



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
31.10.2018 Bulletin 2018/44

(51) Int Cl.:
F23Q 7/00 (2006.01)

(21) Application number: **18165741.2**

(22) Date of filing: **04.04.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **NGK Spark Plug Co., Ltd.**
Nagoya-shi,
Aichi 4678525 (JP)

(72) Inventors:
• **OKADA, Hirofumi**
Nagoya, Aichi 4678525 (JP)
• **EJIRI, Makoto**
Nagoya, Aichi 4678525 (JP)

(30) Priority: **24.04.2017 JP 2017085047**
26.12.2017 JP 2017249216

(74) Representative: **J A Kemp**
14 South Square
Gray's Inn
London WC1R 5JJ (GB)

(54) **GLOW PLUG**

(57) To reduce variation in thermal performance among individual glow plugs.

A glow plug 10 includes a sheath tube (tubular member) 810 whose forward end is closed with a fusion zone 891, and a heat generation coil (coiled heat generation element) 820. The heat generation coil 820 contains W as a main component. The distance A between a first heat-generation-element cross section 902a and a second heat-generation-element cross section 903a is rendered greater than the distance B between the second heat-generation-element cross section 903a and a third heat-generation-element cross section 904a. Namely, the distance A (i.e., space) between the first heat-generation-element cross section 902a and the second heat-generation-element cross section 903a is increased such that the rear end surface 895 of the fusion zone 891 is disposed in the space. Accordingly, even when the amount of the melted material of the sheath tube 810 varies and thus the position of the rear end surface 895 of the fusion zone 891 varies in the axial direction, the position of the rear end surface 895 is located between the first heat-generation-element cross section 902a and the second heat-generation-element cross section 903a without fail.

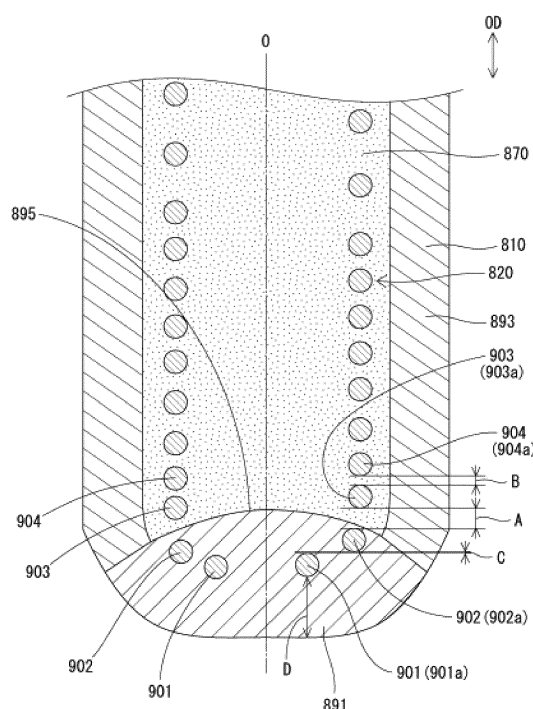


FIG. 3

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 in which a heat generation element containing tungsten (W) as a main component is disposed in a tubular member (tube) is proposed (see WO2014/206847).

[0003] In the case of the glow plug of WO2014/206847, thermal performance may vary among individual glow plugs. Such variation occurs because tungsten (W) used as a main component of a heat generation element is large in resistance ratio (the ratio of the resistance of the heat generation element at 1,000°C to the resistance of the heat generation element at 20°C). If the resistance of the heat generation element at room temperature varies among individual glow plugs, the resistance of the heat generation element when energized varies more greatly among individual glow plugs, and consequently, thermal performance may vary among individual glow plugs.

[0004] Incidentally, in the case of the glow plug of WO2014/206847, the heat generation element is inserted into a fusion zone at the forward end of a tubular member and is joined to the tubular member through the fusion zone. At that time, if the amount of the material of the heat generation element inserted into the fusion zone varies among individual glow plugs, the resistance of the heat generation element at room temperature may vary among individual glow plugs. In particular, in manufacture of the glow plug, the forward end of the tubular member is melted and then solidified to thereby fix the heat generation element in the fusion zone. At that time, if the amount of the melted material of the tubular member varies, the amount of insertion of the heat generation element into the fusion zone may vary among individual glow plugs.

[0005] The present invention has been conceived to solve the above problem and an object of the present invention is to reduce variation in thermal performance among individual glow plugs.

(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. 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, with a cross section which is a rearmost one of cross sections of the heat generation element appearing in the fusion zone on one side of the axial line and which is disposed at least partially within the fusion zone being defined as a first heat-generation-element cross section, with a forwardmost one of cross sections of the heat generation element appearing externally of the fusion zone on the one side of the axial line being defined as a second heat-generation-element cross section, and with 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 second heat-generation-element cross section being defined as a third heat-generation-element cross section, a distance A in the direction of the axial line between a rearmost end of the first heat-generation-element cross section and a forwardmost end of the second heat-generation-element cross section is greater than a distance B in the direction of the axial line between a rearmost end of the second heat-generation-element cross section and a forwardmost end of the third heat-generation-element cross section.

According to the mode of the present invention, the distance A is rendered greater than the distance B. Namely, the distance A (i.e., space) between the first heat-generation-element cross section and the second heat-generation-element cross section is increased such that the rear end surface of the fusion zone is disposed in the space. Accordingly, even when, for example, the amount of the melted material of the tubular member varies and thus the position of the rear end surface of the fusion zone varies some extent in the axial direction, the rear end surface of the fusion zone can be positioned in the inter-turn space between the first heat-generation-element cross section and the second heat-generation-element cross section without fail. Thus, only a predetermined amount of the material of the heat generation element at the forward end thereof can be reliably inserted into the fusion zone, whereby variation in the resistance of the heat generation element at room temperature among individual glow plugs can be suppressed. Accordingly, variation in thermal performance among individual glow plugs can be reduced.

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

(2) The glow plug according to section (1) may be configured such that the distance A and the distance B satisfy a relational expression of $1.30 \leq A/B \leq 4.00$.

When the above-described relational expression is satisfied, variation in the resistance of the heat generation element at room temperature among individual glow plugs can be suppressed while the heat-up performance of the glow plug is secured to a sufficient degree.

(3) The glow plug according to section (1) or (2) may be configured such that, in the cross section of the glow plug,

with a cross section which is one of the cross sections of the heat generation element appearing in the fusion zone on the one side of the axial line and which is located immediately forward of the first heat-generation-element cross section being defined as a fourth heat-generation-element cross section, a distance C in the direction of the axial line between a rearmost end of the fourth heat-generation-element cross section and a forwardmost end of the first heat-generation-element cross section (including the case where $C = 0$) is equal to or less than the distance B.

In this case, since the distance C between the fourth heat-generation-element cross section and the first heat-generation-element cross section is rendered equal to or less than the distance B, the wall thickness of the tubular member between the forward end of the heat generation element and the surface of the tubular member can be rendered sufficiently large. As a result, it is possible to prevent exposure of the heat generation element, which would otherwise occur when the tubular member wears.

In this case, the glow plug can simultaneously achieve reduction of thermal performance variation and improvement of durability.

Notably, the expression " $C = 0$ " means that the axial position of the rearmost end of the fourth heat-generation-element cross section is the same as that of the forwardmost end of the first heat-generation-element cross section.

(4) The glow plug according to section (1) or (2) may be configured such that, in the cross section of the glow plug, with a cross section which is one of the cross sections of the heat generation element appearing in the fusion zone on the one side of the axial line and which is located immediately forward of the first heat-generation-element cross section being defined as a fourth heat-generation-element cross section, a radially outermost end of the fourth heat-generation-element cross section is located inward of a radially innermost end of the first heat-generation-element cross section, and a rearmost end of the fourth heat-generation-element cross section is located rearward of a forwardmost end of the first heat-generation-element cross section.

[0006] In this case, since the rearmost end of the fourth heat-generation-element cross section is located rearward of the forwardmost end of the first heat-generation-element cross section, the wall thickness of the tubular member between the forward end of the heat generation element and the surface of the tubular member can be rendered sufficiently large. As a result, it is possible to prevent exposure of the heat generation element, which would otherwise occur when the tubular member wears.

[0007] In this case, the glow plug can simultaneously achieve reduction of thermal performance variation and improvement of durability.

[0008] 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 flowchart showing a method of manufacturing the glow plug.

FIGS. 5(a) and 5(b) are explanatory views showing a welding process in step S20.

FIGS. 6(a) and 6(b) are explanatory views showing a welding process in step S20 of another embodiment.

FIG. 7 is a sectional view showing a forward end portion of a sheath tube of still another embodiment and its periphery.

1. Glow Plug

[0009] 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."

[0010] 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).

[0011] 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.

[0012] 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.

[0013] 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)).

[0014] 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.

[0015] 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.

[0016] No particular limitation is imposed on the wire diameter of the heat generation coil 820; however, the wire diameter is preferably 0.1 mm to 0.25 mm.

[0017] 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.

[0018] 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 R_{1000} of the heat generation coil 820 at 1,000°C to the resistance R_{20} of the heat generation coil 820 at 20°C and a resistance ratio R2 which is the ratio of the resistance R_{1000} of the rear coil 830 at 1,000°C to the resistance R_{20} of the rear coil 830 at 20°C satisfy a relation of $R1 > R2$.

[0019] 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.

[0020] 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 right side of the axial line O is taken as one side of the axial line O, and the left 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.

[0021] The fusion zone 891 of the sheath tube 810 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.

[0022] Forward n turns (n is a natural number) of the heat generation coil 820 are inserted into the fusion zone 891. In the present embodiment, two turns of the heat generation coil 820 at the forward end are inserted into the fusion zone 891.

[0023] As shown in FIG. 3, in the fusion zone 891, the first turn 901 and the second turn 902 appear in this order from the forward end side (lower side in the drawing) on opposite sides of the axial line O.

[0024] In a region outside the fusion zone 891, the third turn 903 and the fourth turn 904 appear in this order from the forward end side (lower side in the drawing) on the opposite sides of the axial line O.

[0025] 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 902a. Also, a cross section which is one of the cross sections of the heat generation coil 820 appearing in the fusion zone 891 on the one side of the axial line O and which is located immediately forward of the first heat-generation-element cross section 902a will be referred to as a fourth heat-generation-element cross section 901 a. Also, 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 second heat-generation-element cross section 903a. 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 second heat-generation-element cross section 903a will be referred to as a third heat-generation-element cross section 904a.

[0026] In the present embodiment, a distance A between the first heat-generation-element cross section 902a and the second heat-generation-element cross section 903a is rendered greater than a distance B between the second heat-generation-element cross section 903a and the third heat-generation-element cross section 904a.

[0027] No particular limitation is imposed on the distance A; however, the distance A is preferably greater than 0.2 mm and not greater than 0.6 mm.

[0028] No particular limitation is imposed on the distance B; however, the distance B is preferably not less than 0.1 mm and not greater than 0.2 mm.

[0029] The following actions and effects are yielded when the distance A is rendered greater than the distance B.

[0030] According to one mode of the present invention, the distance A (i.e., space) between the first heat-generation-element cross section 902a and the second heat-generation-element cross section 903a is increased such that the rear end surface 895 of the fusion zone 891 is disposed in the space. Accordingly, even when the amount of the melted material of the sheath tube 810 varies and thus the position of the rear end surface 895 of the fusion zone 891 varies in the axial direction, the rear end surface 895 can be positioned between the first heat-generation-element cross section 902a and the second heat-generation-element cross section 903a without fail. Thus, only a predetermined amount of the material of the heat generation coil 820 at the forward end thereof can be reliably inserted into the fusion zone 891, whereby variation in the resistance at room temperature among individual glow plugs can be suppressed. Accordingly, variation in thermal performance among individual glow plugs can be reduced, and the heat generation coil 820 can be prevented from coming off the sheath tube 810. Notably, the reason why the above-described relation of the distances A and B reduces the variation in thermal performance among individual glow plugs will be described in detail in the after-mentioned section "Examples."

[0031] Further, in the present embodiment, preferably, the distance A and the distance B satisfy the following relational expression.

$$1.30 \leq A/B \leq 4.00$$

[0032] When A/B is equal to or greater than 1.30, the variation in thermal performance among individual glow plugs can be suppressed. When A/B is equal to or less than 4.00, the glow plug 10 can have sufficiently high heat-up performance.

[0033] Further, in the present embodiment, desirably, a distance C between the fourth heat-generation-element cross section 901 a and the first heat-generation-element cross section 902a is equal to or less than the distance B.

[0034] No particular limitation is imposed on the distance C between the fourth heat-generation-element cross section

901a and the first heat-generation-element cross section 902a; however, the distance C is preferably not less than 0 mm and not greater than 0.10 mm.

[0035] By setting the distance C to be equal to or less than the distance B, the wall thickness of the sheath tube 810 between the forward end of the heat generation coil 820 and the surface of the sheath tube 810 (thickness indicated by symbol D in FIG. 3) can be rendered sufficiently large. As a result, it is possible to prevent exposure of the coil 820 which would otherwise occur when the sheath tube 810 wears, whereby durability can be improved.

[0036] A glow plug 10 of another (second) embodiment (modification) will be described with reference to FIG. 7. Notably, constituent members or portions of the glow plug 10 of the second embodiment which are approximately the same as those of the glow plug 10 of the above-described embodiment are denoted by like reference numerals, and description of their structures, actions, and effects is omitted.

[0037] In the glow plug 10 of the second embodiment, as in the glow plug 10 of the above-described embodiment, the radially outermost end 901 aa of the fourth heat-generation-element cross section 901 a is located inward of the radially innermost end 902aa of the first heat-generation-element cross section 902a.

[0038] The glow plug 10 of the second embodiment differs from the glow plug 10 of the above-described embodiment in the following point.

[0039] Namely, the rearmost end 901 ab of the fourth heat-generation-element cross section 901 a is located rearward of the forwardmost end 902ab of the first heat-generation-element cross section 902a. Namely, the fourth heat-generation-element cross section 901 a and the first heat-generation-element cross section 902a are disposed to overlap each other in the axial direction OD. By virtue of this arrangement, the wall thickness of the sheath tube 810 between the forward end of the heat generation coil 820 and the surface of the sheath tube 810 (thickness indicated by symbol D in FIG. 7) can be rendered sufficiently large. As a result, it is possible to prevent exposure of the coil 820 which would otherwise occur when the sheath tube 810 wears, whereby durability can be improved.

2. Method of Manufacturing Glow Plug 10

[0040] FIG. 4 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."

[0041] FIGS. 5(a) and 5(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 the second turn 822P of the heat generation coil 820 comes into contact with the sheath tube 810P (FIG. 5(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. 5(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.

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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]

[0046] The present invention will be described further in detail by way of example.

[0047] Notably, experimental examples 2 to 6 are examples of the present invention, and experimental example 1 is a comparative example.

1. Preparation of Glow Plugs

[0048] In the glow plugs 10 of each experimental example, the forward end shape of the heat generation coil 820 was adjusted so as to adjust the distance A, the distance B, and the distance C. 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 0.330 Ω .
- The sheath tube 810 had an outside diameter of 3.25 mm at a small-diameter portion thereof.
- Each distance was measured as follows: each glow plug 10 after temperature measurement was disassembled, and then the sheath heater 800 was cut along the axial line O of the glow plug such that the same number of cross sections of the heat generation element 820 appeared in the fusion zone 891 on the opposite sides of the axial line O, and the cut surface was used for measurement.

[0049] The sheath heater 800 was cut such that the region where the forward end portion 831 of the rear coil 830 and the rear end portion 829 of the heat generation coil 820 are welded together appeared on the cut surface on the left side (on the other side), and the clearances between the cross sections of the heat generation coil 820 were measured on the cut surface on the right side (on one side).

2. Performance Test

2.1 Variation in temperature

[0050] 20 glow plugs 10 were prepared for each experimental example. A rated voltage was applied to each glow plug 10, and the temperature of the glow plugs 10 was measured after elapse of 100 seconds. The value of 3σ was obtained for the temperatures of the 20 glow plugs 10 for each experimental example and was evaluated as follows.

O (good): The value of 3σ was less than 70°C

X (poor): The value of 3σ was equal to or greater than 70°C

[0051] The rated voltage was determined as follows. Namely, the voltage sensitivity of the first glow plug for each experimental example was measured, the relation between voltage and temperature was determined, and a voltage at which the temperature becomes 1,100°C was used as the rated voltage.

[0052] Notably, 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.

2.2 Durability

[0053] A voltage for increasing the glow plug temperature by 1,000°C in two seconds was applied to each glow plug 10; then, a voltage for saturating the glow plug temperature at 1,100°C was applied to each glow plug 10 continuously for 180 seconds. Subsequently, each glow plug 10 was cooled by wind for 120 seconds for lowering the glow plug temperature to room temperature. With this procedure taken as one cycle, a cycle test was conducted. Each glow plug 10 was subjected to 7,000 test cycles. Each glow plug 10 was evaluated on the basis of the results of the determination

as to whether or not a wire breakage occurred during the durability test.

O (good): No wire breakage occurred even after 500 hours (about 6,000 cycles)

X (poor): Wire breakage occurred before 500 hours (about 6,000 cycles)

[0054] Notably, 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.

2.3 Rapid heat-up performance

[0055] A voltage of 11 V was applied to each glow plug 10 for 2 seconds, and its temperature after elapse of 2 seconds was measured. 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. The rapid heat-up performance was evaluated as follows.

O (good): The temperature reached after elapse of 2 seconds was 900°C or higher

X (poor): The temperature reached after elapse of 2 seconds was lower than 900°C

3. Test Results

[0056] Table 1 shows the test results.

Table 1

Experimental example	A (mm)	B (mm)	C (mm)	A/B	C/B	Temp. variation	Durability	Rapid heat-up performance
1	0.10	0.10	0.07	1.00	0.700	X	X ⁽¹⁾	○
2	0.13	0.10	0.07	1.30	0.700	○	○	○
3	0.40	0.10	0.07	4.00	0.700	○	○	○
4	0.45	0.10	0.07	4.50	0.700	○	○	X
5	0.50	0.10	0.10	5.00	1.000	○	○	○
6	0.50	0.10	0.13	5.00	1.300	○	X ⁽²⁾	○
(1) The heat generation coil came off the sheath tube. (2) The forward end of the heat generation coil was exposed from the forward end of the sheath tube.								

[0057] In experimental examples 2 to 6, the value of 3σ (index of temperature variation) was less than 70°C, and the temperature variation among the individual glow plugs 10 was small. Meanwhile, in experimental example 1, the value of 3σ (index of temperature variation) was equal to or greater than 70°C, and the temperature variation was large. Accordingly, it was confirmed that when the distance A is rendered greater than the distance B, the variation in thermal performance among individual glow plugs can be reduced.

[0058] Further, for experimental examples 2 and 3 which also meet the requirement that the value of A/B is not less than 1.30 and not greater than 4.00, it was confirmed that the variation in thermal performance among individual glow plugs can be suppressed, and rapid heat-up performance can be secured to a sufficient degree.

[0059] Also, in the case of experimental examples 2 to 5 which also meet the requirement that the distance C between the first turn and the second turn is equal to or less than the distance B, even after about 6,000 cycles, the forward end of the heat generation coil was not exposed from the forward end of the sheath tube. Thus, it was confirmed that when the distance C is equal to or less than the distance B, durability is excellent.

<Other Embodiments (Modifications)>

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

(1) In the above-described embodiments, as shown in FIG. 5(a), the glow plug 10 is manufactured by use of the sheath tube 810P having the opening 815; however, as shown in FIG. 6(a), the glow plug 10 may be manufactured

by use of a sheath tube 810R having no opening. In FIGS. 6(a) and 6(b), constituent members or portions approximately the same as those of the glow plugs of the above embodiments are denoted by like reference numerals, and description of their structures, actions, and effects is omitted.

(2) In the above-described embodiments, two turns of the heat generation coil 820 at the forward end thereof are inserted into the fusion zone 891. However, the number of turns inserted into the fusion zone 891 is not limited to two. For example, one to five turns of the heat generation coil 820 at the forward end thereof may be inserted into the fusion zone 891.

[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
 890: fusion zone
 891: fusion zone
 893: base metal portion
 901: first turn
 902: second turn
 903: third turn
 904: fourth turn

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 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),
 with a cross section which is a rearmost one of cross sections of the heat generation element (820) appearing
 in the fusion zone (891) on one side of the axial line (O) and which is disposed at least partially within the fusion
 zone (891) being defined as a first heat-generation-element cross section (902a),
 5 with a forwardmost one of cross sections of the heat generation element (820) appearing externally of the fusion
 zone (891) on the one side of the axial line (O) being defined as a second heat-generation-element cross section
 (903a), and
 with 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
 10 second heat-generation-element cross section (903a) being defined as a third heat-generation-element cross
 section (904a),
 a distance A in the direction of the axial line (O) between a rearmost end of the first heat-generation-element
 cross section (902a) and a forwardmost end of the second heat-generation-element cross section (903a) is
 greater than a distance B in the direction of the axial line (O) between a rearmost end of the second heat-
 15 generation-element cross section (903a) and a forwardmost end of the third heat-generation-element cross
 section (904a).

2. A glow plug according to claim 1, wherein the distance A and the distance B satisfy a relational expression of $1.30 \leq A/B \leq 4.00$.

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

in the cross section of the glow plug (10),
 with a cross section which is one of the cross sections of the heat generation element (820) appearing in the
 25 fusion zone (891) on the one side of the axial line (O) and which is located immediately forward of the first heat-
 generation-element cross section (902a) being defined as a fourth heat-generation-element cross section (901
 a),
 a distance C in the direction of the axial line (O) between a rearmost end of the fourth heat-generation-element
 cross section (901 a) and a forwardmost end of the first heat-generation-element cross section (902a) (including
 30 the case where $C = 0$) is equal to or less than the distance B.

4. A glow plug according to claim 1 or 2, wherein

in the cross section of the glow plug (10),
 35 with a cross section which is one of the cross sections of the heat generation element (820) appearing in the
 fusion zone (891) on the one side of the axial line (O) and which is located immediately forward of the first heat-
 generation-element cross section (902a) being defined as a fourth heat-generation-element cross section (901
 a),
 a radially outermost end of the fourth heat-generation-element cross section (901 a) is located inward of a
 40 radially innermost end of the first heat-generation-element cross section (902a), and
 a rearmost end of the fourth heat-generation-element cross section (901a) is located rearward of a forwardmost
 end of the first heat-generation-element cross section (902a).

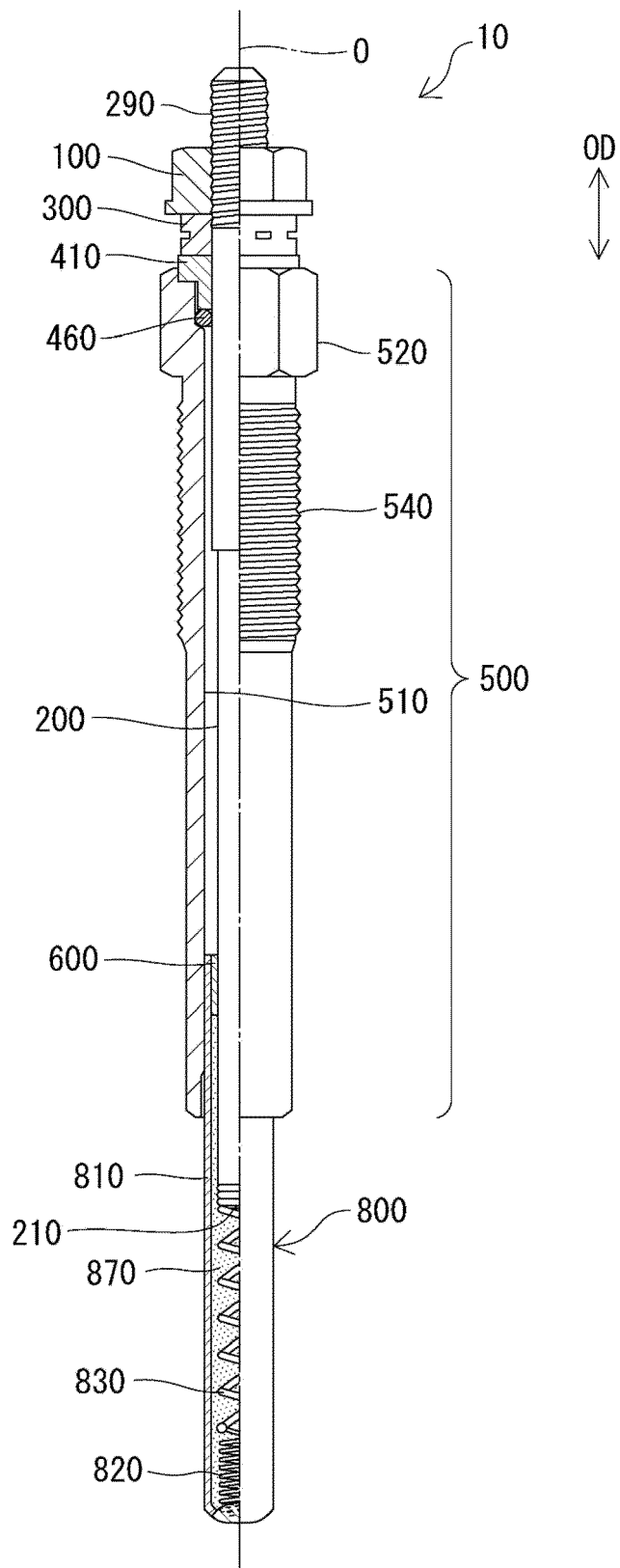


FIG. 1

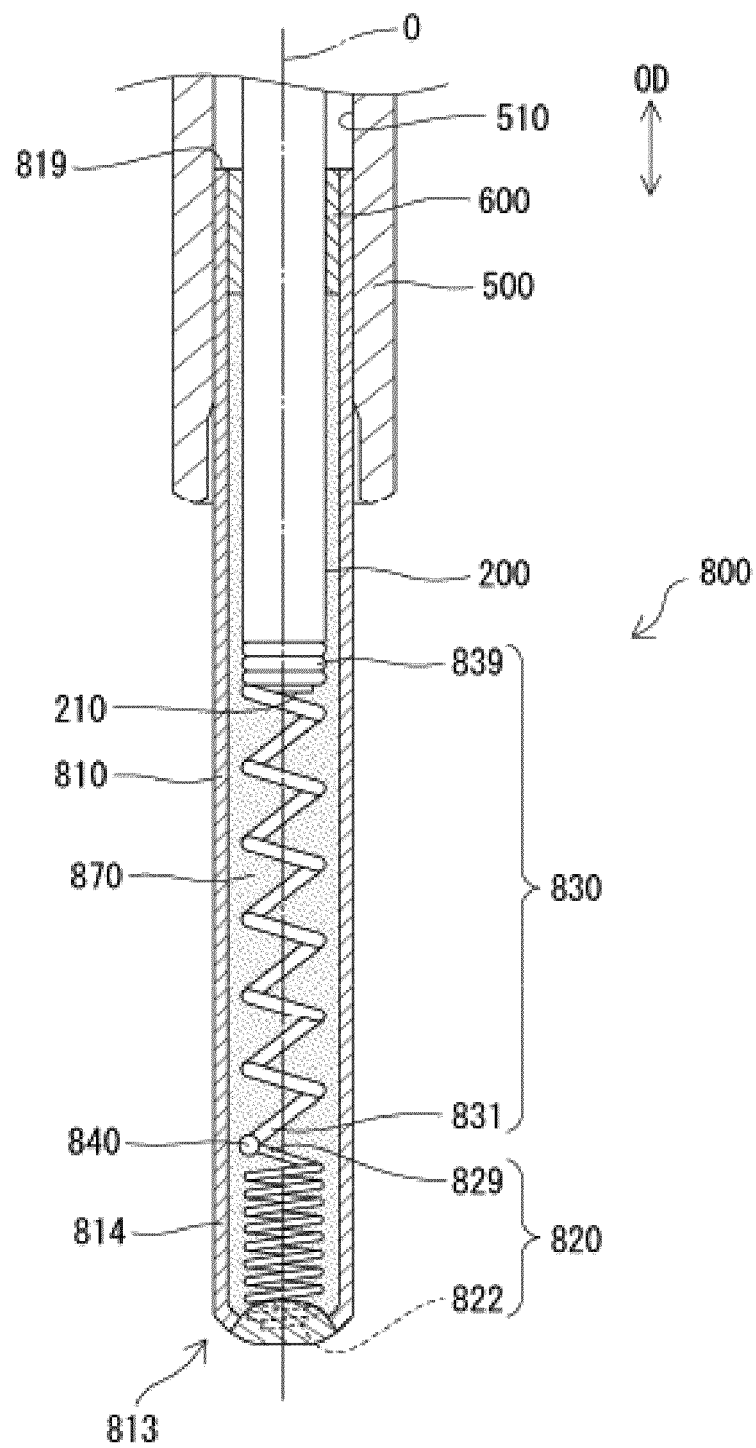


FIG. 2

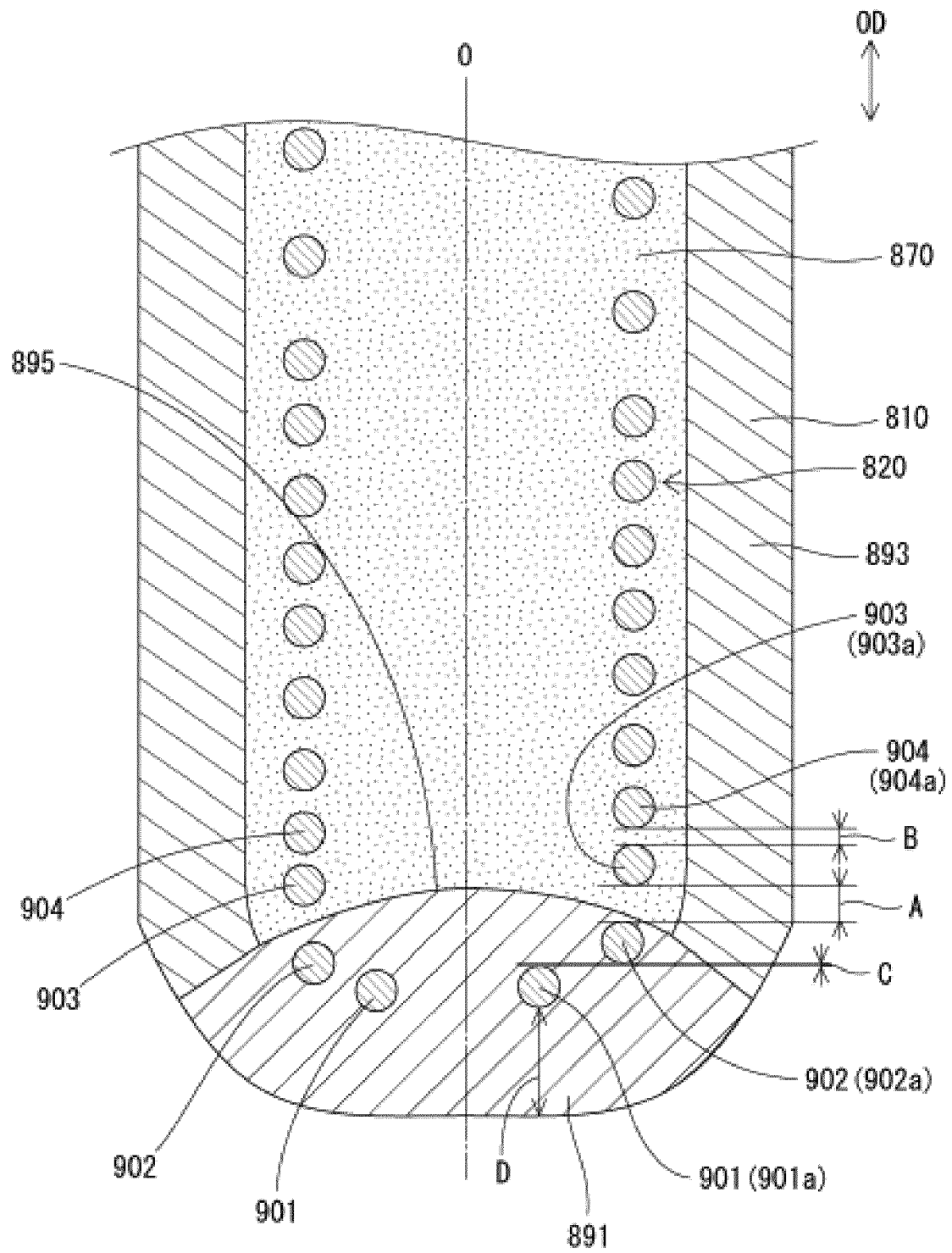


FIG. 3

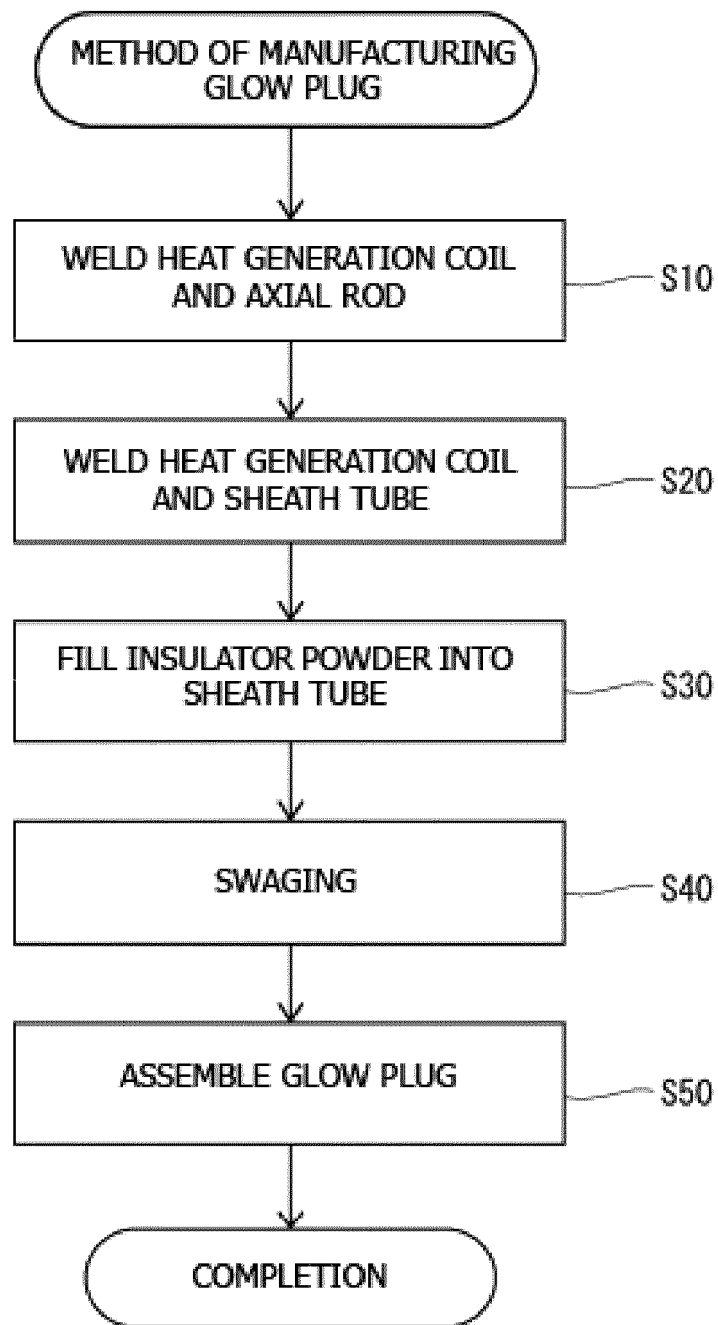


FIG. 4

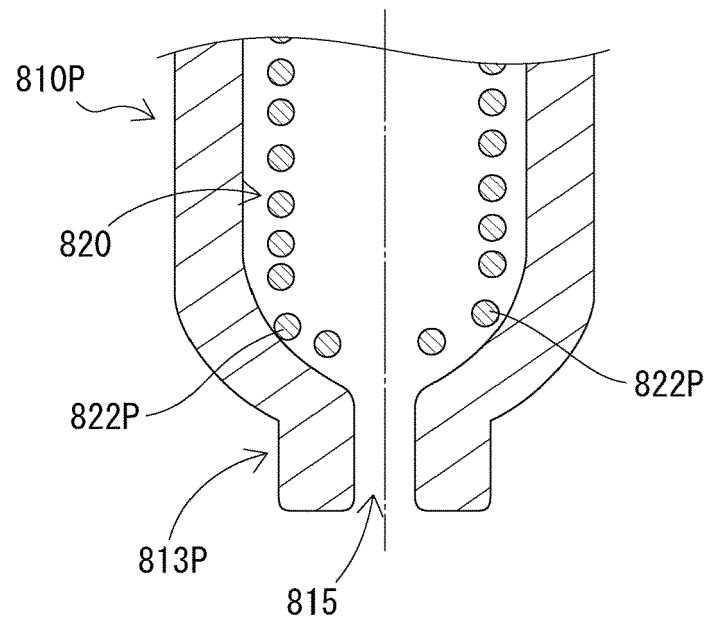


FIG. 5(a)

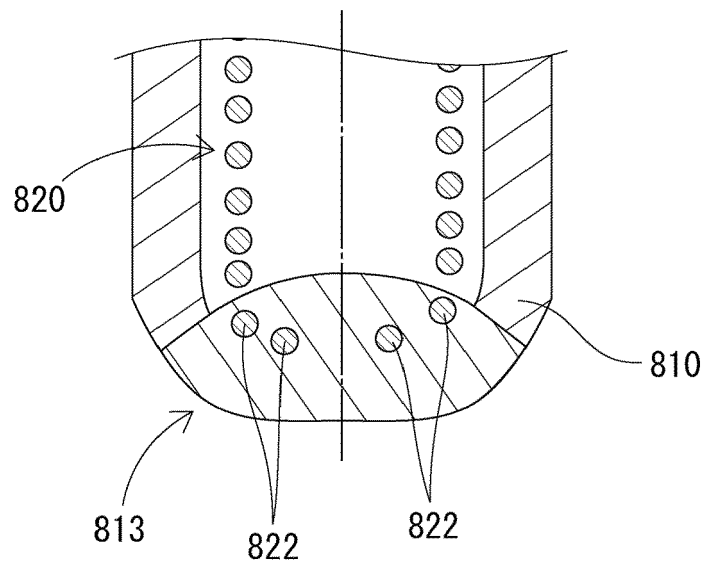


FIG. 5(b)

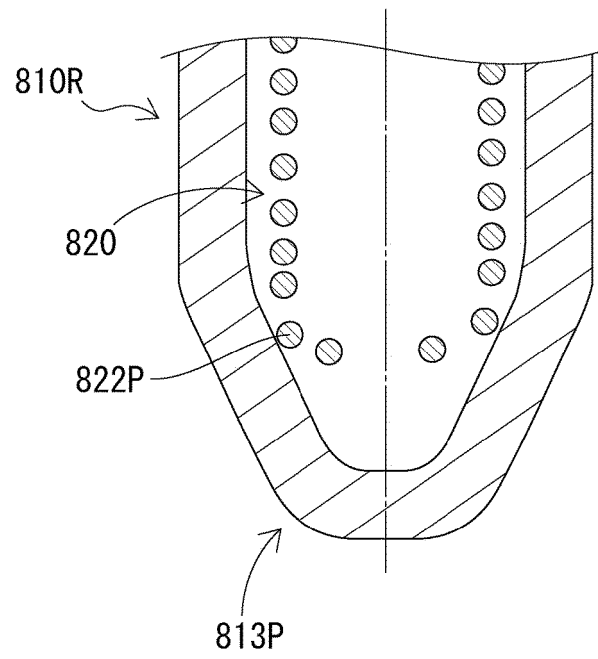


FIG. 6(a)

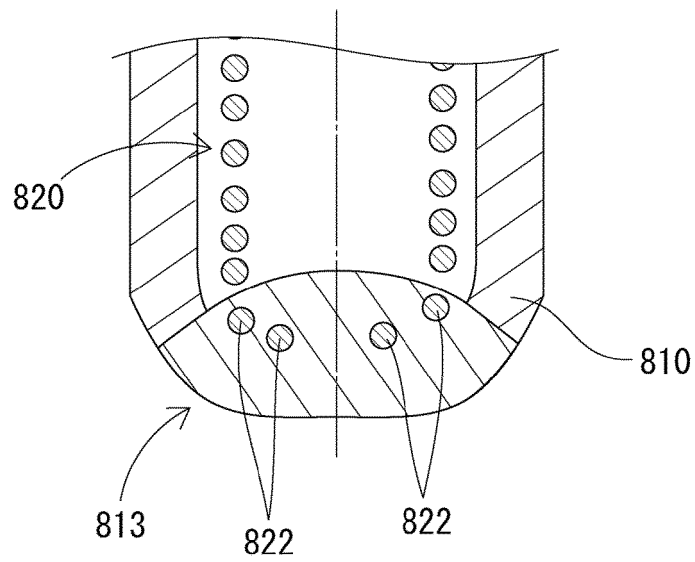


FIG. 6(b)

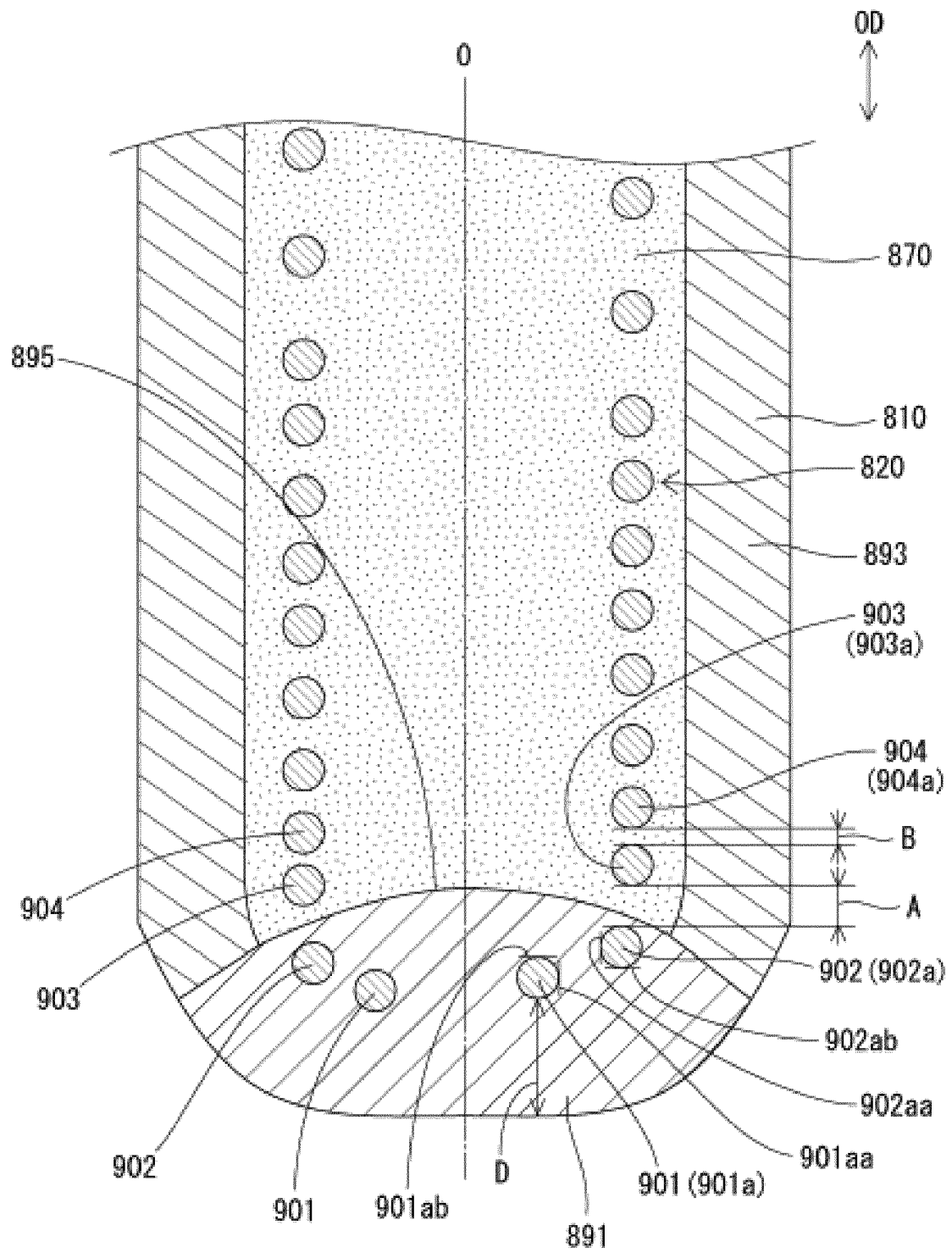


FIG. 7



EUROPEAN SEARCH REPORT

Application Number
EP 18 16 5741

5

10

15

20

25

30

35

40

45

50

55

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	EP 2 587 156 A1 (NGK SPARK PLUG CO [JP]) 1 May 2013 (2013-05-01) * paragraphs [0001], [0004], [0005], [0008]; claim 1 * * paragraphs [0037], [0038] * * paragraphs [0081], [0084] * -----	1	INV. F23Q7/00
A	US 5 118 921 A (AOTA TAKASHI [JP] ET AL) 2 June 1992 (1992-06-02) * column 1, line 8 - line 16; figures 2,3,4A,4B * * column 2, line 60 - column 3, line 15 * * column 4, line 24 - column 5, line 18 * -----	1-4	
A	GB 859 659 A (BOSCH GMBH ROBERT) 25 January 1961 (1961-01-25) * page 1, line 8 - line 18; figures 1-4 * * page 2, line 4 - line 15 * * page 2, line 35 - line 44 * * page 2, line 76 - line 85 * -----	1-4	
A	JP S58 21 A (NGK SPARK PLUG CO) 5 January 1983 (1983-01-05) * the whole document * -----	1-4	TECHNICAL FIELDS SEARCHED (IPC) F23Q
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 21 August 2018	Examiner Hauck, Gunther
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 18 16 5741

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

21-08-2018

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2587156 A1	01-05-2013	DE 102011077239 A1	22-12-2011
		EP 2587156 A1	01-05-2013
		JP 5255706 B2	07-08-2013
		JP W02011162074 A1	19-08-2013
		WO 2011162074 A1	29-12-2011

US 5118921 A	02-06-1992	JP H04119 A	06-01-1992
		JP 2852552 B2	03-02-1999
		US 5118921 A	02-06-1992

GB 859659 A	25-01-1961	NONE	

JP S5821 A	05-01-1983	NONE	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2014206847 A [0002] [0003] [0004]