9	0.40	Good

[0051] Table 2 shows that in Test Examples 2 to 9, in which the melted portion 816 satisfied $a/b < 0.74$, the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was less than or equal to 5 mm. In Test Example 1, in which the melted portion 816 satisfied $0.74 \leq a/b$, the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was more than 5 mm, and heat was generated at a position further toward the back end of the sheath tube. In Test Examples 4 to 9, in which the melted portion 816 satisfied $a/b \leq 0.66$, the distance from the front end 811 of the sheath tube 810 to the maximum heating temperature position was less than or equal to 3 mm.

[0052] The present invention is not limited to the embodiment and examples described in this specification, and may be implemented in various configurations.

[0053] Although the front end portion 822 of the heating coil 820 embedded in the melted portion 816 of the sheath tube 810 has a linear shape in the present embodiment, the front end portion 822 is not limited to this. Fig. 6 is a sectional view of the region around a front end portion of a glow plug 10a according to a modification. The sectional view of Fig. 6 shows a cross section of the sheath heater 800 taken along the axial line O, and illustrates a helical portion 823a and a front end portion 822a of a heating coil 820a, the sheath tube 810, and the insulator 870 sectioned along the axial line O.

[0054] In this modification, the front end portion 822a of the heating coil 820a has a helical shape. As illustrated in Fig. 6, the front end portion 822a of the heating coil 820a is located between the front end 811 of the sheath tube 810 and the front inner wall surface 812 of the sheath tube 810. The front end portion 822a of the heating coil 820a is embedded in the melted portion 816 provided in the front end portion 813 of the sheath tube 810. A front end 821a of the front end portion 822a of the heating coil 820a is disposed in the melted portion 816 and is not exposed at the outer surface of the front end portion 813 of the sheath tube 810 (outer surface of the melted portion 816).

[0055] Also in this modification, when the heating coil 820a and the sheath tube 810 are welded together, the heating coil 820a is hardly melted, and only the sheath tube 810 is melted. Thus, the melted portion 816 in which the front end portion 822a of the heating coil 820a is embedded is formed.

[0056] Also in the glow plug 10a according to the modification having the above-described structure, the heating coil 820a contains tungsten (W) or molybdenum (Mo) as the main component, and the front end portion 822a of the heating coil 820a is embedded in the melted portion 816 provided in the front end portion 813 of the sheath tube 810. As a result, when the melted portion 816 is cooled and solidified, heat can be dissipated through the heating coil 820a, so that the central section of the melted portion 816 is cooled and solidified and contracts in an early stage. Accordingly, the tensile stress applied to the central section of the melted portion 816 can be distributed over the entirety of the melted portion 816.

[0057] In addition, in the cross section of the glow plug 10a according to the modification including the axial line O, the melted portion 816 satisfies $0.46 \leq a/b$, where a is the maximum value of the length of the melted portion 816 in the axial line direction OD and b is the maximum value of the length of the melted portion 816 in the direction perpendicular to the axial line direction OD. When the melted portion 816 has such a specific shape, the tensile stress applied to the melted portion 816 can be reduced.

[0058] By embedding the heating coil 820a made of the specific material in the melted portion 816 having the specific shape, the tensile stress applied to the melted portion 816 can be distributed over the entirety of the melted portion 816, and can also be reduced. Therefore, the occurrence of cracks in the melted portion 816 of the sheath tube 810 can be reduced. As a result, the oxidation resistance of the sheath tube 810 can be maintained.

[0059] Although the front end portion 822 of the heating coil 820 linearly extends along the axial line O in the present embodiment, the front end portion 822 is not limited to this. For example, the front end portion 822 having a linear shape may be displaced from the axial line O or arranged to intersect the axial line O.

[0060] Furthermore, although the heating coil 820 and the back end coil 830 are provided in the present embodiment, the present invention is not limited to this. For example, the glow plug 10 may include a single coil, and the back end portion 829 of the heating coil 820 may be directly connected to the front end portion 210 of the center rod 200. Also, the back end coil 830 of the glow plug 10 may be obtained by connecting a plurality of coils.

[0061] In one embodiment, the alloy of the sheath tube 810 is a nickel-based alloy that comprises, preferably consists of, 18 to 30% by weight of chromium (Cr); 1% or less by weight of aluminium (Al); 0.01 to 3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr), with the balance being nickel (Ni). Preferably, such an alloy contains 50% or more by weight of nickel.

[0062] In another embodiment, the alloy of the sheath tube 810 is a nickel-based alloy that comprises, preferably consists of, 18 to 30% by weight of chromium (Cr); 1% or less by weight of aluminium (Al); 0.01 to 3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr); 0.2 to 1.5% by weight of at least one component selected from silicon (Si), titanium (Ti) and manganese (Mn), with the balance being nickel (Ni). Preferably, such an alloy contains 50% or more by weight of nickel.

[0063] In a further embodiment, the alloy of the sheath tube 810 is a nickel-based alloy that comprises, preferably consists of, 18 to 30% by weight of chromium (Cr); 1% or less by weight of aluminium (Al); 0.01 to 3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr); 0.2 to 1.5% by weight of at least one component selected from silicon (Si), titanium (Ti) and manganese (Mn); 5 to 20% by weight of iron (Fe), with the balance being nickel (Ni). Preferably, such an alloy contains 50% or more by weight of nickel.

[0064] In one embodiment, the alloy of the sheath tube 810 is a nickel-based alloy that consists of 18 to 30% by weight of chromium (Cr); 1% or less by weight of aluminium (Al); 0.01 to 3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr); optionally, 0.2 to 1.5% by weight of at least one component selected from silicon (Si), titanium (Ti) and manganese (Mn); further optionally 5 to 20% by weight of iron (Fe), with the balance being nickel (Ni) and unavoidable impurities. Such an alloy contains 50% or more by weight of nickel.

[0065] In one embodiment, the heating coil 820 comprises 90% or more by weight of tungsten (W) or molybdenum (Mo). In another embodiment, the heating coil 820 comprises 95% or more by weight of tungsten (W) or molybdenum (Mo). In a further embodiment, the heating coil 820 comprises 99% or more by weight of tungsten (W) or molybdenum (Mo).

[0066] In one embodiment, the heating coil 820 comprises 99% or more by weight of tungsten (W). In one embodiment the heating coil 820 comprises 99% or more by weight of molybdenum (Mo).

Claims

1. A glow plug (10, 10a) that extends along an axial line, comprising:

   a sheath tube (810) having a tubular shape with a closed front end and made of an alloy containing 50% or more by weight of nickel (Ni), 18 to 30% by weight of chromium (Cr), 1% or less by weight of aluminum (Al), and 0.01 to 0.3% by weight of at least one component selected from yttrium (Y) and zirconium (Zr); and
   a heating coil (820, 820a) disposed in the sheath tube (810) and including a front end portion connected to a front end portion (813) of the sheath tube (810), the heating coil (820, 820a) generating heat when electricity is applied thereto,
   wherein a main component of the heating coil (820, 820a) is tungsten (W) or molybdenum (Mo),
   wherein the front end portion (822, 822a) of the heating coil (820, 820a) is embedded in a melted portion (816) provided in the front end portion (813) of the sheath tube (810) and is not exposed at an outer surface of the sheath tube (810), and
   wherein, in a sectional view including the axial line, the melted portion (816) satisfies $0.46 \leq a/b$, where a is a maximum value of a length of the melted portion (816) in an axial line direction and b is a maximum value of a length of the melted portion (816) in a direction perpendicular to the axial line direction.

2. The glow plug (10, 10a) according to Claim 1, wherein, in the sectional view including the axial line, the melted portion (816) satisfies $a/b < 0.74$.

3. The glow plug (10, 10a) according to Claim 1 or 2, wherein, in the sectional view including the axial line, the melted portion (816) satisfies $0.54 \leq a/b \leq 0.66$.

4. The glow plug (10, 10a) according to any one of Claims 1 to 3, wherein the melted portion (816) is convex toward an inner region of the sheath tube (810).

Patentansprüche

1. Glühkerze (10, 10a), die sich entlang einer axialen Linie erstreckt, umfassend:

   ein Mantelrohr (810), das eine rohrförmige Form mit einem geschlossenen vorderen Ende aufweist und aus einer Legierung besteht, die 50 Gew.-% oder mehr Nickel (Ni), 18 bis 30 Gew.-% Chrom (Cr), 1 Gew.-% oder weniger Aluminium (Al) und 0,01 bis 0,3 Gew.-% mindestens einer Komponente, ausgewählt aus Yttrium (Y) und Zirconium (Zr), enthält; und
   eine Heizwendel (820, 820a), die in dem Mantelrohr (810) angeordnet ist und einen vorderen Endabschnitt beinhaltet, der mit einem vorderen Endabschnitt (813) des Mantelrohrs (810) verbunden ist, wobei die Heizwendel (820, 820a) Wärme erzeugt, wenn Elektrizität darauf angelegt wird,
   wobei eine Hauptkomponente der Heizwendel (820, 820a) Wolfram (W) oder Molybdän (Mo) ist,
   wobei der vordere Endabschnitt (822, 822a) der Heizwendel (820, 820a) in einem geschmolzenen Abschnitt (816) eingebettet ist, der in dem vorderen Endabschnitt (813) des Mantelrohrs (810) bereitgestellt ist, und nicht an einer Außenfläche des Mantelrohrs (810) freiliegend ist, und
   wobei in einer die axiale Linie enthaltenden Schnittansicht der geschmolzene Abschnitt (816) $0,46 \leq a/b$ erfüllt, wo a ein maximaler Wert einer Länge des geschmolzenen Abschnitts (816) in einer axialen Linienrichtung ist und b ein maximaler Wert einer Länge des geschmolzenen Abschnitts (816) in einer Richtung senkrecht zu der axialen Linienrichtung ist.

2. Glühkerze (10, 10a) nach Anspruch 1, wobei in der die axiale Linie enthaltenden Schnittansicht der geschmolzene Abschnitt (816) $a/b < 0,74$ erfüllt.

3. Glühkerze (10, 10a) nach Anspruch 1 oder 2, wobei in der die axiale Linie enthaltenden Schnittansicht der geschmolzene Abschnitt (816) $0,54 \leq a/b \leq 0,66$ erfüllt.

4. Glühkerze (10, 10a) nach einem der Ansprüche 1 bis 3, wobei der geschmolzene Abschnitt (816) zu einem Innenbereich des Mantelrohrs (810) hin konvex ist.

Revendications

1. Bougie de préchauffage (10, 10a) qui s’étend le long d’une ligne axiale, comprenant :

   un tube de gaine (810) présentant une forme tubulaire avec une extrémité avant fermée et fait d’un alliage contenant 50 % ou plus en poids de nickel (Ni), 18 à 30 % en poids de chrome (Cr), 1 % ou moins en poids d’aluminium (Al), et 0,01 à 0,3 % en poids d’au moins un composant sélectionné parmi : yttrium (Y) et zirconium (Zr) ; et
   une bobine chauffante (820, 820a) disposée dans le tube de gaine (810) et incluant une portion d’extrémité avant connectée à une portion d’extrémité avant (813) du tube de gaine (810), la bobine chauffante (820, 820a) générant de la chaleur lorsque de l’électricité est appliquée sur celle-ci,
   dans laquelle un composant principal de la bobine chauffante (820, 820a) est : tungstène (W) ou molybdène (Mo),
   dans laquelle la portion d’extrémité avant (822, 822a) de la bobine chauffante (820, 820a) est incorporée dans une portion fondue (816) prévue dans la portion d’extrémité avant (813) du tube de gaine (810) et n’est pas exposée au niveau d’une surface extérieure du tube de gaine (810), et
   dans laquelle, en vue en coupe incluant la ligne axiale, la portion fondue (816) satisfait à $0,46 \leq a/b$, où a est une valeur maximum d’une longueur de la portion fondue (816) dans une direction de ligne axiale et b est une valeur maximum d’une longueur de la portion fondue (816) dans une direction perpendiculaire à la direction de ligne axiale.

2. Bougie de préchauffage (10, 10a) selon la revendication 1, dans laquelle, en vue en coupe incluant la ligne axiale, la portion fondue (816) satisfait à $a/b < 0,74$.

3. Bougie de préchauffage (10, 10a) selon la revendication 1 ou 2, dans laquelle, en vue en coupe incluant la ligne axiale, la portion fondue (816) satisfait à $0,54 \leq a/b \leq 0,66$.

4. Bougie de préchauffage (10, 10a) selon l’une quelconque des revendications 1 à 3, dans laquelle la portion fondue (816) est convexe vers une région intérieure du tube de gaine (810).

FIG. 1

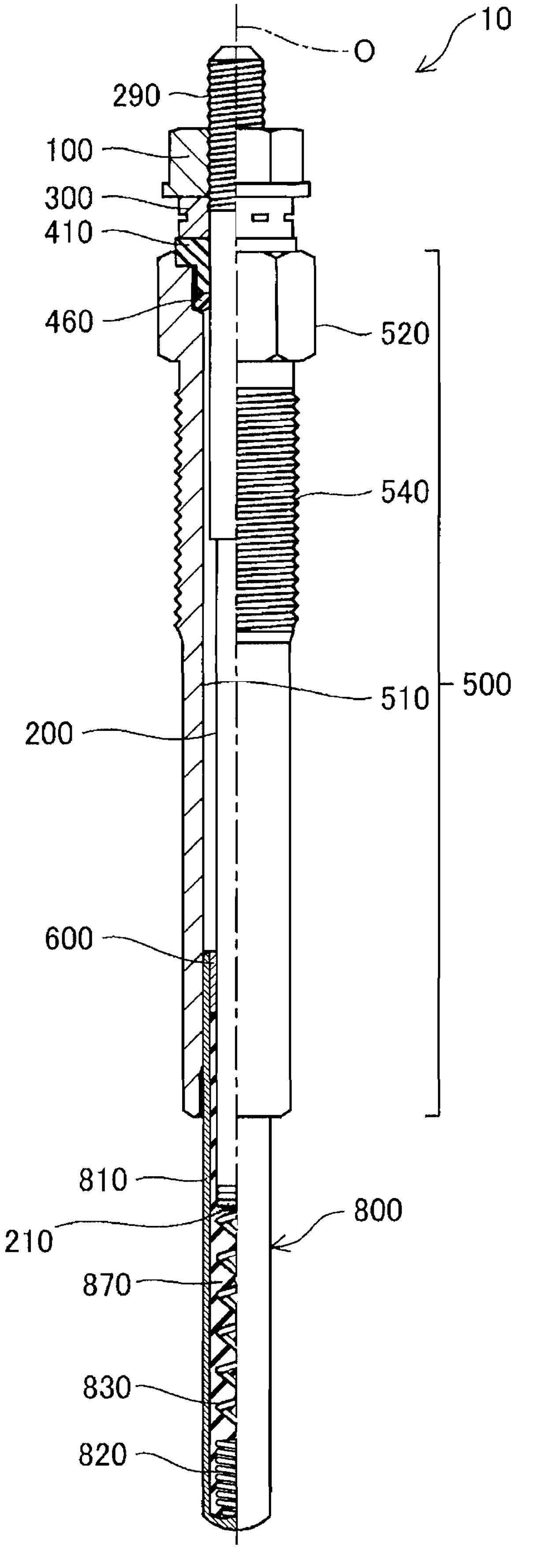
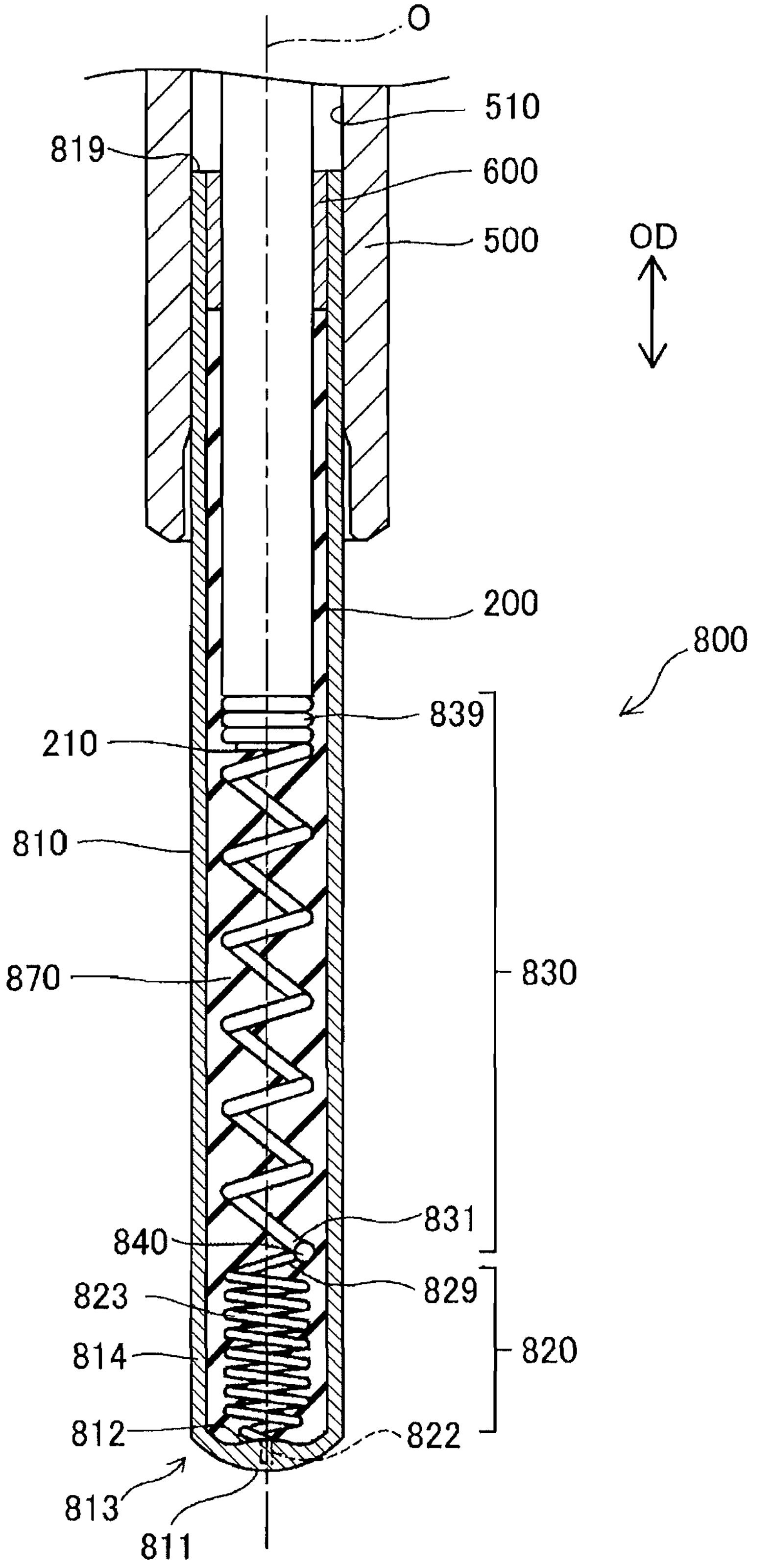

10
O
290
100
300
410
460
520
540
OD
510
500
200
600
810
210
870
830
820
800

FIG. 2


O
510
819
600
500
OD
200
800
839
210
810
870
830
831
840
829
823
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820
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822
813
811

FIG. 3

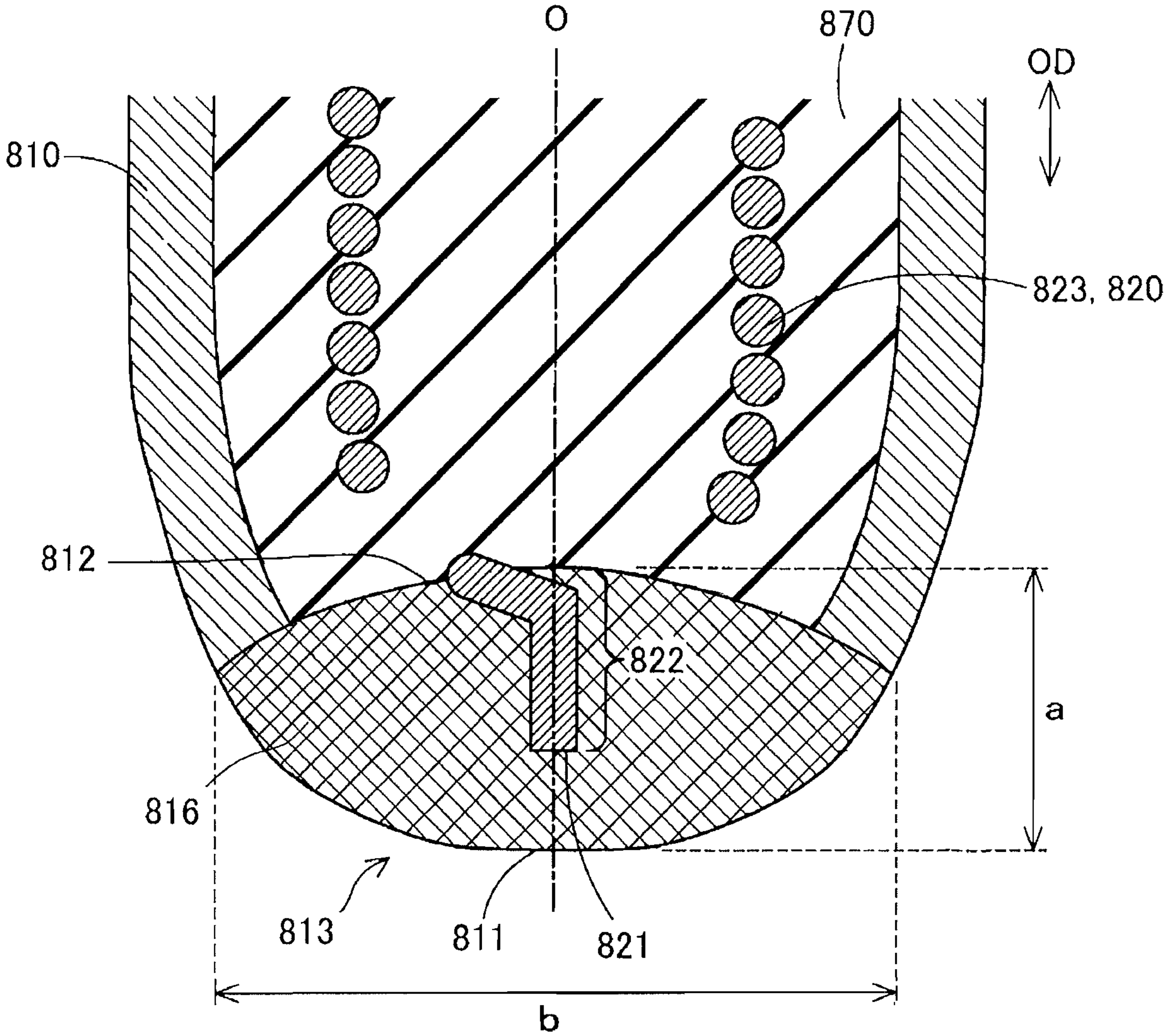


FIG. 4

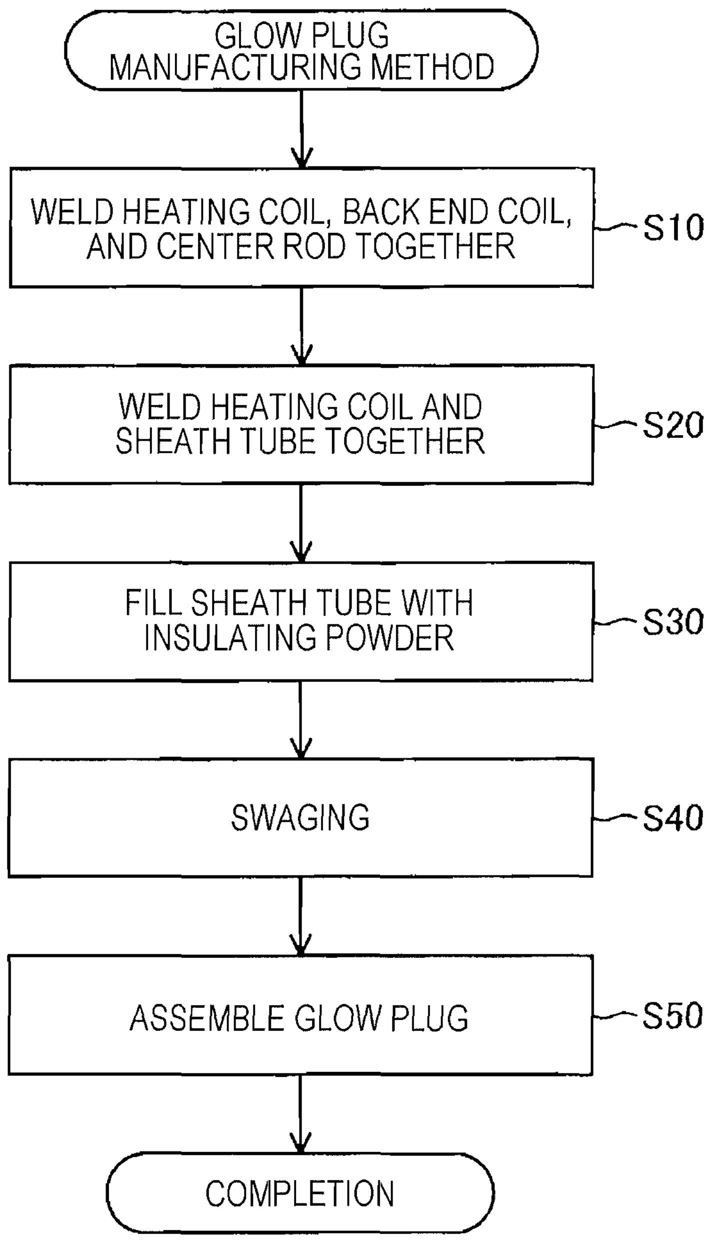

GLOW PLUG MANUFACTURING METHOD
WELD HEATING COIL, BACK END COIL, AND CENTER ROD TOGETHER
S10
WELD HEATING COIL AND SHEATH TUBE TOGETHER
S20
FILL SHEATH TUBE WITH INSULATING POWDER
S30
SWAGING
S40
ASSEMBLE GLOW PLUG
S50
COMPLETION

FIG. 5B

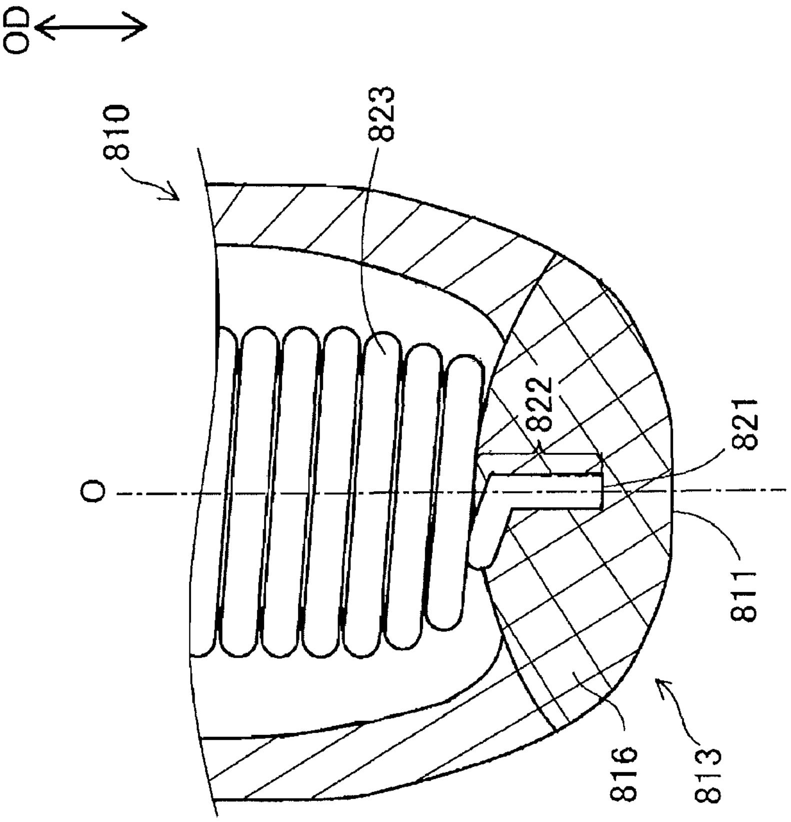


FIG. 5A

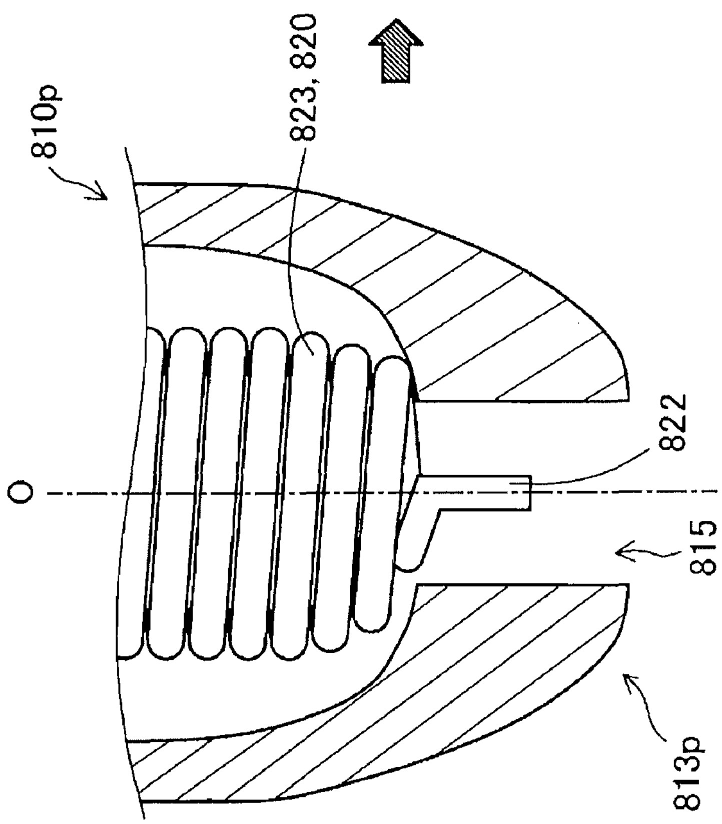
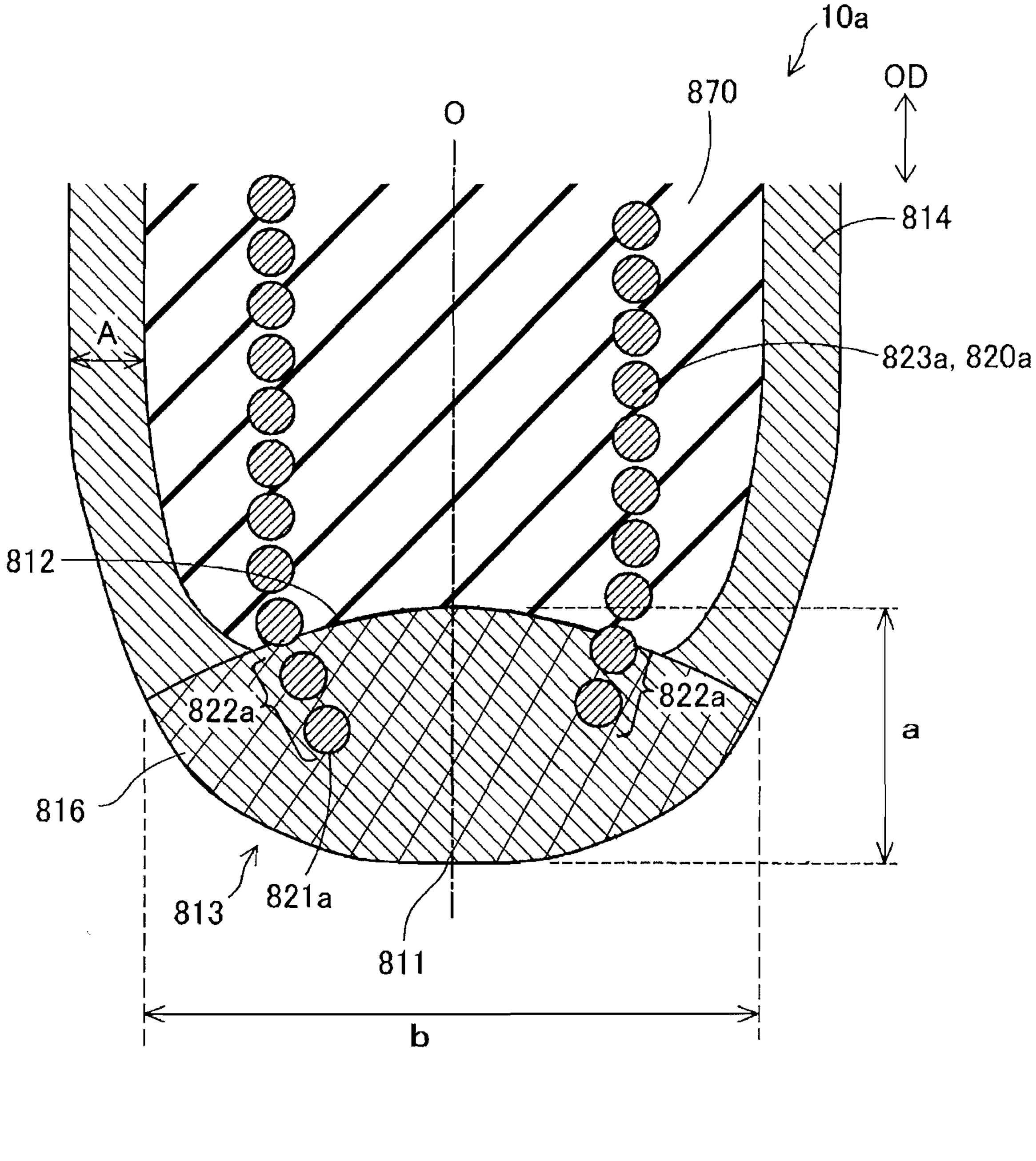


FIG. 6



REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2016148506 A **[0004]**
- JP 2015078784 A **[0004]**
- EP 2863126 A1 **[0004]**