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(54) **GLOW PLUG**

(57) To provide a glow plug having a heat generation element fixed at a desired position in a forward end of a tubular member.

A radial distance F between the radially outermost end of a first heat-generation-element cross section 901 which is a rearmost one of the cross sections of a heat generation coil 820 appearing in a fusion zone 891 and disposed on one side of an axial line and the radially innermost end of a base metal portion 893 is 0.200 mm or less. Specifically, the distance F between a straight line L1 extending along the axial line from the radially outermost end of the first heat-generation-element cross section 901 and a straight line L2 extending along the axial line from the radially innermost end of the base metal portion 893 is 0.200 mm or less. Further, a radial distance G between the radially outermost end of a second heat-generation-element cross section 902 which is a rearmost one of the cross sections of the heat generation coil 820 appearing in the fusion zone 891 and disposed on the other side of the axial line and the radially innermost end of the base metal portion 893 is 0.200 mm or less. Specifically, the distance G between a straight line L3 extending along the axial line from the radially outermost end of the second heat-generation-element cross section 902 and a straight line L4 extending along the axial line from the radially innermost end of the base metal portion 893 is 0.200 mm or less.

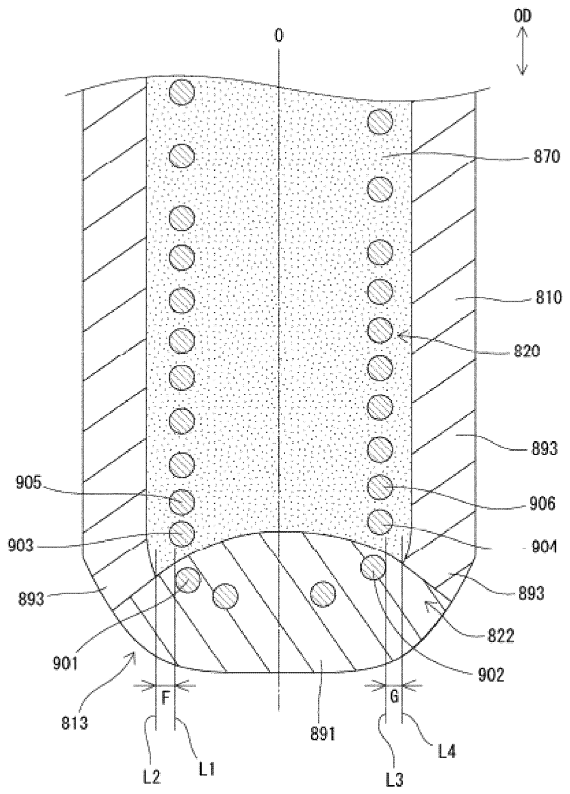

FIG. 3

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Description

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

[0002] In recent years, in order to cope with stricter exhaust gas regulations on diesel engines, glow plugs have been required to provide higher heating-up temperature. In order to provide higher heating-up temperature, a glow plug having a heat generation element which contains tungsten (W) as a main component is proposed (see WO2014/206847). In the glow plug of WO2014/206847, the heat generation element is inserted into a fusion zone at a forward end of a tubular member (tube) to thereby be joined to the tubular member. The reason for such a joining form is as follows: since the heat generation element which contains W as a main component is high in melting point, the heat generation element hardly melts, whereas the tubular member melts to form the fusion zone. Further, according to Patent Document 1, in the fusion zone, the coiled heat generation element reduces in diameter toward its forward end.

[0003] In manufacture of a glow plug, a forward end of a tubular member is melted and then solidified to thereby fix a forward end of a coiled heat generation element in a fusion zone. Specifically, the forward end of the tubular member in which the forward end of the heat generation element is disposed is melted; then, the melted forward end is solidified, thereby forming the fusion zone into which the forward end of the heat generation element is inserted. In the course of solidification, the fusion zone is solidified such that solidification starts from its periphery and gradually proceeds toward the center.

[0004] Meanwhile, in the case of the glow plug of Patent Document 1, the forward end of the heat generation element is fixed in a region around the center of the fusion zone. The region around the center of the fusion zone is the latest to undergo solidification. Therefore, before the heat generation element is fixed, the heat generation element may move or be offset from the center. Particularly, since the fusion zone contracts in the course of solidification, when the periphery of the fusion zone is solidified, tensile stress is applied to the center of the fusion zone; consequently, the heat generation element is apt to move. As a result, the heat generation element may fail to be fixed at a desired position.

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

(1) A mode of the present invention provides a glow plug comprising a tubular member whose forward end is closed with a fusion zone, and a coiled heat generation element disposed in the tubular member and containing W as a main component. The tubular member has a base metal portion connected to the fusion zone and having a microstructure different from that of the fusion zone. A forward end portion of the heat generation element is inserted into the fusion zone to thereby be joined to the tubular member. In a cross section of the glow plug taken along an axial line of the glow plug such that the same number of cross sections of the heat generation element appear in the fusion zone on opposite sides of the axial line, a radial distance F between a radially outermost end of a first heat-generation-element cross section and a radially innermost end of the base metal portion is 0.200 mm or less, the first heat-generation-element cross section being a rearmost one of the cross sections of the heat generation element appearing in the fusion zone on one side of the axial line, the first heat-generation-element cross section being disposed at least partially within the fusion zone, and a radial distance G between a radially outermost end of a second heat-generation-element cross section and a radially innermost end of the base metal portion is 0.200 mm or less, the second heat-generation-element cross section being a rearmost one of the cross sections of the heat generation element appearing in the fusion zone on the other side of the axial line, the second heat-generation-element cross section being disposed at least partially within the fusion zone.

According to the one mode of the present invention, in the fusion zone, the radial distance between the radially outermost end of the first heat-generation-element cross section and the radially innermost end of the base metal portion is 0.200 mm or less and the radial distance between the radially outermost end of the second heat-generation-element cross section and the radially innermost end of the base metal portion is 0.200 mm or less. That is, a portion of the heat generation element disposed within the fusion zone is more in contiguity with the base metal portion. Therefore, as a result of the heat generation element being positioned in a portion of the fusion zone (the periphery of the fusion zone) which solidifies at an early stage of solidification, in the course of solidification of the fusion zone, the heat generation element is fixed at a desired position without movement or offsetting. Accordingly, the temperature distribution around the glow plug in the circumferential direction can be rendered uniform, whereby the startability of an engine can be stabilized. Also, since the heat generation element is not offset from the center, contact of the side of the heat generation element with the tubular member is restrained to thereby reduce the occurrence of short circuit, so that durability is improved.

Notably, the "first heat-generation-element cross section" and the "second heat-generation-element cross section" may be disposed at least partially within the fusion zone. Specifically, the entire first heat-generation-element cross section and the entire second heat-generation-element cross section may be disposed within the fusion zone; alternatively, a portion of the first heat-generation-element cross section and a portion of the second heat-generation-element cross section may be disposed within the fusion zone.

(2) In the glow plug according to section (1), the absolute value of a difference between the distance F and the distance G may be 0.150 mm or less.

As a result of employment of the above configuration, offsetting of the heat generation element from the center is further restrained, whereby durability is further improved.

(3) The glow plug according to section (1) or (2) can be configured such that half or more of a region A overlaps a region B and such that half or more of a region C overlaps a region D, where in the section,

the region A represents a region between two straight lines extending along the axial line from radially opposite ends of a third heat-generation-element cross section which is a forwardmost one of the cross sections of the heat generation element appearing externally of the fusion zone on the one side of the axial line,

the region B represents a region between two straight lines extending along the axial line from radially opposite ends of the first heat-generation-element cross section,

the region C represents a region between two straight lines extending along the axial line from radially opposite ends of a fourth heat-generation-element cross section which is a forwardmost one of the cross sections of the heat generation element appearing externally of the fusion zone on the other side of the axial line, and

the region D represents a region between two straight lines extending along the axial line from radially opposite ends of the second heat-generation-element cross section.

In some cases, the diameter of the heat generation element inside the fusion zone is smaller than that outside the fusion zone. In such a case, a portion of the heat generation element that is to be fixed to the fusion zone approaches a central portion of the tubular member (the center of the fusion zone) and thus is located away from the base metal portion (the periphery of the fusion zone). As a result, due to slow solidification around the portion of the heat generation element, the heat generation element may fail to be fixed at a desired position.

According to the one mode of the present invention, the heat generation element is hardly reduced in diameter within the fusion zone and thus is easily fixed at a desired position.

(4) The glow plug according to any one of sections (1) to (3) can be configured such that the wire diameter of the heat generation element is 0.1 mm to 0.25 mm.

Since the heat generation element containing tungsten (W) as a main component is small in specific resistance, the amount of generated heat may become relatively small. In view of this, a relatively small wire diameter of 0.1 mm to 0.25 mm is imparted to the heat generation element containing tungsten (W) as a main component, so that the heat generation element can generate sufficient heat.

However, in the case of a wire diameter of the heat generation element of 0.1 mm to 0.25 mm, the heat generation element is low in rigidity; as a result, in the course of solidification of the fusion zone, due to subjection to tensile stress, the heat generation element tends to be offset from the center without being fixed at a desired position.

According to the one mode of the present invention, since the heat generation element is positioned in a region that solidifies at an early stage of solidification (the periphery of the fusion zone), even the heat generation element having such a small wire diameter can be fixed at a desired position without being offset from the center.

(5) The glow plug according to any one of sections (1) to (4) can be configured such that:

with a third heat-generation-element cross section representing a forwardmost one of the cross sections of the heat generation element appearing externally of the fusion zone on the one side of the axial line,

with a fourth heat-generation-element cross section representing a forwardmost one of the cross sections of the heat generation element appearing externally of the fusion zone on the other side of the axial line,

with a fifth heat-generation-element cross section representing a cross section which is one of the cross sections of the heat generation element appearing externally of the fusion zone on the one side of the axial line and which is located immediately rearward of the third heat-generation-element cross section, and

with a sixth heat-generation-element cross section representing a cross section which is one of the cross sections of the heat generation element appearing externally of the fusion zone on the other side of the axial line and which is located immediately rearward of the fourth heat-generation-element cross section,

a gap along the axial line between a rearmost end of the first heat-generation-element cross section and a forwardmost end of the third heat-generation-element cross section is greater than a gap along the axial line between a rearmost end of the third heat-generation-element cross section and a forwardmost end of the fifth heat-generation-element cross section, and

a gap along the axial line between a rearmost end of the second heat-generation-element cross section and a forwardmost end of the fourth heat-generation-element cross section is greater than a gap along the axial line between a rearmost end of the fourth heat-generation-element cross section and a forwardmost end of the sixth heat-generation-element cross section.

[0006] If the gap along the axial line between the rearmost end of the first heat-generation-element cross section and the forwardmost end of the third heat-generation-element cross section is small, a portion of the heat generation element having the third heat-generation-element cross section may be caught in the fusion zone and thus may fail to yield the function of the heat generation element. In the present mode, since the gap along the axial line between the rearmost end of the first heat-generation-element cross section and the forwardmost end of the third heat-generation-element cross section is greater than the gap along the axial line between the rearmost end of the third heat-generation-element cross section and the forwardmost end of the fifth heat-generation-element cross section, the portion of the heat generation element having the third heat-generation-element cross section is less likely to be caught in the fusion zone.

[0007] Similarly, if the gap along the axial line between the rearmost end of the second heat-generation-element cross section and the forwardmost end of the fourth heat-generation-element cross section is small, a portion of the heat generation element having the fourth heat-generation-element cross section may be caught in the fusion zone and thus may fail to yield the function of the heat generation element. In the present mode, since the gap along the axial line between the rearmost end of the second heat-generation-element cross section and the forwardmost end of the fourth heat-generation-element cross section is greater than the gap along the axial line between the rearmost end of the fourth heat-generation-element cross section and the forwardmost end of the sixth heat-generation-element cross section, the portion of the heat generation element having the fourth heat-generation-element cross section is less likely to be caught in the fusion zone.

[0008] In this manner, since the portion of the heat generation element having the third heat-generation-element cross section and the portion of the heat generation element having the fourth heat-generation-element cross section are less likely to be caught in the fusion zone and thus yield the function of the heat generation element, the glow plug can provide high heating-up temperature.

[0009] The invention will be further described by way of non-limitative example with reference to the accompanying drawings, in which:

FIG. 1 is a view showing a glow plug.
FIG. 2 is a sectional view showing the structure of a sheath heater in detail.
FIG. 3 is a sectional view showing a forward end portion of a sheath tube and its periphery.
FIG. 4 is a sectional view showing a forward end portion of the sheath tube and its periphery.
FIG. 5 is a sectional view showing a forward end portion of the sheath tube and its periphery.
FIG. 6 is a flowchart showing a method of manufacturing the glow plug.
FIGS. 7(a) and 7(b) are explanatory views showing a welding process in step S20.
FIGS. 8(a) and 8(b) are explanatory views showing a welding process in step S20 of another embodiment.

1. Glow Plug

[0010] FIG. 1 shows a glow plug 10. 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. 1 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."

[0011] 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 thereof. Also, the metallic shell 500 holds the axial rod 200 at a rear end portion thereof through an insulation member 410 and an O-ring 460. The position of the insulation member 410 along the axial line O 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).

[0012] 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.

[0013] FIG. 2 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." The heat generation coil 820 corresponds to the coiled heat generation element of the present invention.

[0014] The sheath tube 810 is a tubular member extending in the axial direction OD and having a closed forward end and corresponds to the tubular member of the present invention. 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)).

[0015] 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.

[0016] 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. The main component of the heat generation coil 820 is tungsten (W). Notably, the main component is a substance whose content (% by mass) is 50% by mass or higher. Preferably, the tungsten (W) content of the heat generation coil 820 is 99% by mass or higher.

[0017] No particular limitation is imposed on the wire diameter of the heat generation coil 820. The wire diameter is preferably 0.1 mm to 0.25 mm, more preferably 0.15 mm to 0.25 mm, and particularly preferably 0.18 mm to 0.25 mm. The heat generation coil 820 contains, as a main component, tungsten (W) having a smaller specific resistance. However, by imparting a wire diameter of 0.1 mm to 0.25 mm to the heat generation coil 820, the heat generation coil 820 can generate sufficient heat. By contrast, if the heat generation coil 820 reduces in wire diameter, its rigidity lowers; as a result, in the course of solidification of a fusion zone 891, which will be described later, due to subjection to tensile stress, the heat generation coil 820 tends to be offset from the center without being fixed at a desired position. According to the present embodiment, since the heat generation coil 820 is positioned in a region that solidifies at an early stage of solidification (the periphery of the fusion zone 891), even the heat generation coil 820 having such a small wire diameter can be fixed at a desired position without being offset from the center.

[0018] 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.

[0019] In view of securement of rapid heat-up performance, preferably, the resistance R_{20} of the glow plug 10 at 20°C is 0.6 Ω or less. In the present embodiment, the resistance R_{20} of the glow plug 10 at 20°C is the sum of the resistance of the heat generation coil 820 at 20°C and the resistance of the rear coil 830 at 20°C. In the present embodiment, the resistance R_{20} of the glow plug 10 at 20°C is 0.4 Ω. In the present embodiment, a resistance ratio R1 which is the ratio of the resistance $R1_{1000}$ of the heat generation coil 820 at 1,000°C to the resistance $R1_{20}$ of the heat generation coil 820 at 20°C and a resistance ratio R2 which is the ratio of the resistance $R2_{1000}$ of the rear coil 830 at 1,000°C to the resistance $R2_{20}$ of the rear coil 830 at 20°C satisfy a relation of $R1 > R2$.

[0020] FIG. 3 is a sectional view showing the forward end portion 813 of the sheath tube 810 and its periphery. The forward end of the sheath tube 810 is closed with the fusion zone 891.

[0021] FIG. 3 shows a cross section of the glow plug 10 taken along the axial line O of the glow plug 10 such that the same number of cross sections of the heat generation coil 820 appear in the fusion zone 891 on opposite sides of the axial line O. In FIG. 3, the left side of the axial line O is taken as one side of the axial line O, and the right side is taken as the other side. In FIG. 3, two cross sections of the heat generation coil 820 appear in the fusion zone 891 on each of opposite sides of the axial line O. FIG. 3 shows the heat generation coil 820, the sheath tube 810, and the insulator

870 which are cut along a plane passing through the axial line O.

[0022] In the sheath tube 810, the fusion zone 891 contains columnar crystals (dendrite), whereas a base metal portion 893 other than the fusion zone 891 has a microstructure different from that of the fusion zone 891. Examples of the microstructure of the base metal portion 893 include a fibrous microstructure and a forged microstructure. The microstructure can be identified as columnar crystals, a fibrous microstructure, or a forged microstructure by a publicly known metal microstructure observation method; specifically, by electrolytic etching of a cut surface in an oxalate solution (JIS G 5071 2012), for example.

[0023] The forward end portion 822 of the heat generation coil 820 is inserted into the fusion zone 891. The rearmost one of the cross sections of the heat generation coil 820 appearing in the fusion zone 891 on one side of the axial line O will be referred to as a first heat-generation-element cross section 901. Similarly, the rearmost one of the cross sections of the heat generation coil 820 appearing in the fusion zone 891 on the other side of the axial line O will be referred to as a second heat-generation-element cross section 902.

[0024] The forwardmost one of the cross sections of the heat generation coil 820 appearing externally of the fusion zone 891 on the one side of the axial line O will be referred to as a third heat-generation-element cross section 903. Similarly, the forwardmost one of the cross sections of the heat generation coil 820 appearing externally of the fusion zone 891 on the other side of the axial line O will be referred to as a fourth heat-generation-element cross section 904. The third heat-generation-element cross section 903 and the fourth heat-generation-element cross section 904 are located away from the fusion zone 891.

[0025] Further, a cross section which is one of the cross sections of the heat generation element 820 appearing externally of the fusion zone 891 on the one side of the axial line O and which is located immediately rearward of the third heat-generation-element cross section 903 will be referred to as a fifth heat-generation-element cross section 905. Similarly, a cross section which is one of the cross sections of the heat generation element 820 appearing externally of the fusion zone 891 on the other side of the axial line O and which is located immediately rearward of the fourth heat-generation-element cross section 904 will be referred to as a sixth heat-generation-element cross section 906.

[0026] In the present embodiment, a radial distance F between the radially outermost end of the first heat-generation-element cross section 901 and the radially innermost end of the base metal portion 893 is 0.200 mm or less.

[0027] That is, the distance F between a straight line L1 extending axially from the radially outermost end of the first heat-generation-element cross section 901 and a straight line L2 extending axially from the radially innermost end of the base metal portion 893 is 0.200 mm or less. Preferably, the distance F is 0.180 mm or less.

[0028] Further, in the present embodiment, a radial distance G between the radially outermost end of the second heat-generation-element cross section 902 and the radially innermost end of the base metal portion 893 is 0.200 mm or less.

[0029] That is, the distance G between a straight line L3 extending axially from the radially outermost end of the second heat-generation-element cross section 902 and a straight line L4 extending axially from the radially innermost end of the base metal portion 893 is 0.200 mm or less. Preferably, the distance G is 0.180 mm or less.

[0030] The following actions and effects are yielded by specifying, as mentioned above, the distance relation between the first heat-generation-element cross section 901 and the base metal portion 893 and the distance relation between the second heat-generation-element cross section 902 and the base metal portion 893. By specifying such distance relations, a portion of the heat generation coil 820 disposed within the fusion zone 891 is more in contiguity with the base metal portion 893. Therefore, as a result of the heat generation coil 820 being positioned in a portion of the fusion zone 891 (the periphery of the fusion zone 891) which solidifies at an early stage of solidification, in the course of solidification of the fusion zone 891, the heat generation coil 820 is fixed at a desired position without movement or offsetting. Accordingly, the temperature distribution around the glow plug 10 in the circumferential direction can be uniformized, whereby the startability of an engine can be stabilized. Also, since the heat generation coil 820 is not offset from the center, contact of the side of the heat generation coil 820 with the sheath tube 810 is restrained to thereby reduce the occurrence of short circuit, so that durability is improved. Notably, improvement of durability as a result of reduction in occurrence of short circuit by virtue of the above distance relations will be described in detail in the aftermentioned section "Examples."

[0031] In the present embodiment, preferably, the absolute value of the difference between the distance F and the distance G is 0.150 mm or less. If the absolute value of the difference between the distance F and the distance G is 0.150 mm or less, offsetting of the heat generation coil 820 is further restrained, whereby durability is further improved.

[0032] Further, in the present embodiment, the first heat-generation-element cross section 901, the second heat-generation-element cross section 902, the third heat-generation-element cross section 903, and the fourth heat-generation-element cross section 904 satisfy the following relations.

[0033] As shown in FIG. 4, a region A represents a region between two straight lines M1 extending along the axial line O from radially opposite ends of the third heat-generation-element cross section 903. A region B represents a region between two straight lines N1 extending along the axial line O from radially opposite ends of the first heat-generation-element cross section 901. In this case, preferably, half or more of the region A overlaps the region B. More preferably, 65% or more of the region A overlaps the region B, and particularly preferably, 75% or more of the region A overlaps the region B.

[0034] Similarly, as shown in FIG. 4, a region C represents a region between two straight lines M2 extending along the axial line O from radially opposite ends of the fourth heat-generation-element cross section 904. A region D represents a region between two straight lines N2 extending along the axial line O from radially opposite ends of the second heat-generation-element cross section 902. In this case, preferably, half or more of the region C overlaps the region D. More preferably, 65% or more of the region C overlaps the region D, and particularly preferably, 75% or more of the region C overlaps the region D.

[0035] The following actions and effects are yielded by specifying the above relation between the first heat-generation-element cross section 901, the second heat-generation-element cross section 902, the third heat-generation-element cross section 903, and the fourth heat-generation-element cross section 904.

[0036] In some cases, the diameter of the heat generation coil 820 inside the fusion zone 891 is smaller than that outside the fusion zone 891. In such a case, a portion of the heat generation coil 820 that is to be fixed to the fusion zone 891 approaches a central portion of the sheath tube 810 (the center of the fusion zone 891) and thus is located away from the base metal portion 893 (the periphery of the fusion zone 891). As a result, due to slow solidification around the portion of the heat generation coil 820, the heat generation coil 820 may fail to be fixed at a desired position.

[0037] According to the present embodiment, since the diameter of the heat generation coil 820 is hardly reduced within the fusion zone 891 as compared with the diameter of the heat generation coil 820 measured outside the fusion zone 891, a portion of the fusion zone 891 around the heat generation coil 820 solidifies at an early stage of solidification, so that the heat generation coil 820 is easily fixed at a desired position.

[0038] Further, in the present embodiment, the first heat-generation-element cross section 901, the second heat-generation-element cross section 902, the third heat-generation-element cross section 903, the fourth heat-generation-element cross section 904, the fifth heat-generation-element cross section 905, and the sixth heat-generation-element cross section 906 satisfy the following relations.

[0039] As shown in FIG. 5, a gap a1 along the axial line O between the first heat-generation-element cross section 901 and the third heat-generation-element cross section 903 is greater than a gap b1 along the axial line O between the third heat-generation-element cross section 903 and the fifth heat-generation-element cross section 905.

[0040] Similarly, a gap a2 along the axial line O between the second heat-generation-element cross section 902 and the fourth heat-generation-element cross section 904 is greater than a gap b2 along the axial line O between the fourth heat-generation-element cross section 904 and the sixth heat-generation-element cross section 906.

[0041] If the gap a1 between the first heat-generation-element cross section 901 and the third heat-generation-element cross section 903 is small, a portion of the heat generation coil 820 having the third heat-generation-element cross section 903 may be caught in the fusion zone 891 and thus may fail to yield the function of the heat generation element. In the present embodiment, since the gap a1 is greater than the gap b1, the portion of the heat generation coil 820 having the third heat-generation-element cross section 903 is less likely to be caught in the fusion zone 891.

[0042] Similarly, if the gap a2 between the second heat-generation-element cross section 902 and the fourth heat-generation-element cross section 904 is small, a portion of the heat generation coil 820 having the fourth heat-generation-element cross section 904 may be caught in the fusion zone 891 and thus may fail to yield the function of the heat generation element. In the present embodiment, since the gap a2 is greater than the gap b2, the portion of the heat generation coil 820 having the fourth heat-generation-element cross section 904 is less likely to be caught in the fusion zone 891.

[0043] In this manner, since the portion of the heat generation coil 820 having the third heat-generation-element cross section 903 and the portion of the heat generation coil 820 having the fourth heat-generation-element cross section 904 are less likely to be caught in the fusion zone 891 and thus yield the function of the heat generation element, the glow plug 10 can provide high heating-up temperature.

2. Method of Manufacturing Glow Plug 10

[0044] FIG. 6 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 process."

[0045] FIGS. 7(a) and 7(b) are explanatory views showing a welding process in step S20. In the welding process, 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 disposed inside the forward end portion 813P of the prepared sheath tube 810P such that a second turn 822P of the heat generation coil 820 comes into contact with the sheath tube 810P (FIG. 7(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. 7(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. Also, in the welding process, 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.

[0046] Notably, 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.

[0047] When the welding process 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.

[0048] After the completion of assembling of the sheath heater 800, 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 to the interior of the sheath heater 800, thereby densifying the insulator 870.

[0049] After swaging is performed on the sheath heater 800, the sheath heater 800 and the metallic shell 500 are combined to thereby assemble the glow plug 10 (step S50), whereby the glow plug 10 is completed. Specifically, the sheath heater 800 integrated 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.

[Examples]

[0050] The present invention will be described further in detail by way of example.

[0051] Experimental examples 1 to 7 correspond to examples of the present invention, and experimental examples 8 and 9 correspond to comparative examples.

1. Preparation of Glow Plugs

[0052] The glow plugs 10 of the experimental examples were adjusted in the forward end shape of the heat generation coil 820 so as to adjust the radial distance F between the radially outermost end of the first heat-generation-element cross section 901 and the radially innermost end of the base metal portion 893 and the radial distance G between the radially outermost end of the second heat-generation-element cross section 902 and the radially innermost end of the base metal portion 893. Notably, the distance between the base metal portion 893 and the heat generation coil 820 was measured as follows: the offsetting of the heat generation coil 820 from the center was checked before disassembly by use of X rays, and then the sheath heater 800 was sectioned for measurement such that the most offset first heat-generation-element cross section 901 appeared on the one side of the axial line O or such that the most offset second heat-generation-element cross section 902 appeared on the other side of the axial line O.

[0053] Other conditions are as follows:

- A tungsten material (wire diameter ϕ: 0.20 mm) was used to form the heat generation coil 820.
- A nickel-chromium alloy material (wire diameter ϕ: 0.38 mm) was used to form the rear coil 830.
- Resistance at room temperature was adjusted to 0.310 Ω.
- The sheath tube 810 had an outside diameter of 3.25 mm at a small-diameter portion thereof and an outside diameter of 4.00 mm at a rear portion thereof.

2. Durability Test

[0054] A voltage for increasing the glow plug temperature by 1,000°C in two seconds was applied to the glow plugs 10; then, a voltage for saturating the glow plug temperature at 1,150°C was applied to the glow plugs 10 continuously for 180 seconds. Subsequently, the glow plugs 10 were cooled by wind for 120 seconds for lowering the temperature of the glow plugs 10 to room temperature. With this procedure taken as one cycle, a cycle test was conducted. In the course of the cycle test, the number of cycles at which a short circuit occurred was counted.

[0055] Criteria were as follows:

A (excellent): No short circuit within 7,000 cycles
B (good): Occurrence of short circuit at 3,501 to 7,000 cycles
C (poor): Occurrence of short circuit within 3,500 cycles

[0056] The temperature was measured at a position located 2 mm from the forward end of the sheath tube 810 by use of a PR thermocouple (platinum-platinum rhodium thermocouple) and a radiation thermometer.

3. Test Results

[0057] Table 1 shows the test results. Experimental examples 1 to 7 were free from the occurrence of short circuit within 3,500 cycles. By contrast, experimental examples 8 and 9 suffered the occurrence of short circuit within 3,500 cycles. Therefore, it has been confirmed that durability is improved in the case where the radial distance F between the radially outermost end of the first heat-generation-element cross section 901 and the radially innermost end of the base metal portion 893 and the radial distance G between the radially outermost end of the second heat-generation-element cross section 902 and the radially innermost end of the base metal portion 893 are 0.200 mm or less.

[0058] Of experimental examples 1 to 7, experimental examples 1 to 5 in which the absolute value of the difference between the distance F and the distance G was 0.150 mm or less were free from the occurrence of short circuit even at 7,000 cycles. Therefore, it has been confirmed that durability further improves when the absolute value of the difference between the distance F and the distance G is 0.150 mm or less.

[0059] The reason for the occurrence of short circuit as a result of the durability test is inferred as follows. During the durability test, voids are formed among particles of the charged insulation powder. As a result, in the case of excessive temperature rise of the heat generation coil 820, heat of the heat generation coil 820 melts the sheath tube 810, and the resultant molten metal moves toward the heat generation coil 820, resulting in the occurrence of short circuit.

Table 1

Experimental example	Disposition of heat generation coil within fusion zone of sheath tube			Judgment
	Distance F (mm)	Distance G (mm)	Absolute value of difference between distance F and distance G (mm)	
1	0.078	0.076	0.002	A
2	0.092	0.042	0.050	A
3	0.130	0.054	0.076	A
4	0.169	0.061	0.108	A
5	0.172	0.026	0.146	A
6	0.182	0.023	0.159	B
7	0.198	0.010	0.188	B
8	0.210	0.020	0.190	C
9	0.210	0.430	0.220	C

<Other Embodiments (Modifications)>

[0060] The present invention is not limited to the above embodiment and examples, but may be embodied in various other forms without departing from the gist of the invention.

(1) In the above embodiment, as shown in FIG. 7(a), the glow plug 10 is manufactured by use of the sheath tube 810P having the opening 815; however, as shown in FIG. 8(a), the glow plug 10 may be manufactured by use of a sheath tube 810R having no opening. In FIGS. 8(a) and 8(b), constituent members or portions approximately similar to those of the glow plug of the above embodiment are denoted by like reference numerals, and description of their structures, actions, and effects is omitted.

(2) In the above embodiment, the radial distance F between the radially outermost end of the first heat-generation-element cross section 901 and the radially innermost end of the base metal portion 893 and the radial distance G between the radially outermost end of the second heat-generation-element cross section 902 and the radially innermost end of the base metal portion 893 differ from each other. However, so long as the radial distance F between the radially outermost end of the first heat-generation-element cross section 901 and the radially innermost end of the base metal portion 893 and the radial distance G between the radially outermost end of the second heat-generation-element cross section 902 and the radially innermost end of the base metal portion 893 are 0.200 mm or less, the radial distances F and G are not necessarily different distances, but may be the same distance.

[Description of Reference Numerals]

[0061]

10: glow plug
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
601: INCONEL
800: sheath heater
810: sheath tube
813: forward end portion
814: side portion
815: opening
819: rear end portion
820: heat generation coil
822: forward end portion
829: rear end portion
830: rear coil
831: forward end portion
839: rear end portion
840: connection
870: insulator
891: fusion zone
893: base metal portion
901: first heat-generation-element cross section
902: second heat-generation-element cross section
903: third heat-generation-element cross section
904: fourth heat-generation-element cross section
905: fifth heat-generation-element cross section
906: sixth heat-generation-element cross section

Claims

1. A glow plug (10) comprising:

   a tubular member (810) whose forward end is closed with a fusion zone (891), and
   a coiled heat generation element (820) disposed in the tubular member (810) and containing W as a main component,
   wherein the tubular member (810) has a base metal portion (893) connected to the fusion zone (891) and having a microstructure different from that of the fusion zone (891);
   a forward end portion of the heat generation element (820) is inserted into the fusion zone (891) to thereby be joined to the tubular member (810); and
   in a cross section of the glow plug (10) taken along an axial line (O) of the glow plug (10) such that the same number of cross sections of the heat generation element (820) appear in the fusion zone (891) on opposite sides of the axial line (O),
   a radial distance F between a radially outermost end of a first heat-generation-element cross section (901) and a radially innermost end of the base metal portion (893) is 0.200 mm or less, the first heat-generation-element cross section being a rearmost one of the cross sections of the heat generation element (820) appearing in the fusion zone (891) on one side of the axial line (O), the first heat-generation-element cross section being disposed at least partially within the fusion zone (891), and
   a radial distance G between a radially outermost end of a second heat-generation-element cross section (902) and a radially innermost end of the base metal portion (893) is 0.200 mm or less, the second heat-generation-element cross section being a rearmost one of the cross sections of the heat generation element (820) appearing in the fusion zone (891) on the other side of the axial line (O), the second heat-generation-element cross section being disposed at least partially within the fusion zone (891).

2. A glow plug according to claim 1, wherein the absolute value of a difference between the distance F and the distance G is 0.150 mm or less.

3. A glow plug according to claim 1 or 2, wherein in the section,

   with a region A representing a region between two straight lines (M1) extending along the axial line (O) from radially opposite ends of a third heat-generation-element cross section (903) which is a forwardmost one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the one side of the axial line (O) and
   with a region B representing a region between two straight lines (N1) extending along the axial line (O) from radially opposite ends of the first heat-generation-element cross section (901),
   half or more of the region A overlaps the region B, and
   with a region C representing a region between two straight lines (M2) extending along the axial line (O) from radially opposite ends of a fourth heat-generation-element cross section (904) which is a forwardmost one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the other side of the axial line (O) and
   with a region D representing a region between two straight lines (N2) extending along the axial line (O) from radially opposite ends of the second heat-generation-element cross section (902),
   half or more of the region C overlaps the region D.

4. A glow plug according to any one of claims 1 to 3, wherein the heat generation element (820) has a wire diameter of 0.1 mm to 0.25 mm.

5. A glow plug according to any one of claims 1 to 4, wherein in the section,

   with a third heat-generation-element cross section (903) representing a forwardmost one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the one side of the axial line (O),
   with a fourth heat-generation-element cross section (904) representing a forwardmost one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the other side of the axial line (O),
   with a fifth heat-generation-element cross section (905) representing a cross section which is one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the one side of

the axial line (O) and which is located immediately rearward of the third heat-generation-element cross section (903), and
with a sixth heat-generation-element cross section (906) representing a cross section which is one of the cross sections of the heat generation element (820) appearing externally of the fusion zone (891) on the other side of the axial line (O) and which is located immediately rearward of the fourth heat-generation-element cross section (904),
a gap (a1) along the axial line (O) between a rearmost end of the first heat-generation-element cross section (901) and a forwardmost end of the third heat-generation-element cross section (903) is greater than a gap (b1) along the axial line (O) between a rearmost end of the third heat-generation-element cross section (903) and a forwardmost end of the fifth heat-generation-element cross section (905), and
a gap (a2) along the axial line (O) between a rearmost end of the second heat-generation-element cross section (902) and a forwardmost end of the fourth heat-generation-element cross section (904) is greater than a gap (b2) along the axial line (O) between a rearmost end of the fourth heat-generation-element cross section (904) and a forwardmost end of the sixth heat-generation-element cross section (906).

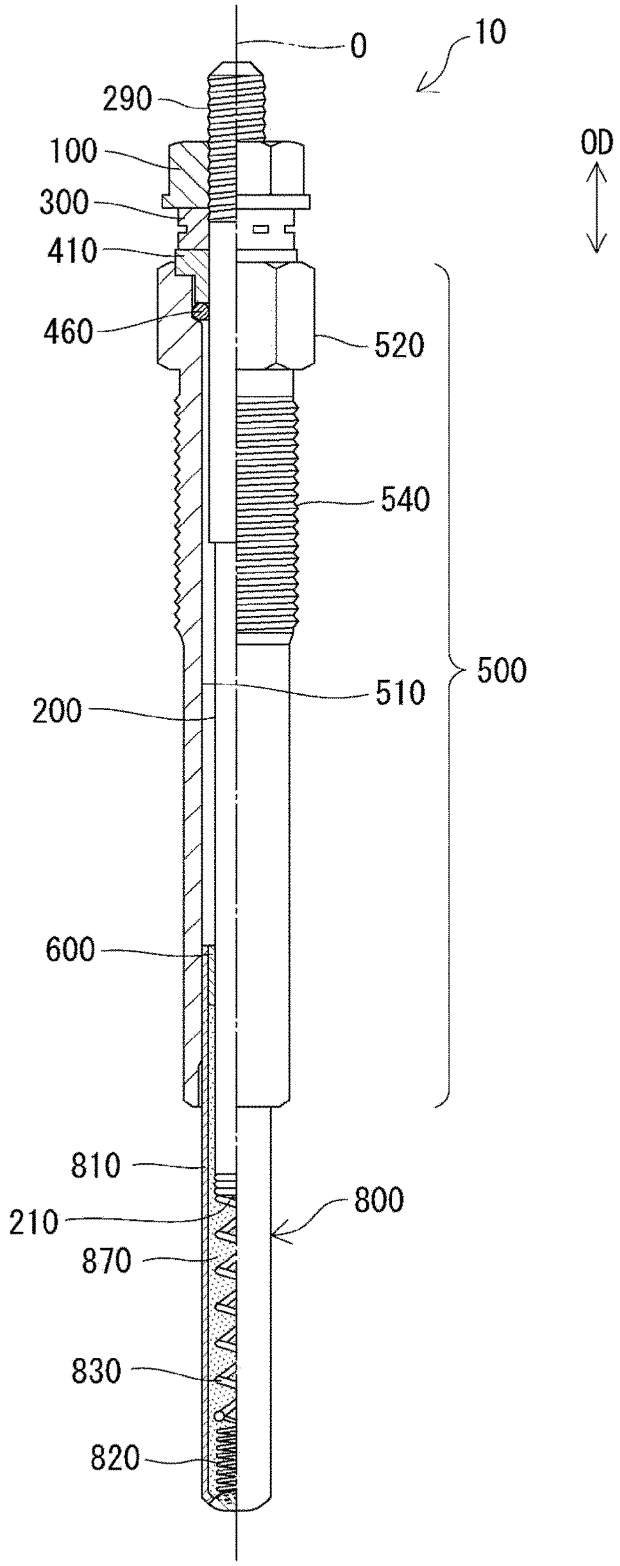
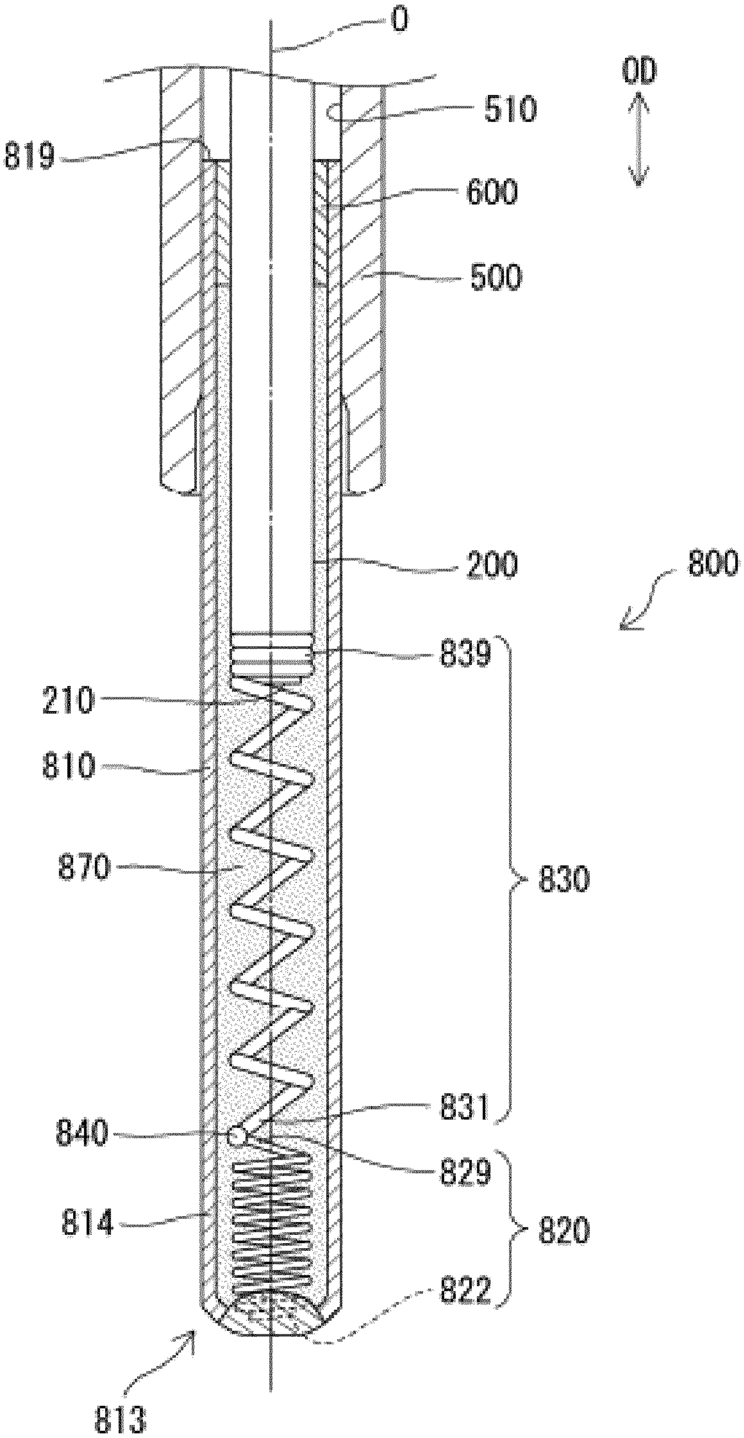

0
10
290
100
300
410
460
520
OD
540
500
510
200
600
810
210
800
870
830
820

FIG. 1


0
OD
510
819
600
500
200
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839
210
810
870
830
831
840
829
814
820
822
813

FIG. 2

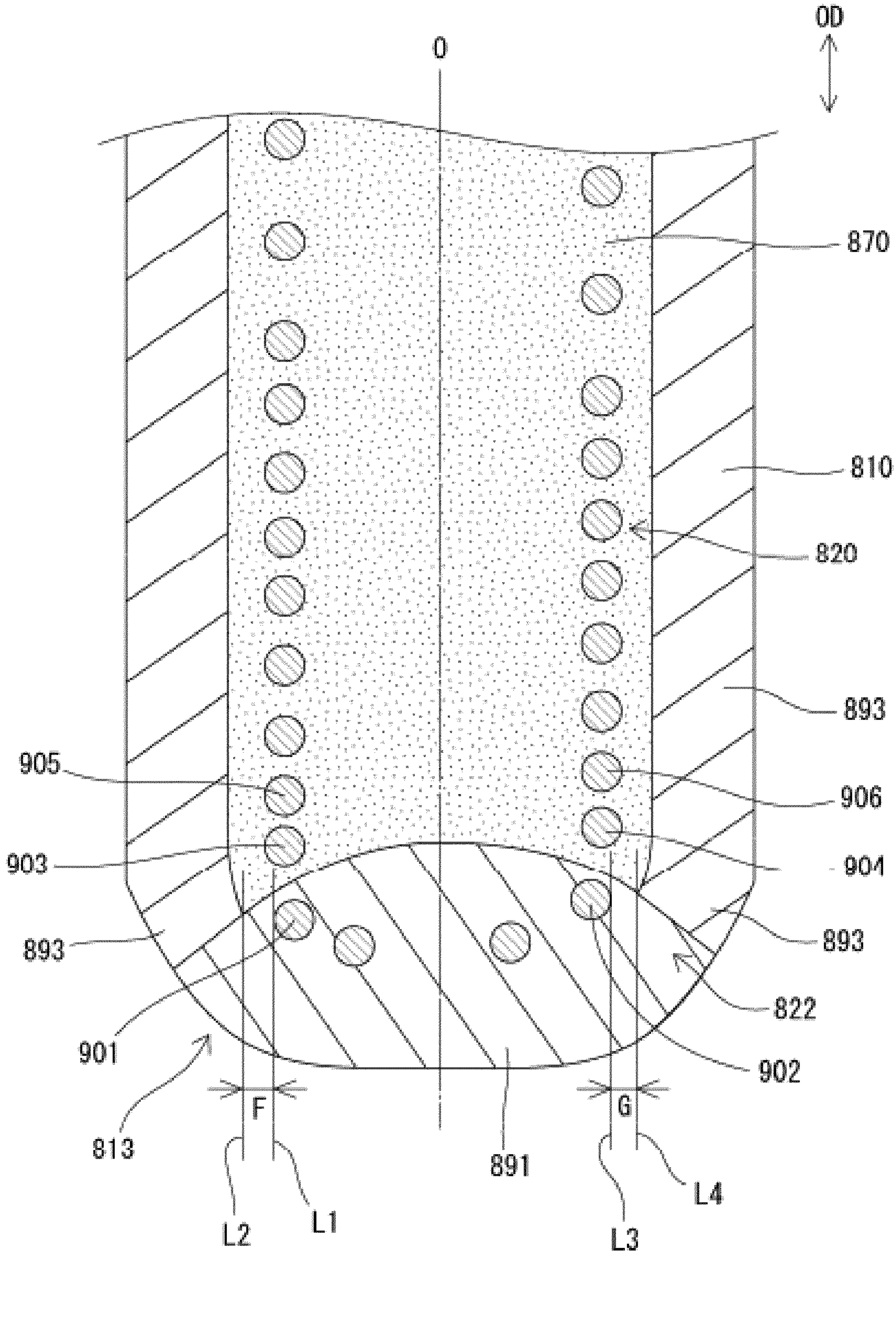
OD
O
870
810
820
893
905
906
903
904
893
893
822
901
902
813
F
G
891
L2
L1
L3
L4

FIG. 3

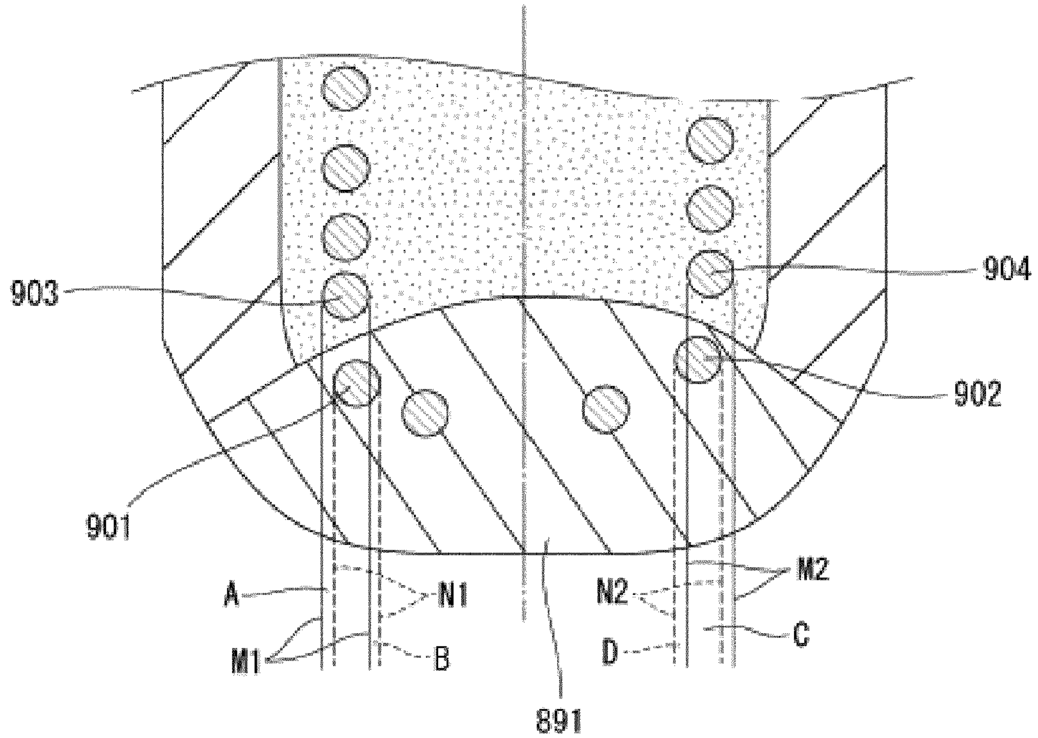
903
904
902
901
A
N1
M1
B
N2
M2
D
C
891

FIG. 4

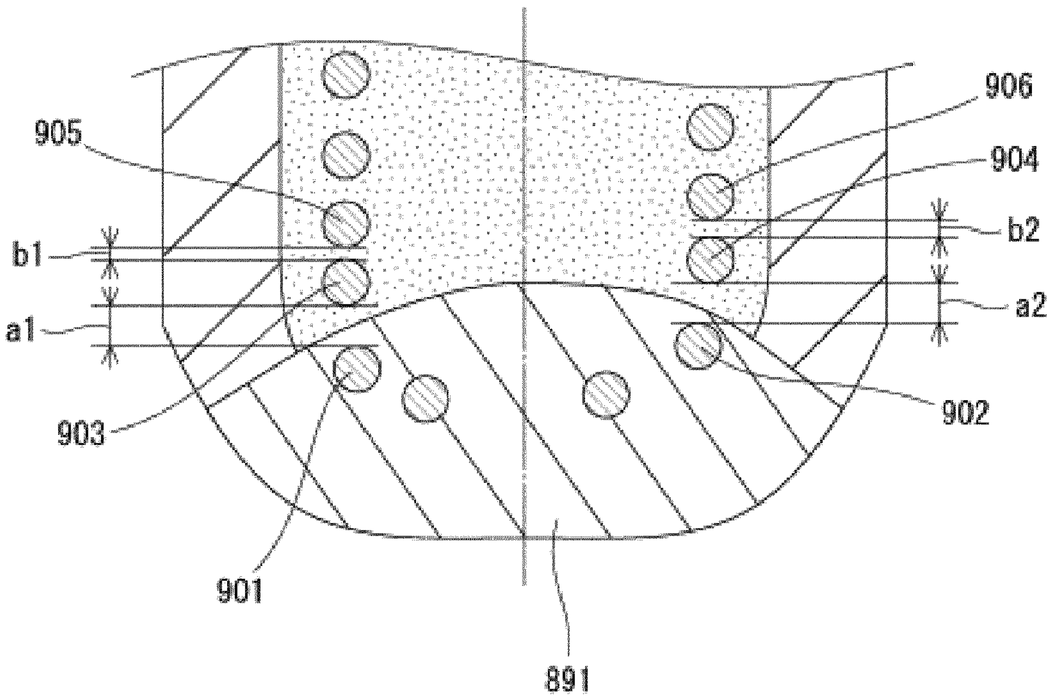
906
905
904
b1
b2
a1
a2
903
902
901
891

FIG. 5

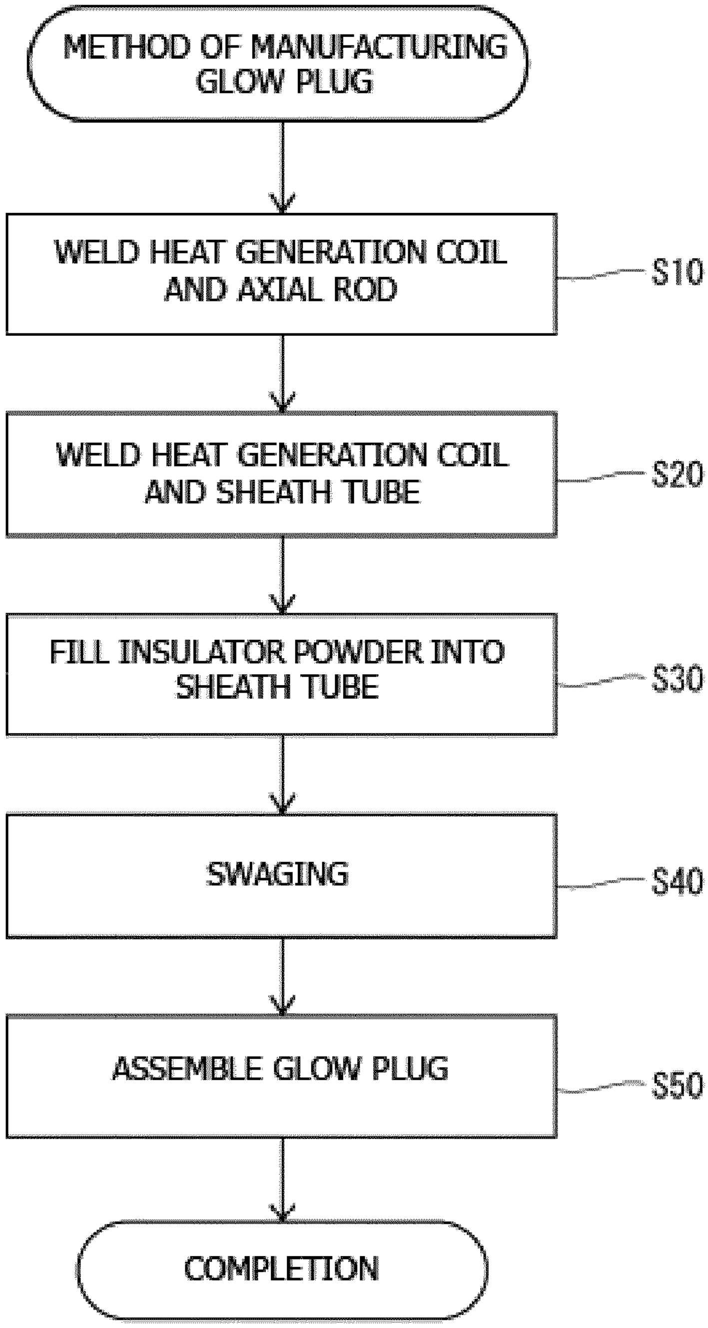
METHOD OF MANUFACTURING GLOW PLUG
WELD HEAT GENERATION COIL AND AXIAL ROD
S10
WELD HEAT GENERATION COIL AND SHEATH TUBE
S20
FILL INSULATOR POWDER INTO SHEATH TUBE
S30
SWAGING
S40
ASSEMBLE GLOW PLUG
S50
COMPLETION

FIG. 6

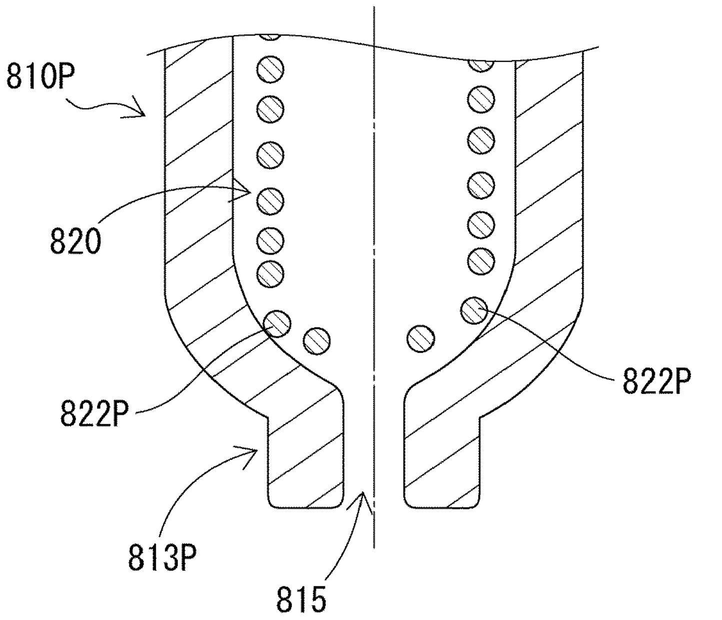

FIG. 7(a)

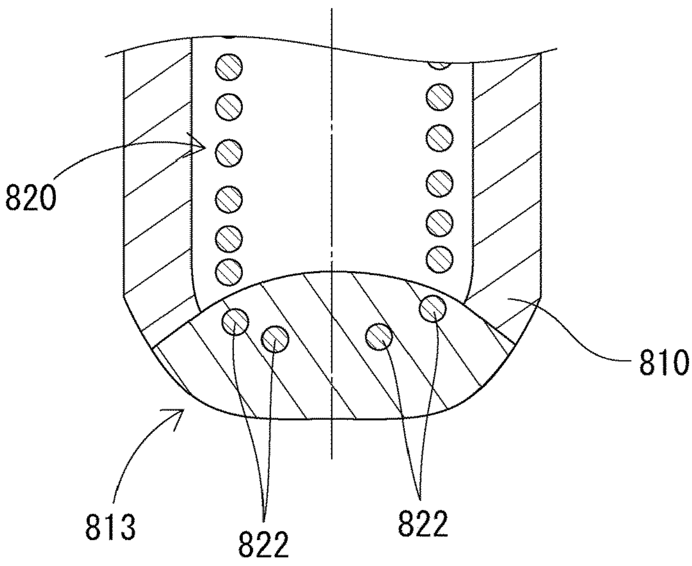

FIG. 7(b)

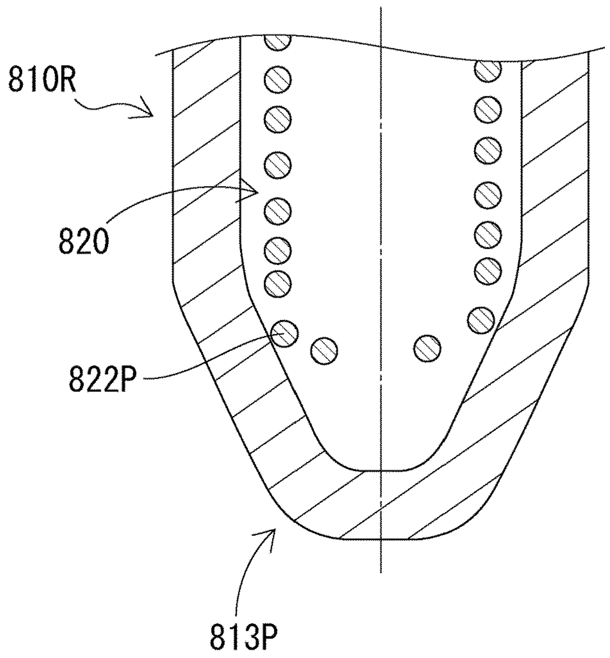

FIG. 8(a)

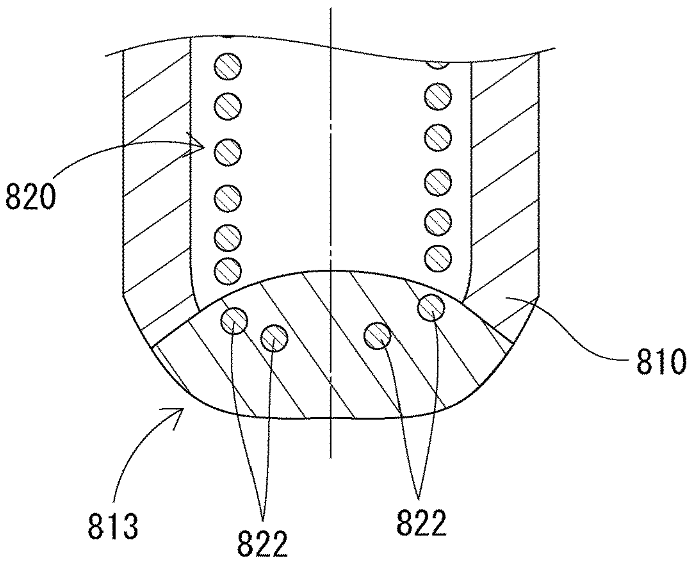

FIG. 8(b)

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 5735

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	WO 2014/206847 A1 (BOSCH GMBH ROBERT [DE]) 31 December 2014 (2014-12-31) * page 1, line 10 - page 9, line 5; figures 1-4 * -----	1	INV. F23Q7/00
A	DE 101 12 781 A1 (DENSO CORP [JP]) 4 October 2001 (2001-10-04) * paragraph [0005] - paragraph [0070]; figures 1-8 * -----	1	
A	DE 10 2005 043415 A1 (BOSCH GMBH ROBERT [DE]) 15 March 2007 (2007-03-15) * paragraph [0004] - paragraph [0024]; figures 1,2 * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

F23Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	23 August 2018	Theis, Gilbert

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23-08-2018

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Patent documents cited in the description

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