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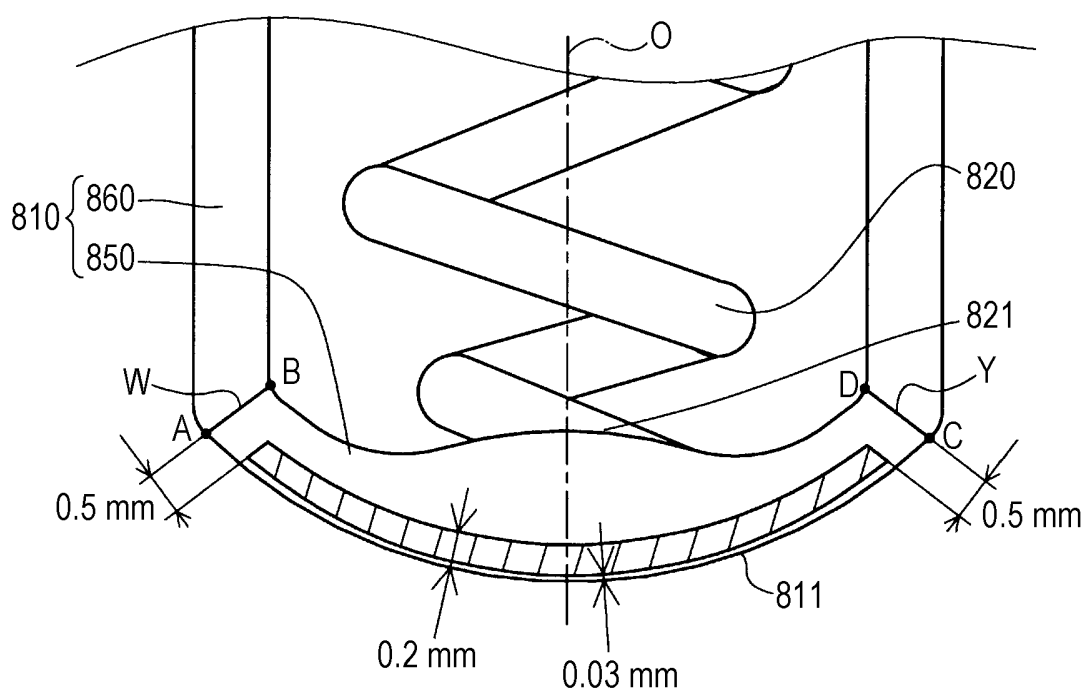
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(54) **GLOW PLUG AND METHOD FOR MANUFACTURING THE SAME**

(57) A tubular sheath included in a glow plug includes a cylindrical member that is disposed around the heating element and extends in a direction of an axis, and a melted portion that contains at least a main component of the cylindrical member and a main component of the heating element and blocks a front end of the cylindrical member.

When C represents an average chromium content in terms of mass% and A represents an average aluminum content in terms of mass% in a region in which a distance from an outer surface of the melted portion in a direction toward an inner region is more than 0.03 mm, an average content ratio C/A is 2.1 or more and 6.7 or less.

FIG. 5



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

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

2. Description of the Related Art

[0002] Glow plugs are heaters used as auxiliary heat sources for compression-ignition internal combustion engines, such as diesel engines. Glow plugs are required to have, for example, sufficient durability in the environment in combustion chambers in which they are used. To improve such characteristics, various material compositions have been proposed (see, for example, Japanese Unexamined Patent Application Publication No. 2004-264013).

[0003] When electricity is supplied to a glow plug, an oxide film composed of Cr_2O_3 is formed on the surface of the glow plug when the glow plug contains chromium, and an oxide film composed of Al_2O_3 is formed on the surface of the glow plug when the glow plug contains aluminum. The oxide film protects a bulk from oxidation, so that the durability is increased. Here, the bulk is a portion located on the inner side of the oxide film.

[0004] Because the oxide film is formed on the surface of the glow plug as described above, the oxide film receives a thermal stress every time combustion occurs in the combustion chamber. The oxide film may be separated from the bulk owing to the thermal stress. When the oxide film is separated, a surface layer of the bulk is exposed and converted into an oxide film. The newly formed oxide film may also be separated owing to the thermal stress. Each time an oxide film is separated, the thickness of that portion decreases. This phenomenon is called oxidation consumption in this specification.

[0005] Because the oxide film not only protects the bulk but also leads to oxidation consumption as described above, an adequate amount of oxide film is preferably formed. The amount of oxide film that is formed can presumably be controlled by adjusting the amount of at least one of aluminum and chromium contained in the glow plug to an adequate amount.

[0006] When electricity is repeatedly applied to the glow plug, a crack may be formed in a region around the front end of the glow plug. The crack is often formed in an interface of a melted portion formed when a cylinder portion and a heating coil are welded together. The formation of a crack is also presumably affected by the amounts of aluminum and chromium.

SUMMARY OF THE INVENTION

[0007] In light of the above-described circumstances, an object of the present disclosure is to suppress oxidation consumption and formation of a crack in a melted

portion by controlling the amount of at least one of aluminum and chromium contained in a glow plug, thereby increasing the durability of the glow plug.

[0008] The present invention has been made to achieve this object and has the following aspects.

(1) According to an aspect of the present invention, a glow plug is provided. The glow plug includes a heating element that generates heat when electricity is applied to the heating element; and a tubular sheath including a cylindrical member that is disposed around the heating element and extends in a direction of an axis, and a melted portion that contains at least a main component of the cylindrical member and a main component of the heating element and blocks a front end of the cylindrical member. In this glow plug, when C represents an average chromium content in terms of mass% and A represents an average aluminum content in terms of mass% in a predetermined region in which a distance from an outer surface of the melted portion in a direction toward an inner region is more than 0.03 mm, an average content ratio C/A is 2.1 or more and 6.7 or less. According to this aspect, oxidation consumption and formation of a crack in the melted portion can be suppressed.

(2) In the above-described aspect, the average content ratio C/A may be 2.9 or more and 5.4 or less. According to this aspect, oxidation consumption and formation of a crack in the melted portion can be further suppressed.

(3) In the above-described aspect, the average content ratio C/A may be 3.5 or more and 3.7 or less. According to this aspect, oxidation consumption and formation of a crack in the melted portion can be further suppressed.

(4) In the above-described aspect, in cross section including the axis, a thickness of the melted portion along the axis may be 0.5 mm or more and 1.0 mm or less. According to this aspect, even when oxidation consumption occurs in the melted portion, nitrogen-blocking performance of the melted portion is maintained.

(5) In the above-described aspect, the average aluminum content A may be 2.4 mass% or more in the predetermined region. According to this aspect, the nitrogen-blocking performance of the melted portion can be increased, and nitridation of the heating element can be suppressed.

(6) In the above-described aspect, the average aluminum content A may be 4.5 mass% or less in the predetermined region. According to this aspect, the average content ratio C/A can be easily set to a value within the above-described range.

(7) In the above-described aspect, the average chromium content C may be 8 mass% or more and 16 mass% or less in the predetermined region. According to this aspect, the average content ratio C/A can

be easily set to a value within the above-described range.

(8) In the above-described aspect, the cylindrical member may have an aluminum content of 1.2 mass% or more and 2.2 mass% or less, a chromium content of 14.5 mass% or more and 22.1 mass% or less, and a nickel content of 66.1 mass% or more. According to this aspect, the average content ratio C/A can be easily set to a value within the above-described range.

(9) In the above-described aspect, the heating element may have an aluminum content of 3.8 mass% or more and 10 mass% or less, a chromium content of 13.1 mass% or more and 20.3 mass% or less, and an iron content of 69.5 mass% or more and 80.3 mass% or less. According to this aspect, the average content ratio C/A can be easily set to a value within the above-described range.

(10) In the above-described aspect, the melted portion may have an aluminum content of less than 5 mass% in a region near a boundary between the melted portion and the cylindrical member. According to this aspect, the difference between the aluminum content in the cylindrical member and the average aluminum content in the melted portion can be easily reduced.

(11) In the above-described aspect, an average iron content may be 17 mass% or more and 21 mass% or less in the predetermined region. According to this aspect, aggregation of iron can be suppressed, so that oxidation consumption can be suppressed.

(12) According to another aspect, a method for manufacturing the glow plug according to the above-described aspect is provided. The method includes a step of forming the melted portion by welding the heating element and the cylindrical member together. Before the step, the heating element includes a helical portion and a linear portion that is connected to a front end of the helical portion and that has a front end that serves as a front end of the heating element. Before the step, the cylindrical member includes a narrowing portion having a diameter that decreases toward a front end of the narrowing portion and an opening at the front end of the narrowing portion. In the step, the welding is started in a state such that the linear portion is positioned at a front end side with respect to the opening in the narrowing portion. According to this aspect, compared with the case in which the front end of the heating element has, for example, a wound shape, the amount of a portion of the heating element that is melted in the welding process can be more easily adjusted. Therefore, the above-described numerical ranges can be more easily achieved in the above-described glow plug.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

- 5 Fig. 1 is a partially sectioned external view of a glow plug;
 Fig. 2 is a partially sectioned view of a region around a melted portion;
 10 Fig. 3 illustrates a region around a front end before a tubular sheath and a heating coil are welded together;
 Fig. 4 illustrates regions to be analyzed near boundaries between the melted portion and a cylinder portion;
 15 Fig. 5 illustrates a region to be analyzed near the surface of the melted portion;
 Fig. 6 is a table showing the relationship between the average content ratio and durability;
 Fig. 7 is a diagram used to describe a crack growth rate;
 20 Fig. 8 is a table showing the relationship between the thickness of the melted portion and durability against breakage;
 Fig. 9 illustrates a region around a front end before a tubular sheath and a heating coil are welded together according to another embodiment; and
 25 Fig. 10 illustrates a region around a front end before a tubular sheath and a heating coil are welded together according to another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

35 **[0010]** Fig. 1 illustrates a glow plug 10. In Fig. 1, the external structure of the glow plug 10 is shown on the right side of an axis O, and the cross sectional structure of the glow plug 10 is shown on the left side of the axis O. The glow plug 10 functions as a heat source that assists ignition when a diesel engine is started.

40 **[0011]** The glow plug 10 includes a center wire 200, a metal shell 500, and a sheath heater 800 that generates heat when electricity is applied thereto. These members are assembled together along the axis O of the glow plug 10. In this specification, a side at which the sheath heater 800 is provided in the glow plug 10 is referred to as a "front end side", and a side opposite the front end side is referred to as a "rear end side".

45 **[0012]** The metal shell 500 is a cylindrical member formed of carbon steel. The sheath heater 800 is held by a front end portion of the metal shell 500. The center wire 200 is held by a rear end portion of the metal shell 500 with an insulating member 410 and an O-ring 460 interposed therebetween. A ring 300, which is in contact with the rear end of the insulating member 410, is crimped onto the center wire 200, so that the position of the insulating member 410 in the direction of the axis O is fixed.
 50 The rear end of the metal shell 500 is insulated from the center wire 200 by the insulating member 410. The metal shell 500 covers a portion of the center wire 200 that

extends from the insulating member 410 to the sheath heater 800. The metal shell 500 has an axial hole 510, a tool engagement portion 520, and an externally threaded portion 540.

[0013] The axial hole 510 is a through hole that extends along the axis O, and has a diameter greater than that of the center wire 200. When the center wire 200 is positioned with respect to the axial hole 510, an air gap that electrically insulates the axial hole 510 and the center wire 200 from each other is provided between the axial hole 510 and the center wire 200. The sheath heater 800 is bonded to a front end portion of the axial hole 510 by being press-fitted into the axial hole 510. The externally threaded portion 540 is on the rear side of the sheath heater 800 that is press-fitted, and is fastened to an internally threaded portion formed in an internal combustion engine (not shown). The tool engagement portion 520, which is on the rear side of the externally threaded portion 540, engages with a tool (not shown) used to attach and detach the glow plug 10.

[0014] The center wire 200 is a columnar member made of a conductive material. The center wire 200 is arranged so as to extend along the axis O in such a manner that the center wire 200 is inserted in the axial hole 510 in the metal shell 500. The center wire 200 includes a center-wire front end portion 210 formed at the front end thereof and a connecting portion 290 formed at the rear end thereof. The center-wire front end portion 210 is inserted in the sheath heater 800. The connecting portion 290 is an externally threaded portion that projects from the metal shell 500. The connecting portion 290 is fastened to an engagement member 100.

[0015] Fig. 2 is a partially sectioned view illustrating the detailed structure of the sheath heater 800. The sheath heater 800 includes a tubular sheath 810, a heating coil 820 that functions as a heating element, a control coil 830, and insulating powder 840.

[0016] The tubular sheath 810 extends in the direction of the axis O, and has the shape of a cylinder with a bottom. The tubular sheath 810 accommodates the heating coil 820, the control coil 830, and the insulating powder 840. The tubular sheath 810 includes a tubular-sheath front end portion 811 and a tubular-sheath rear end portion 819. The tubular-sheath front end portion 811 is an externally rounded end portion provided at the front end of the tubular sheath 810. The tubular-sheath rear end portion 819 is an end portion that opens at the rear end of the tubular sheath 810. The center-wire front end portion 210 of the center wire 200 is inserted into the tubular sheath 810 through the tubular-sheath rear end portion 819. The tubular sheath 810 is electrically insulated from the center wire 200 by a packing 600 and the insulating powder 840. The packing 600 is an insulating member that is disposed at the rear end of the tubular sheath 810 in the direction of the axis O and interposed between the center wire 200 and the tubular sheath 810. The tubular sheath 810 is electrically connected to the metal shell 500.

[0017] The control coil 830 is formed of a conductive material whose temperature coefficient of electrical resistivity is greater than that of the material of the heating coil 820. The conductive material is preferably nickel. Alternatively, the conductive material may be an alloy having, for example, cobalt or nickel as the main component. The control coil 830 is disposed in the tubular sheath 810, and controls the electric power supplied to the heating coil 820. The control coil 830 includes a control-coil front end portion 831 at the front end thereof and a control-coil rear end portion 839 at the rear end thereof. The control-coil front end portion 831 is welded to a heating-coil rear end portion 829 of the heating coil 820, and is thereby electrically connected to the heating coil 820. The control-coil rear end portion 839 is bonded to the center-wire front end portion 210 of the center wire 200, and is thereby electrically connected to the center wire 200.

[0018] The insulating powder 840 is powder that has an electrically insulating property. The insulating powder 840 may be, for example, powder of magnesium oxide (MgO). The inner space of the tubular sheath 810 is filled with the insulating powder 840, so that the tubular sheath 810 is electrically insulated from the heating coil 820, the control coil 830, and the center wire 200.

[0019] The heating coil 820 is a coil made of a conductive material. The heating coil 820 is disposed in the tubular sheath 810 so as to extend in the direction of the axis O, and generates heat when electricity is supplied thereto. The heating coil 820 includes a heating-coil front end portion 821 at the front end thereof and the heating-coil rear end portion 829 at the rear end thereof. The heating-coil front end portion 821 is welded to a portion of the tubular sheath 810 around the front end thereof, and is thereby electrically connected to the tubular sheath 810.

[0020] Fig. 3 illustrates a region around the front end before the tubular sheath 810 and the heating coil 820 are welded together. The tubular sheath 810 includes a first cylindrical portion 813, a narrowing portion 814, and a second cylindrical portion 815 when the sheath tube 810 is not yet welded to the heating coil 820. The first cylindrical portion 813 is a portion having a substantially constant diameter in the direction of the axis O. The narrowing portion 814 is connected to the front end of the cylindrical portion 813. The narrowing portion 814 is a portion having a diameter that decreases toward the front end thereof. The second cylindrical portion 815 is connected to the front end of the narrowing portion 814, and is a portion having a substantially constant diameter in the direction of the axis O. The narrowing portion 814 has an opening 816 at the front end thereof. The opening 816 is an air gap provided at the boundary between the narrowing portion 814 and the second cylindrical portion 815.

[0021] The heating coil 820 includes a helical portion 823 and a linear portion 824 when the heating coil 820 is not yet welded to the tubular sheath 810. The helical

portion 823 is a portion having a helical shape. The linear portion 824 is a portion that has a linear shape and that is connected to the front end of the helical portion 823. The front end of the linear portion 824 serves as the front end of the heating coil 820 before welding.

[0022] The heating coil 820 is arranged such that the linear portion 824 extends to the opening 816 before being welded. In the present embodiment, the linear portion 824 is arranged so as to extend through the opening at the front end of the second cylindrical portion 815. As illustrated in Fig. 3, the linear portion 824 extends at an angle with respect to the axis O. In this arrangement, the process of welding the tubular sheath 810 and the heating coil 820 together is started. After the welding process, a melted portion 850 is formed and a portion around the front end is shaped as illustrated in Fig. 2. In the present embodiment, arc welding is performed in the welding process.

[0023] Fig. 4 illustrates a region around the melted portion 850 after the tubular sheath 810 and the heating coil 820 are welded together. The melted portion 850 is a portion formed when parts of the heating coil 820 and the tubular sheath 810 are mixed together in the melted state and then solidified. In Fig. 4, the melted portion 850 is shown as a hatched area. The outer surface of the melted portion 850 forms the tubular-sheath front end portion 811. A cylinder portion 860 illustrated in Fig. 4 is a portion of the tubular sheath 810 excluding the melted portion 850. The cylinder portion 860 is a cylindrical member that extends in the direction of the axis O. The melted portion 850 is formed as a result of the welding process as described above, and therefore contains at least the main component of the heating coil 820 and the main component of the cylinder portion 860. Here, the main component is the component with the highest mass%, which may be less than 50 mass%, or greater than or equal to 50 mass%.

[0024] Component analysis of the melted portion 850 will be described with reference to Fig. 4. The subject of the analysis described below is regions near boundaries between the melted portion 850 and the cylinder portion 860. The regions to be analyzed are determined as follows. That is, first, on the left side of the axis O in Fig. 4, a straight line W is drawn so that the line W passes through the foremost point A and the rearmost point B of the interface between the melted portion 850 and the cylinder portion 860. The straight line W is not necessarily the interface between the melted portion 850 and the cylinder portion 860.

[0025] The interface between the melted portion 850 and the cylinder portion 860 is determined as follows. That is, for example, the cross section is subjected to mirror-polishing, and is then subjected to electrolytic etching using oxalic acid dihydrate. Then, the interface is visually determined on the basis of an enlarged image of the cross section.

[0026] Then, a straight line X obtained by translating the straight line W toward the axis O by 0.3 mm is drawn.

Points located every 10 μm along the straight line X on the melted portion 850 are analyzed. The aluminum content is determined by the analysis for each point, and the average value of the determined aluminum contents is calculated as the aluminum content in the region near the boundary. Points in a region within 0.03 mm from the surface of the melted portion 850 are excluded from the analysis result since an oxide film is likely to be included in that region.

[0027] Similarly, on the right side of the axis O in Fig. 4, a straight line Y is drawn so that the line Y passes through the foremost point C and the rearmost point D of the interface between the melted portion 850 and the cylinder portion 860. Then, a straight line Z obtained by translating the straight line Y toward the axis O by 0.3 mm is drawn. Points located every 10 μm along the straight line Z on the melted portion 850 are analyzed. However, points in a region within 0.03 mm from the surface of the melted portion 850 are excluded from the analysis result since an oxide film is likely to be included in that region.

[0028] The regions to be analyzed are determined as described above because it is assumed that a crack is easily formed in these regions. Here, the crack is a line formed at the interface. An intermetallic compound having low toughness is easily formed in a region near the boundary between the melted portion 850 and the cylinder portion 860, and has thermal expansion characteristics different from those of the original metals. In addition, the region near the boundary is mechanically weak. Therefore, a crack may be formed at the interface near the boundary when thermal expansion and contraction are repeated. In the present embodiment, each of the above-described regions is regarded as the region near the boundary.

[0029] The analysis procedure will be described. In a first step, qualitative analysis of the melted portion 850 is performed by using a wavelength dispersive X-ray spectrometer (WDS) of an electron probe micro analyzer (EPMA). This analysis is performed to determine the elements contained in the melted portion 850. The element with the highest mass% is determined as the main component.

[0030] In a second step, measurement conditions for the EPMA are determined. The determination is carried out to increase the analysis accuracy. The measurement conditions are determined so that a measurement count number of 10,000 or more can be obtained at a beam current that does not cause a counting loss due to a high X-ray dose when the main component determined in the first step is detected.

[0031] In a third step, quantitative analysis of the element determined in the first step is performed under the conditions determined in the second step. Then, the above-described average value for the analysis points is calculated as the aluminum content. At an acceleration voltage of 20 kV, a probe current of 2.5×10^{-8} A, and a beam spot diameter of 10 μm , the main peak is acquired

for 10 seconds and the background is acquired for 5 seconds for each of the high-angle side and the low-angle side. The count per second (CPS) of each element is determined from the raw intensity, and quantitative calculation is performed by a ZAF method by using the CPS of a comparative sample (standard sample produced by ASTIMEX) analyzed under the same conditions. The aluminum content of the comparative sample is analyzed in advance. ZAF is an acronym of atomic number effect (Z effect), absorption effect, and fluorescence excitation effect. In the quantitative calculation, normalization (standardization) is performed so that the total content is 100%.

[0032] The aluminum content in the region near the boundary was determined by the above-described method for Experiment Nos. 4 to 16 and 18 (see Fig. 6), which will be described below. As a result, the aluminum content was less than 5 mass% for each of Experiment Nos. 4 to 16 and 18.

[0033] The thickness T of the melted portion 850 is defined as illustrated in Fig. 4. As illustrated in Fig. 4, the thickness T is defined as the thickness of the melted portion 850 along the axis O in the cross section including the axis O.

[0034] Component analysis of a region near the surface of the melted portion 850 will be described. The component analysis of the region near the surface is performed to analyze the contents of aluminum, chromium, and iron in terms of mass%. In Fig. 5, the region subjected to the analysis is shown as a hatched area. Similar to Fig. 4, Fig. 5 illustrates a region near the melted portion 850. The region subjected to the analysis is a region in which the depth from the surface of the melted portion 850 is in the range of 0.03 mm to 0.2 mm. As illustrated in Fig. 5, the depth direction described herein is the direction perpendicular to the surface. The region in which the depth is less than 0.03 mm is excluded to exclude the oxide film from the region to be analyzed, as described above.

[0035] The regions near the boundaries between the melted portion 850 and the tubular sheath 810 are also excluded from the region to be analyzed. More specifically, as illustrated in Fig. 5, the regions in which the distance from the straight lines W and Y is less than 0.5 mm are excluded. When the regions near the boundaries between the tubular sheath 810 and the melted portion 850 are analyzed by the EPMA, even a small change in position may cause a large variation in the content of the main component or switching of the element determined as the main component. Such a region is not suitable as a measurement subject for which the average content in the melted portion 850 is measured, and is therefore excluded. The region near the boundary between the heating coil 820 and the melted portion 850 is also excluded from the measurement subject. However, in the case where the thickness T is large and the boundary between the heating coil 820 and the melted portion 850 is separated from the region to be analyzed, it is not necessary to exclude the region near the boundary from the meas-

urement subject.

[0036] The aluminum content is determined for each of a predetermined number of points (for example, 10 points) selected from the region to be analyzed, and the average value of the aluminum contents is calculated as the average aluminum content in the region near the surface. The average content is also calculated for chromium and iron in a similar manner. The analysis for each point is carried out by a method similar to that including the above-described first to third steps for analyzing the region near the boundary. However, the beam spot diameter is changed to 100 μm . The points to be analyzed may be selected randomly or such that they are distributed as evenly as possible.

[0037] Fig. 6 is a table illustrating the results of experiments for studying the relationship between the average content ratio C/A (described below) in the region near the surface of the melted portion 850 and durability (described below). Fig. 6 also shows the compositions of the heating coil 820 and the cylinder portion 860 used to achieve the average aluminum and chromium contents in the melted portion 850 for each experiment number in terms of mass%. For each experiment number, the thickness T was 0.4 mm before the experiment, and the average iron content in the melted portion 850 was 17 mass% or more and 21 mass% or less.

[0038] For each experiment number, the sum of the contents of components of the heating coil 820 was 99.8%, and the sum of the contents of components of the cylinder portion 860 was 99.7%. For each of the heating coil 820 and the cylinder portion 860, the sum of the contents of the components was less than 100% because small amounts of additives and impurities are contained. The impurities include, for example, carbon, silicon, titanium, and manganese.

[0039] The above-described average content ratio C/A is the quotient obtained by dividing the average chromium content in the melted portion 850 by the average aluminum content in the melted portion 850. The above-described durability is the durability against the above-described crack, oxidation consumption, and breakage of the heating coil 820 (in the following description, "breakage" means a breakage of the heating coil 820).

[0040] The durability test was performed by applying a thermal load to the glow plug 10. The conditions of the thermal load were as follows. That is, the glow plug 10 was repeatedly heated and cooled until a breakage occurred. After 8,000 cycles were performed, the application of thermal load was temporarily stopped to perform evaluations regarding crack and oxidation consumption.

[0041] In each cycle, the glow plug 10 was heated for 20 seconds so that the temperature of the surface of the glow plug 10 reached 1150°C, and was cooled for 60 seconds on the condition that the temperature decreased by 149°C in one second after the start of the cooling process. The numerical values of the experimental conditions are all examples, and may be changed in any way in reproductive experiments. For example, the temperature

may be dropped by 139°C to 159°C in one second after the start of the cooling process, and the surface of the glow plug 10 may be heated to a temperature in the range of 1140°C to 1160°C in the heating process. The surface temperature of the glow plug 10 was measured with a monochromatic radiation thermometer at an emissivity of $\varepsilon = 1.0$ during the measurement and a measurement spot diameter of 2 mm. The measurement point was positioned 2 mm away from the tubular-sheath front end portion 811 of the tubular sheath 810 toward the rear end in the direction of the axis O.

[0042] The evaluation results regarding crack shown in Fig. 6 are based on a crack growth rate. Fig. 7 is a diagram used to describe how the crack growth rate is determined. Fig. 7 is an enlarged view illustrating the region around the boundary between the melted portion 850 and the cylinder portion 860. Fig. 7 illustrates the state in which a crack K is formed in the region around the boundary.

[0043] The crack growth rate is calculated by dividing the length L1 by the length L2 in Fig. 7. The length L1 is a crack depth. In the present embodiment, the crack depth is defined as the length of a line connecting the starting point k1 and the end point k2 of the crack. The length L2 is defined as the length of a line connecting the starting point k1 of the crack and an intersecting point k3. The intersecting point k3 is the point at which the extension of the line connecting the starting point k1 and the end point k2 of the crack intersects with the outer surface of the tubular sheath 810.

[0044] In the evaluation results regarding crack shown in Fig. 6, 'A' means that the crack growth rate was zero, that is, that no crack was formed, 'B' means that the crack growth rate was greater than zero and less than 10%, 'C' means that the crack growth rate was 10% or more and less than 15%, and 'D' means that the crack growth rate was 15% or more.

[0045] In the evaluation results regarding oxidation consumption shown in Fig. 6, 'A' means that an amount by which the thickness was reduced as a result of oxidation consumption (hereinafter referred to as "amount of consumption") was less than 0.05 mm, 'B' means that the amount of consumption was 0.05 mm or more and less than 0.10 mm, 'C' means that the amount of consumption was 0.10 mm or more and less than 0.15 mm, and 'D' means that the amount of consumption was 0.15 mm or more and less than 0.20 mm.

[0046] In the evaluation results regarding breakage shown in Fig. 6, 'A' means that the number of cycles at which a breakage occurred was 12,000 or more, 'B' means that the number of cycles at which a breakage occurred was 11,000 or more and less than 12,000, 'C' means that the number of cycles at which a breakage occurred was 10,000 or more and less than 11,000, and 'D' means that the number of cycles at which a breakage occurred was less than 10,000.

[0047] As shown in Fig. 6, the evaluation regarding breakage was not performed for Experiment No. 18. This

is because the number of cycles at which a breakage occurred was smaller than that at which a breakage occurred in samples evaluated as 'D'. The reason why a breakage occurred at such a small number of cycles is presumably because since the average aluminum content in the melted portion 850 was as low as 2.30 mass%, nitrogen in the atmosphere passed through the melted portion 850 and entered the tubular sheath 810. This phenomenon presumably occurs when, in particular, the number of cycles exceeds 8,000. When the average aluminum content in the melted portion 850 was 2.40 mass% or more, the above-described phenomenon did not occur. Therefore, the average aluminum content A in the melted portion 850 is preferably 2.40 mass% or more. In the following description, experiments other than Experiment No. 18 will be discussed.

[0048] When the average content ratio C/A was 2.1 or more (Experiment Nos. 4 to 17), the evaluation result regarding crack was 'C' or higher. Therefore, the average content ratio C/A in the region near the surface of the melted portion 850 is preferably 2.1 or more.

[0049] When the average content ratio C/A was 2.9 or more (Experiment Nos. 6 to 17), the evaluation result regarding crack was 'B' or higher. Therefore, the average content ratio C/A is preferably 2.9 or more.

[0050] When the average content ratio C/A was 3.5 or more (Experiment Nos. 10 to 17), the evaluation result regarding crack was 'A'. Therefore, the average content ratio C/A is preferably 3.5 or more.

[0051] When the average content ratio C/A was 6.7 or less (Experiment Nos. 1 to 16), the evaluation result regarding oxidation consumption was 'C' or higher. Therefore, the average content ratio C/A is preferably 6.7 or less.

[0052] When the average content ratio C/A was 5.4 or less (Experiment Nos. 1 to 14), the evaluation result regarding oxidation consumption was 'B' or higher. Therefore, the average content ratio C/A is preferably 5.4 or more.

[0053] When the average content ratio C/A was 1.2 or more and 1.96 or less (Experiment Nos. 1 to 2), 2.1 or more and 2.9 or less (Experiment Nos. 4 to 6), and 3.5 or more and 3.7 or less (Experiment Nos. 10 and 11), the evaluation result regarding oxidation consumption was 'A'. Therefore, the average content ratio C/A is preferably 1.2 or more and 1.96 or less, 2.1 or more and 2.9 or less, or 3.5 or more and 3.7 or less.

[0054] When the average content ratio C/A was 2.1 or more and 6.7 or less (Experiment Nos. 4 to 16), the evaluation result regarding breakage of the heating coil 820 was 'C' or higher. Therefore, the average content ratio C/A is preferably 2.1 or more and 6.7 or less.

[0055] When the average content ratio C/A was 2.9 or more and 5.4 or less (Experiment Nos. 6 to 14), the evaluation result regarding breakage of the heating coil 820 was 'B' or higher. Therefore, the average content ratio C/A is preferably 2.9 or more and 5.4 or less.

[0056] When the average content ratio C/A was 3.5 or

more and 3.7 or less (Experiment Nos. 10 and 11), the evaluation result regarding breakage of the heating coil 820 was 'A'. Therefore, the average content ratio C/A is preferably 3.5 or more and 3.7 or less.

[0057] The evaluation result regarding breakage has a correlation with the evaluation results regarding crack and oxidation consumption. More specifically, in Experiment Nos. 1 to 17, the evaluation result regarding breakage is the same as the lower one of the evaluation results regarding crack and the oxidation consumption. This implies that the occurrence of breakage is influenced by the crack and the oxidation consumption. The influences will be described.

[0058] It is presumed that the more the heating coil 820 is nitrided, the more fragile the heating coil 820 becomes and the more readily a breakage occurs. When the glow plug 10 is not used, the tubular sheath 810 blocks nitrogen in the atmosphere so that the heating coil 820 disposed in the tubular sheath 810 is hardly nitrided. However, when the glow plug 10 is repeatedly heated and cooled, the tubular sheath 810 becomes unable to block nitrogen, and nitrogen in the atmosphere enters the tubular sheath 810. As a result, nitridation of the heating coil 820 progresses. Some of the factors that make the tubular sheath 810 unable to block nitrogen are the crack and the oxidation consumption.

[0059] In the region in which a crack is formed, the tubular sheath 810 relatively easily allows nitrogen to pass therethrough because the thickness thereof is reduced. When the crack is formed so as to extend from the inner surface to the outer surface, the tubular sheath 810 loses the nitrogen-blocking function. Also when the oxidation consumption progresses, the melted portion 850 relatively easily allows nitrogen to pass therethrough since the thickness thereof is reduced.

[0060] Therefore, to suppress breakage, it is important to increase the durability against both the crack and the oxidation consumption. Accordingly, the relationship between the average content ratio C/A and the oxidation consumption, and the relationship between the average content ratio C/A and the crack will be discussed.

[0061] From the viewpoint of suppressing the formation of a crack, the average aluminum content is preferably as low as possible. When the average aluminum content in the melted portion 850 is high, an intermetallic compound containing aluminum is easily formed in the region around the boundary between the melted portion 850 and the cylinder portion 860. As described above, such an intermetallic compound has low toughness or a coefficient of thermal expansion that differs from those of original metals. As a result, a crack is easily formed in the region around the boundary between the melted portion 850 and the cylinder portion 860. This explains the fact that, in Fig. 6, the evaluation result regarding crack tends to be better for experiment numbers for which the average aluminum content in the melted portion 850 is low.

[0062] From the viewpoint of oxidation consumption,

the average chromium content is preferably as low as possible. For an alloy containing chromium and aluminum, an oxide film made of chromium oxide is formed on the surface. When thermal load is repeatedly applied, formation and separation of an oxide film are repeated, as described above, and rapid oxidation consumption may occur. Therefore, the oxide film is preferably not too thick. When the average chromium content is low, a chromium oxide film that is not too thick can be accurately formed, so that the oxidation consumption can be suppressed. This explains the fact that the evaluation result regarding oxidation consumption is better for experiment numbers for which the average chromium content in the melted portion 850 is low.

[0063] It cannot be said that the average content is lower the better for both aluminum and chromium. When the average aluminum content is too low, the melted portion 850 loses the nitrogen-blocking function, as in the case of Experiment No. 18. In addition, the aluminum oxide film is fine and has a function of protecting the inner portion from oxidation. Therefore, the average aluminum content is preferably not too low.

[0064] With regard to the average chromium content, it is presumed that formation of a crack can be suppressed when the average chromium content is high. This presumption is based on the fact that the evaluation result regarding crack for Experiment Nos. 4 and 5 (average aluminum content was 3.60 mass% or more and 3.80 mass% or less) was 'C', while that for Experiment Nos. 7 and 8 (average aluminum content was 4.00 mass% or more and 4.50 mass% or less) was 'B'. The reason why the evaluation result regarding crack was better when the average aluminum content was high is presumably because the average chromium content for Experiment Nos. 4 and 5 was 8.0 mass%, while that for Experiment Nos. 7 and 8 was 13.0 mass% or more and 15.0 mass% or less.

[0065] The above-described experiment results show that breakage can be suppressed by setting the average content ratio C/A to an appropriate value.

[0066] For Experiment Nos. 4 to 16, for which the evaluation result regarding breakage of the heating coil 820 was 'C' or higher, the average aluminum content was 2.4 mass% or more. Therefore, the average aluminum content is preferably 2.4 mass% or more. Also, for Experiment Nos. 4 to 16, the average aluminum content was 4.5 mass% or less. Therefore, average aluminum content is preferably 4.5 mass% or less.

[0067] For Experiment Nos. 4 to 16, the average chromium content was 8.0 mass% or more. Therefore, the average aluminum content is preferably 8.0 mass% or more. Also, for Experiment Nos. 4 to 16, the average aluminum content was 16.0 mass% or less. Therefore, the average aluminum content is preferably 16.0 mass% or less.

[0068] For Experiment Nos. 4 to 16, the aluminum content in the heating coil 820 was 3.8 mass% or more and 10 mass% or less, the chromium content in the heating

coil 820 was 13.1 mass% or more and 20.3 mass% or less, and the iron content in the heating coil 820 was 69.5 mass% or more and 80.3 mass% or less. Therefore, these ranges are preferable.

[0069] For Experiment Nos. 4 to 16, the aluminum content in the cylinder portion 860 was 1.2 mass% or more and 2.2 mass% or less, the chromium content in the cylinder portion 860 was 14.5 mass% or more and 22.1 mass% or less, and the nickel content in the cylinder portion 860 was 66.1 mass% or more. Therefore, these ranges are preferable.

[0070] For Experiment Nos. 4 to 16, as described above, the aluminum content in the melted portion 850 was less than 5 mass% in the region near the boundary between the melted portion 850 and the cylinder portion 860. Accordingly, it is presumed that the amount of intermetallic compound containing aluminum formed at the boundary between the melted portion 850 and the cylinder portion 860 was small and the formation of a crack was suppressed in the region around the boundary between the melted portion 850 and the cylinder portion 860.

[0071] As described above, the average iron content in the melted portion 850 was 17 mass% or more and 21 mass% or less. When the average iron content is 17 mass% or more and 21 mass% or less, exposure of aggregated iron at the surface due to oxidation consumption can be prevented. When aggregated iron is exposed at the surface, rapid oxidation occurs and the oxidation consumption is locally accelerated. Therefore, iron is preferably not aggregated in the melted portion. For this purpose, the average iron content is preferably 17 mass% or more and 21 mass% or less, as described above.

[0072] The results of experiments for studying the influence of the thickness T (see Fig. 4) of the melted portion 850 will now be described. Fig. 8 is a table showing the results of experiments for studying the relationship between the thickness T and the breakage of the heating coil 820. The experiments were performed under the condition that the composition is the same as that for Experiment No. 16, and how the evaluation result regarding breakage changes when the thickness T before the experiment is changed was studied.

[0073] As shown in Fig. 8, when the thickness T was 0.3 mm (Experiment No. 19) and 1.2 mm (Experiment No. 23), the evaluation result regarding breakage was 'C', which is the same as that for Experiment No. 16. When the thickness T was 0.5 mm or more and 1.0 mm or less (Experiment Nos. 20 to 22), the evaluation result regarding breakage was 'B'. Thus, the thickness T is preferably 0.5 mm or more and 1.0 mm or less.

[0074] The reason why the evaluation result regarding breakage improved when the thickness T was 0.5 mm or more and 1.0 mm or less will be discussed. When the thickness T is large, even when a certain amount of oxidation consumption occurs, the melted portion 850 remains thick enough to maintain the nitrogen-blocking function. As a result, nitridation of the heating coil 820 is

suppressed. This is presumably the reason why the evaluation result regarding breakage improved.

[0075] The reason why the evaluation result regarding breakage was 'C' when the thickness T was 1.2 mm is presumably as follows. That is, as the thickness of the melted portion 850 increases, the heat capacity of the melted portion 850 increases. As a result, as the thickness of the melted portion 850 increases, a larger amount of heat needs to be generated by the heating coil 820 to increase the surface temperature of a predetermined portion to a target temperature. Accordingly, the temperature of the heating coil 820 in the heating process increases. The above-described predetermined portion is a portion of a surface of the tubular sheath 810 that is separated from the tubular-sheath front end portion 811 toward the rear end by 2 mm in the direction of the axis O. Therefore, it is assumed that, in the above-described durability test, the load on the heating coil 820 was increased and breakage occurred before the number of cycles reached 11,000.

[0076] A change in the thickness T has the above-described influence on the occurrence of breakage. Accordingly, it is assumed that, when the thickness T is 0.5 mm or more and 1.0 mm or less, the evaluation result regarding breakage can be improved not only for the composition for Experiment No. 16 but also for other compositions for the same reason.

[0077] The present invention is not limited to the above-described embodiments, and may be implemented in various forms within the gist thereof. For example, the technical features of the embodiments corresponding to the technical features according to the aspects described in the Summary of the Invention section may be replaced or combined as appropriate to solve some or all of the above-described problems or obtain some or all of the above-described effects. The technical features may also be omitted as appropriate unless they are described as being essential in this specification. Examples of such embodiments will be described.

[0078] Fig. 9 illustrates the shapes of a tubular sheath 810 and a heating coil 820a before they are welded together as another embodiment. The heating coil 820a is a substitute for the heating coil 820 in the above-described embodiment. The heating coil 820a includes a linear portion 824a in place of the linear portion 824 of the heating coil 820. As illustrated in Fig. 9, the linear portion 824a is formed so as to extend substantially parallel to the axis O.

[0079] Fig. 10 illustrates the shapes of a tubular sheath 810 and a heating coil 820b before they are welded together as another embodiment. The heating coil 820b is a substitute for the heating coil 820 in the above-described embodiment. As illustrated in Fig. 10, a front end portion of the heating coil 820b that projects from the opening is densely wound. In other words, the heating coil 820b does not include a linear portion before being welded.

[0080] The heating coil may have a shape different

from those illustrated in Figs. 3, 9, and 10 before being welded. For example, the linear portion may be shorter than those illustrated in Figs. 3 and 9. For example, the length of the linear portion may be such that, when the heating coil is placed in position for welding, the front end of the linear portion is disposed in the second cylindrical portion. In other words, it is not necessary that the linear portion project from the second cylindrical portion when the heating coil is placed in position for welding.

[0081] The tubular sheath may also have a shape different from those illustrated in Figs. 3, 9, and 10 before being welded. For example, it is not necessary that the tubular sheath include the second cylindrical portion before being welded. In this case, the front end of the narrowing portion is the front end of the tubular sheath before welding. When the front end of the narrowing portion is the front end of the tubular sheath before welding and when the linear portion extends through the opening of the narrowing portion, the linear portion projects from the front end of the tubular sheath. Alternatively, the shape of the tubular sheath before welding may be such that a portion having a shape different from that of the second cylindrical portion is connected to the front end of the narrowing portion. For example, a portion having a diameter that increases toward the front end may be connected to the front end of the narrowing portion.

[0082] A method for analyzing the aluminum content in the melted portion is not limited to that described in the embodiment. The devices used for the analysis and the region to be analyzed may be changed. For example, a region in which a crack is easily formed may be selected and determined as the region to be analyzed. For example, the region in which aggregation of aluminum is at a maximum may be selected as the region in which a crack is easily formed. The region in which aggregation of aluminum is at a maximum may be visually determined by, for example, an observer on the basis of an image showing the aluminum content distribution. The magnification of this image may be, for example, 30. The number of measurement points and intervals between the measurement points may be changed as appropriate to those suitable for the durability evaluation.

[0083] In this specification, the melted portion is a portion that contains at least the main component of a cylinder portion and the main component of a heating element and blocks the front end of the cylinder portion, the cylinder portion being disposed around the heating element and extending in a direction of an axis. The melted portion is not limited to a portion produced by welding.

Claims

1. A glow plug (10) comprising:

a heating element (820, 820a, 820b) that generates heat when electricity is applied to the heating element (820, 820a, 820b); and

a tubular sheath (810) including a cylindrical member (860) that is disposed around the heating element (820, 820a, 820b) and extends in a direction of an axis (O), and a melted portion (850) that contains at least a main component of the cylindrical member (860) and a main component of the heating element (820, 820a, 820b) and blocks a front end of the cylindrical member (860),

wherein, when C represents an average chromium content in terms of mass% and A represents an average aluminum content in terms of mass% in a predetermined region in which a distance from an outer surface of the melted portion (850) in a direction toward an inner region is more than 0.03 mm, an average content ratio C/A is 2.1 or more and 6.7 or less.

2. The glow plug (10) according to Claim 1, wherein the average content ratio C/A is 2.9 or more and 5.4 or less.
3. The glow plug (10) according to Claim 2, wherein the average content ratio C/A is 3.5 or more and 3.7 or less.
4. The glow plug (10) according to any one of Claims 1 to 3, wherein, in cross section including the axis (O), a thickness of the melted portion (850) along the axis (O) is 0.5 mm or more and 1.0 mm or less.
5. The glow plug (10) according to any one of Claims 1 to 4, wherein the average aluminum content A is 2.4 mass% or more in the predetermined region.
6. The glow plug (10) according to any one of Claims 1 to 5, wherein the average aluminum content A is 4.5 mass% or less in the predetermined region.
7. The glow plug (10) according to any one of Claims 1 to 6, wherein the average chromium content C is 8 mass% or more and 16 mass% or less in the predetermined region.
8. The glow plug (10) according to any one of Claims 1 to 7, wherein the cylindrical member (860) has an aluminum content of 1.2 mass% or more and 2.2 mass% or less, a chromium content of 14.5 mass% or more and 22.1 mass% or less, and a nickel content of 66.1 mass% or more.
9. The glow plug (10) according to any one of Claims 1 to 8, wherein the heating element (820, 820a, 820b) has an aluminum content of 3.8 mass% or more and 10 mass% or less, a chromium content of 13.1 mass% or more and 20.3 mass% or less, and an iron content of 69.5 mass% or more and 80.3 mass% or less.

10. The glow plug (10) according to any one of Claims 1 to 9, wherein the melted portion (850) has an aluminum content of less than 5 mass% in a region near a boundary between the melted portion (850) and the cylindrical member (860). 5
11. The glow plug (10) according to any one of Claims 1 to 10, wherein an average iron content is 17 mass% or more and 21 mass% or less in the predetermined region. 10
12. A method for manufacturing the glow plug (10) according to any one of Claims 1 to 11, the method comprising: 15
- a step of forming the melted portion (850) by welding the heating element (820) and the cylindrical member (860) together, wherein, before the step, the heating element (820) includes a helical portion (823) and a linear portion (824) that is connected to a front end of the helical portion (823) and that has a front end that serves as a front end of the heating element (820), 20
- wherein, before the step, the cylindrical member (860) includes a narrowing portion (814) having a diameter that decreases toward a front end of the narrowing portion (814) and an opening (816) at the front end of the narrowing portion (814), and 25
- wherein, in the step, the welding is started in a state such that the linear portion (824) is positioned at a front end side with respect to the opening (816) in the narrowing portion (814). 30
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FIG. 1

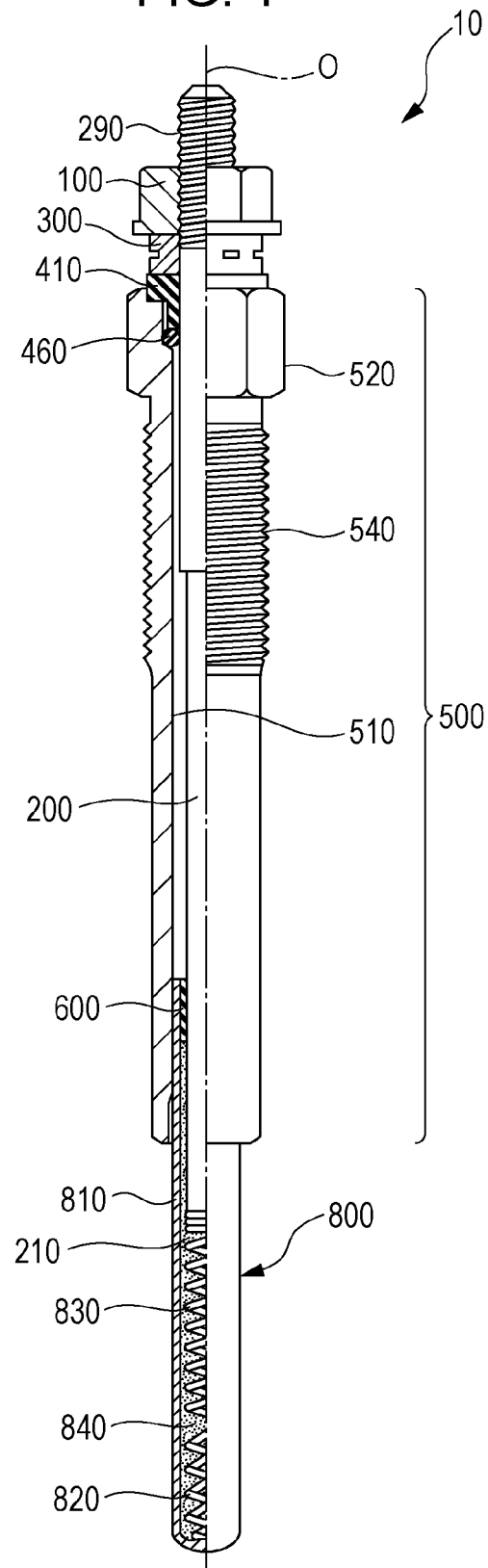


FIG. 2

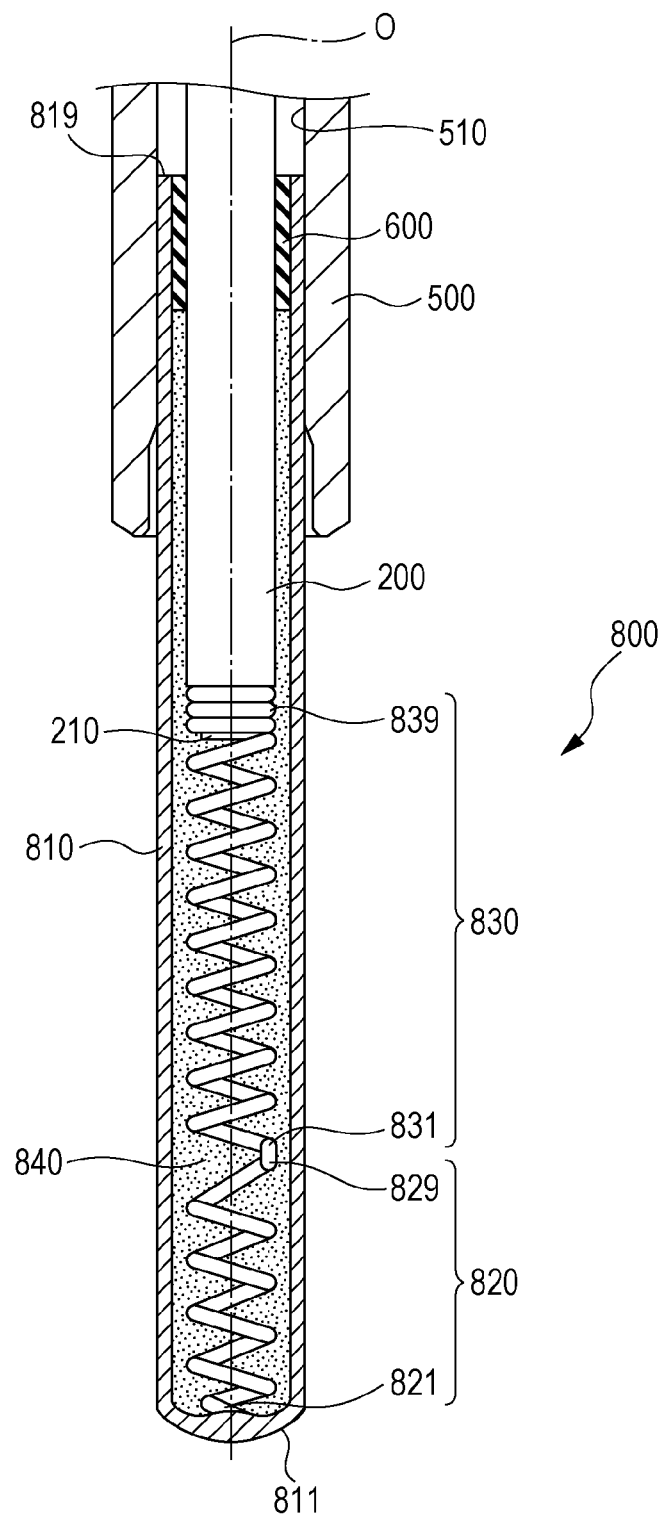


FIG. 3

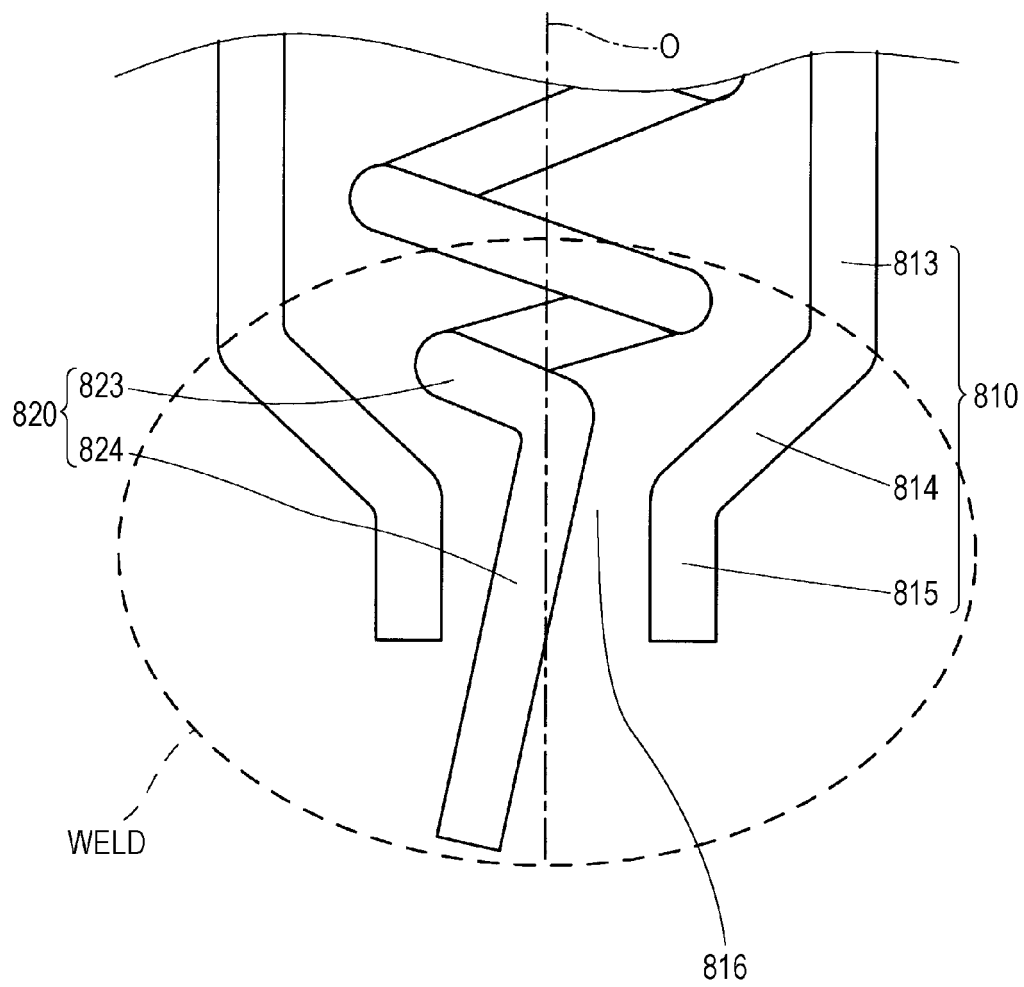


FIG. 4

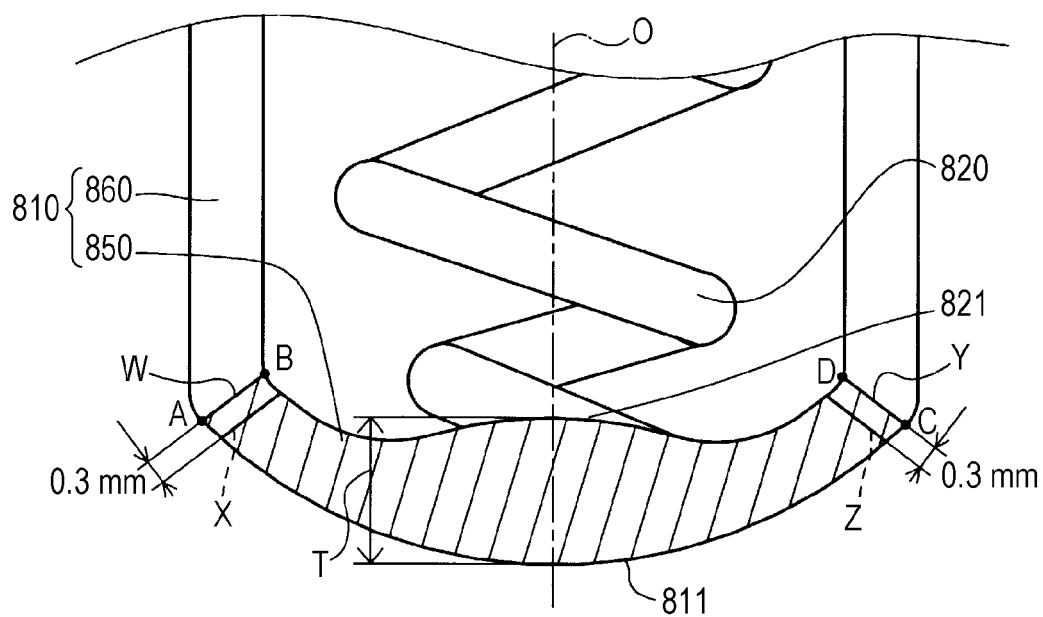


FIG. 5

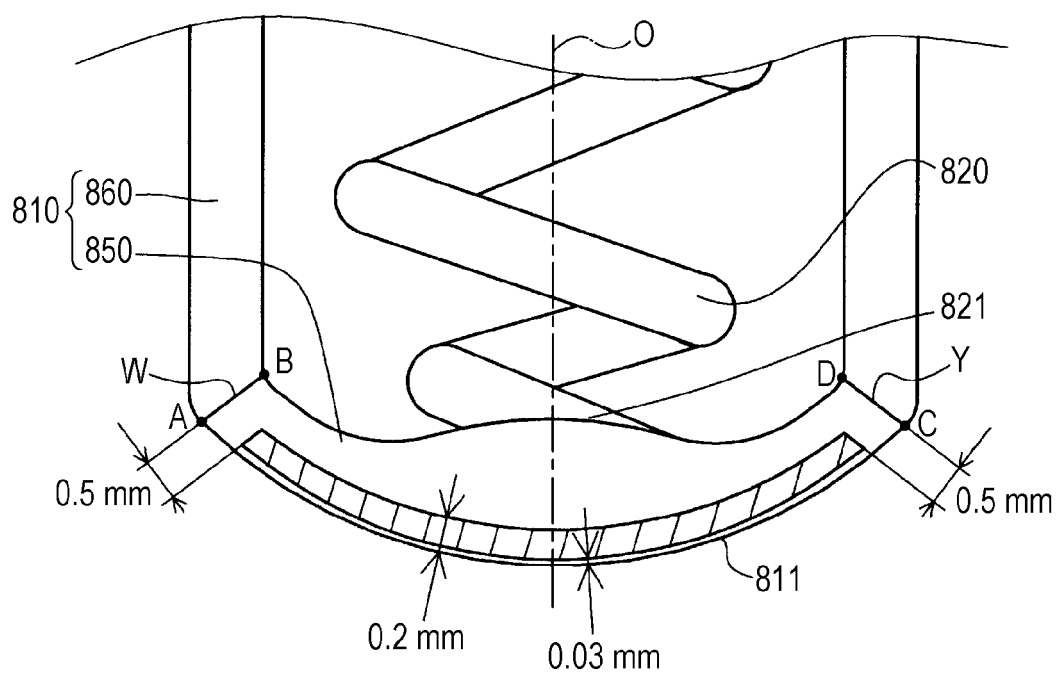


FIG. 6

No.	MELTED PORTION			HEATING COIL				CYLINDER PORTION				CRACK	OXIDATION CONSUMPTION	BREAKAGE
	Cr	Al	C/A	Al	Cr	Fe		Al	Cr	Fe	Ni			
1	7.0	6.00	1.2	10	13.1	76.7		2.2	14.5	6.5	76.5	D	A	D
2	10.0	5.10	1.96	10	15.7	74.1		2.2	16.3	6.5	74.7	D	A	D
3	10.2	5.00	2.04	10	18.2	71.6		2.2	19.3	6.5	71.7	D	B	D
4	8.0	3.80	2.1	7.7	13.1	79		2.2	14.5	6.5	76.5	C	A	C
5	8.0	3.60	2.2	7.7	13.1	79		2.2	14.5	6.5	76.5	C	A	C
6	10.0	3.50	2.9	7.7	15.7	76.4		2.2	16.3	6.5	74.7	B	A	B
7	13.0	4.00	3.3	10	20.3	69.5		2.2	22.1	9.3	66.1	B	B	B
8	15.0	4.50	3.3	10	19.5	70.3		2.2	20.1	9.3	68.1	B	B	B
9	12.0	3.50	3.4	7.7	18.2	73.9		2.2	19.3	6.5	71.7	B	B	B
10	10.0	2.85	3.5	5.2	15.7	78.9		1.2	16.3	6.5	75.7	A	A	A
11	10.0	2.70	3.7	3.8	15.7	80.3		1.2	16.3	6.5	75.7	A	A	A
12	12.0	2.85	4.2	5.2	18.2	76.4		1.2	19.3	6.5	72.7	A	B	B
13	12.0	2.70	4.4	3.8	18.2	77.8		1.2	19.3	6.5	72.7	A	B	B
14	15.0	2.80	5.4	5.2	19.5	75.1		1.2	20.1	9.3	69.1	A	B	B
15	15.9	2.70	5.9	5.2	20.3	74.3		1.2	22.1	9.3	67.1	A	C	C
16	16.0	2.40	6.7	3.8	19.5	76.5		1.2	20.1	9.3	69.1	A	C	C
17	16.2	2.40	6.8	3.8	20.3	75.7		1.2	22.1	9.3	67.1	A	D	D
18	10.0	2.30	4.3	3.8	20.3	75.7		1.2	22.1	9.3	67.1	A	A	-

FIG. 7

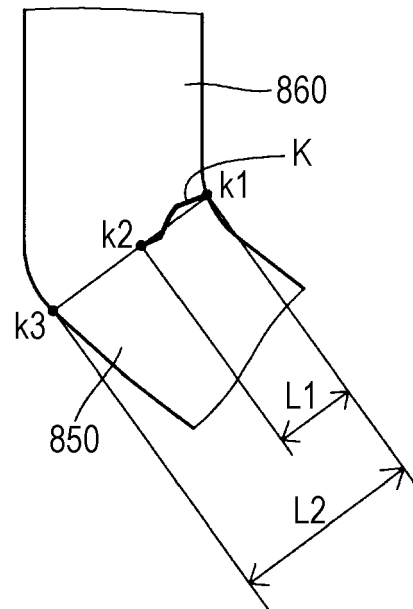


FIG. 8

No.	THICKNESS T OF MELTED PORTION	BREAKAGE
19	0.3 mm	C
20	0.5 mm	B
21	0.7 mm	B
22	1.0 mm	B
23	1.2 mm	C

FIG. 9

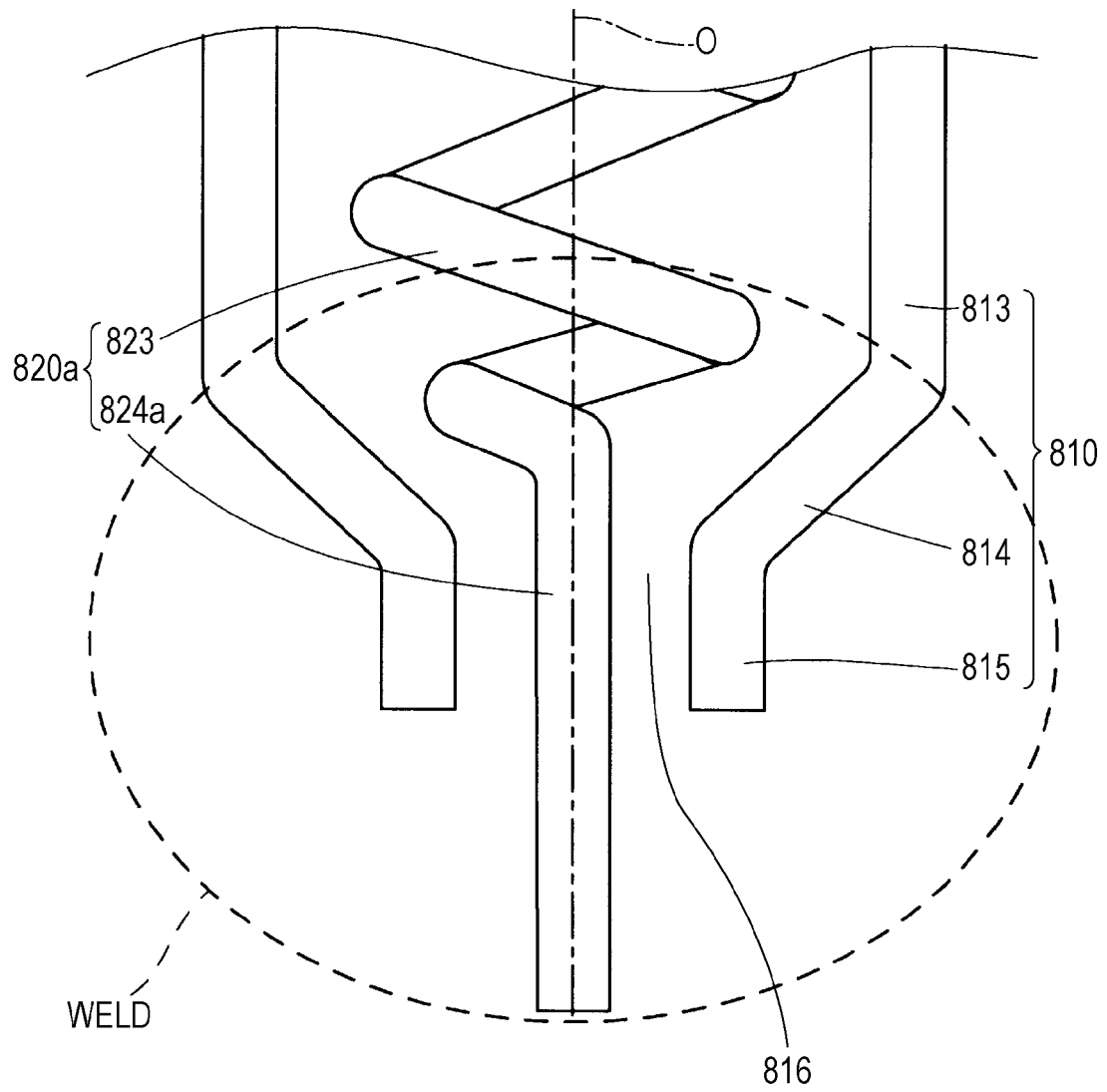
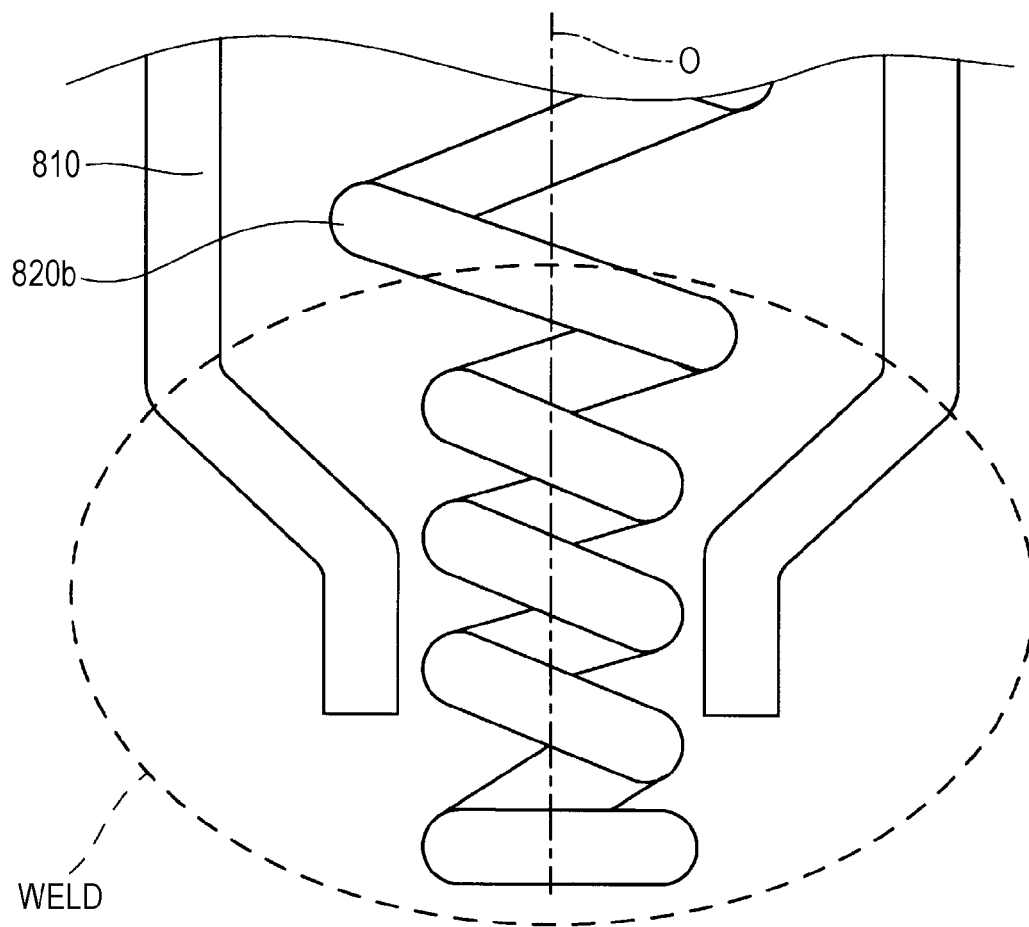


FIG. 10





EUROPEAN SEARCH REPORT

Application Number
EP 15 19 0642

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	EP 2 587 156 A1 (NGK SPARK PLUG CO [JP]) 1 May 2013 (2013-05-01) * paragraph [0056] - paragraph [0101]; figures 1-3 *	1,2,4-6, 8-11 3,7	INV. F23Q7/00
X,P	EP 2 873 920 A1 (NGK SPARK PLUG CO [JP]) 20 May 2015 (2015-05-20) * paragraph [0010] - paragraph [0053]; claims 1-10; figures 1-9 *	1,2,4-7, 10-12	
A	US 5 118 921 A (AOTA TAKASHI [JP] ET AL) 2 June 1992 (1992-06-02) * column 3, line 51 - column 5, line 38; figures 1-4 *	1	
A	JP 2014 137169 A (NGK SPARK PLUG CO) 28 July 2014 (2014-07-28) * paragraph [0010] - paragraph [0053]; figures 1-7 *	1	
			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 11 February 2016	Examiner Theis, Gilbert
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 15 19 0642

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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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
		WO 2011162074 A1	29-12-2011

EP 2873920 A1	20-05-2015	EP 2873920 A1	20-05-2015
		JP 2015117930 A	25-06-2015

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

JP 2014137169 A	28-07-2014	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004264013 A [0002]