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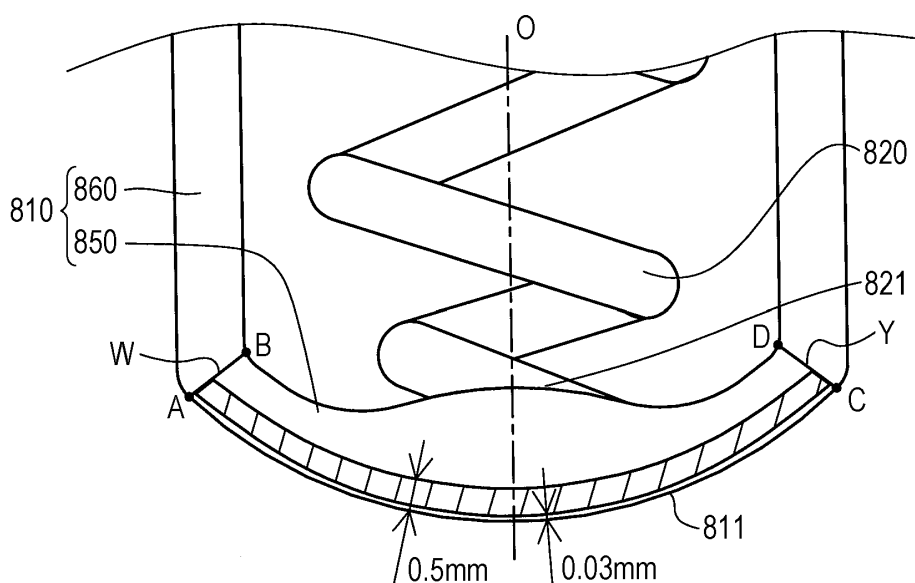
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(54) **Glow plug**

(57) A glow plug (10), comprising: a heating unit (820); and a sheath tube (810) including a tube portion (860) and a welded portion (850), the tube portion (860) being disposed at an outer circumference of the heating unit (820) and extending in an axial direction, the welded portion (850) containing at least a main constituent

of the tube portion (860) and a main constituent of the heating unit (820) and blocking a front end portion (811) of the tube portion (850). In a range of 0.03 mm or more to 0.5 mm or less from a surface of the welded portion (860) to an inside of the surface, an average content ratio of aluminum is 2.5 mass% or less.

FIG. 6



Description

BACKGROUND

1. Technical Field

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

2. Related Art

[0002] The glow plug includes a sheath heater. The sheath heater is employed as an auxiliary heat source for an internal combustion engine (for example, a diesel engine) by compression ignition system. The glow plug is required to have durability like, for example, enduring usage environment inside of a combustion chamber. To improve such characteristics, there has been proposed various combinations of materials (for example, see JP-A-2004-264013).

[0003] The problem of the above-described prior art is that there is a room for improvement in durability. Assuming the case where electricity is transmitted to the glow plug, if the glow plug contains chrome in the surface, an oxide film of Cr_2O_3 is generated on the surface, and if the glow plug contains aluminum in the surface, an oxide film of Al_2O_3 is generated on the surface. The oxide film enhances the durability of a bulk by protecting the bulk from oxidation. Here, the bulk means a part positioning inside more than the oxide film.

[0004] The oxide film is present on the surface of the glow plug as described above. In view of this, whenever burning is generated in the combustion chamber, thermal stress is applied to the oxide film. This thermal stress may peel off the oxide film from the bulk. When peeling off the oxide film, a surface layer of the exposed bulk changes to the oxide film. A newly generated oxide film may be peeled off due to the thermal stress. Thus, whenever the oxide film is peeled off, the bulk becomes thin. In this description, this phenomenon is referred to as oxidative consumption. The improvement of durability, which is the object of the present invention, especially means improvement of a property suppressing such oxidative consumption (oxidation resistance).

SUMMARY

[0005] The present invention solves the above-described problem, and is, for example, achieved as the following configurations.

(1) A glow plug provided by an embodiment of the present invention (this glow plug) includes: a heating unit that generates heat by transmission of electricity; and a sheath tube including a tube portion and a welded portion, the tube portion being disposed at an outer circumference of the heating unit and extending in an axial line direction, the welded portion containing at least a main constituent of the tube

portion and a main constituent of the heating unit and closing a front end of the tube portion. In this glow plug, in a range of 0.03 mm or more to 0.5 mm or less from a surface of the welded portion to an inside of the surface, an average content ratio of aluminum is 2.5 mass% or less.

[0006] With this glow plug, durability of the welded portion is improved. The reason is that the average content ratio of aluminum in the range being 2.5 mass% or less suppresses the oxidative consumption.

(2) With this glow plug, at least one of the tube portion and the heating unit may contain aluminum. According to this configuration, in the case where at least one of the tube portion and the heating unit contains aluminum, the above-described effect can be obtained.

(3) With this glow plug, the heating unit may contain aluminum. According to this configuration, when the heating unit contains aluminum, the above-described effect can be obtained.

(4) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of chrome may be 10 mass% or more to 40 mass% or less. According to this configuration, the durability of the welded portion is improved. The reason is that the average content ratio of chrome in the range being 10 mass% or more to 40 mass% or less suppresses the oxidative consumption.

(5) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of chrome may be 15 mass% or more to 30 mass% or less. According to this configuration, the durability of the welded portion is improved. The reason is that the average content ratio of chrome in the range being 15 mass% or more to 30 mass% or less further suppresses the oxidative consumption.

(6) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of chrome may be 15 mass% or more to 21 mass% or less. According to this configuration, the durability of the welded portion is improved. The reason is that the average content ratio of chrome in the range being 15 mass% or more to 21 mass% or less further suppresses the oxidative consumption.

(7) With this glow plug, the tube portion may contain aluminum at a content ratio of more than 1.7 mass%. According to this configuration, the above-described effect can be obtained when the content ratio of aluminum of the tube portion is more than 1.7 mass%.

(8) With this glow plug, the tube portion may contain

chrome at a content ratio of 24 mass% or more to 26 mass% or less. The tube portion may contain aluminum at a content ratio of 1.8 mass% or more to 2.4 mass% or less. According to this configuration, the above-described effect can be obtained when the content ratio of chrome of the tube portion is 24 mass% or more to 26 mass% or less and the content ratio of aluminum of the tube portion is 1.8 mass% or more to 2.4 mass% or less.

(9) With this glow plug, a main constituent of the heating unit may be nickel. According to this configuration, the above-described effect can be obtained when the main constituent of the heating unit is nickel.

(10) With this glow plug, the welded portion may contain aluminum at a content ratio of less than 5 mass% at a part near a boundary with the tube portion. According to this configuration, the durability of the welded portion is improved. The reason for it is as follows. At the part near the boundary with the tube portion, when a content ratio of aluminum is less than 5 mass%, this minimizes generation of an intermetallic compound from aluminum and another metal. In most cases, the intermetallic compound has low toughness, possibly causing degrade of the durability.

(11) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of aluminum may be 1.2 mass% or less. According to this configuration, the durability of the welded portion can further be improved.

(12) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of aluminum may be 0.04 mass% or more. According to this configuration, the oxide film of aluminum is not thinned too much, ensuring suppression of invasion of nitrogen in the sheath tube. Consequently, this ensures suppressing nitriding of the heating unit, ensuring improving the durability of the heating unit.

(13) With this glow plug, in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of iron may be 17 mass% or more to 21 mass% or less. According to this configuration, exposure of the aggregated iron to the surface and oxidation of the iron are suppressed.

[0007] The embodiments of the present invention can be achieved in various configurations other than the above-described configurations. For example, the embodiments of the present invention can be achieved as a method for manufacturing a glow plug or a similar method.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

5 FIG. 1 is an external view and a sectional view of a glow plug;

FIG. 2 is a sectional view of a sheath heater;

10 FIG. 3 is a sectional view of near front ends of a sheath tube and a heat generating coil before welding the sheath tube and the heat generating coil;

15 FIG. 4 illustrates a part to be analyzed near a boundary of a welded portion and a tube portion;

FIG. 5 shows a relationship between a content ratio of aluminum and generation of a crack near the boundary;

20 FIG. 6 illustrates a part to be analyzed near a surface of the welded portion;

25 FIG. 7 shows a relationship between average content ratios of aluminum and chrome and oxidative consumption near the surface;

30 FIG. 8 is a sectional view of near front ends of a sheath tube and a heat generating coil before welding the sheath tube and the heat generating coil of another embodiment; and

35 FIG. 9 is a sectional view of near front ends of a sheath tube and a heat generating coil before welding the sheath tube and the heat generating coil of another embodiment.

DETAILED DESCRIPTION

40 **[0009]** In the following detailed description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

50 **[0010]** FIG. 1 illustrates a glow plug 10. FIG. 1 illustrates an external constitution of the glow plug 10 on the right side of an axial line O on the paper. A cross-sectional structure of the glow plug 10 is illustrated on the left side of the axial line O on the paper. The glow plug 10 functions as a heat source assisting an ignition at a start of a diesel engine.

55 **[0011]** The glow plug 10 includes a center rod member 200, a metal shell 500, and a sheath heater 800. The sheath heater 800 generates heat by transmission of electricity. These members are assembled along the ax-

ial line O of the glow plug 10. In this description, the sheath heater 800 side in the glow plug 10 is referred to as a "front end side" while the opposite side is referred to as a "rear end side."

[0012] The metal shell 500 is formed into a tubular shape and made of carbon steel. The metal shell 500 holds the sheath heater 800 at an end portion on the front end side. The metal shell 500 holds the center rod member 200 at the end portion on the rear end side via an insulating member 410 and an O-ring 460. A position of the insulating member 410 in the axial line O direction is secured by crimping a ring 300 in contact with a rear end of the insulating member 410 to the center rod member 200. The insulating member 410 insulates the rear end side of the metal shell 500. The metal shell 500 incorporates a part of the center rod member 200 from the insulating member 410 to the sheath heater 800. The metal shell 500 includes an axial hole 510, a tool engagement portion 520, and an external thread portion 540.

[0013] The axial hole 510 is a through hole formed along the axial line O. The axial hole 510 has a diameter larger than the center rod member 200. In a state where the center rod member 200 is arranged in the axial hole 510, a space is formed between the axial hole 510 and the center rod member 200 so as to provide an electrical insulation therebetween. The sheath heater 800 is press-fitted to the front end side of the axial hole 510 and is bonded. The external thread portion 540 fits an internal thread formed at an internal combustion engine (not illustrated). The tool engagement portion 520 engages a tool (not illustrated) used for installation and removal of the glow plug 10.

[0014] The center rod member 200 includes a cylindrically-formed conductive material. The center rod member 200 is assembled along the axial line O while being inserted into the axial hole 510 of the metal shell 500. The center rod member 200 includes a center rod member front end portion 210 formed at the front end side and a connecting portion 290 formed at the rear end side. The center rod member front end portion 210 is inserted to the inside of the sheath heater 800. The connecting portion 290 is an external thread projected from the metal shell 500. The engaging member 100 is fitted to the connecting portion 290.

[0015] FIG. 2 is a sectional view illustrating a detailed constitution of the sheath heater 800. The sheath heater 800 includes a sheath tube 810, a heat generating coil 820 as a heating unit, a control coil 830, and insulating powder 840.

[0016] The sheath tube 810 extends in the axial line O direction. The sheath tube 810 is a tubular member whose front end is blocked. The sheath tube 810 incorporates the heat generating coil 820, the control coil 830, and the insulating powder 840. The sheath tube 810 includes a sheath tube front end portion 811 and a sheath tube rear end portion 819. The sheath tube front end portion 811 is an end portion formed to a rounded shape to the outside at the front end side of the sheath tube

810. The sheath tube rear end portion 819 is an end portion open at the rear end side of the sheath tube 810. The center rod member front end portion 210 of the center rod member 200 is arranged at the inside from the sheath tube rear end portion 819 to the sheath tube 810. A packing 600 and the insulating powder 840 electrically insulate the sheath tube 810 from the center rod member 200. The packing 600 is an insulating member sandwiched between the center rod member 200 and the sheath tube 810. The sheath tube 810 is electrically connected to the metal shell 500.

[0017] The control coil 830 is a coil made of a conductive material. The control coil 830 has a temperature coefficient of electrical resistivity larger than a material forming the heat generating coil 820. As this conductive material, nickel is preferable. In addition to this, for example, the conductive material may be an alloy mainly containing cobalt or nickel. The control coil 830 is disposed inside of the sheath tube 810. The control coil 830 controls electric power supplied to the heat generating coil 820. The control coil 830 includes a control coil front end portion 831 and a control coil rear end portion 839. The control coil front end portion 831 is at the end portion on the front end side. The control coil rear end portion 839 is at the end portion on the rear end side. The control coil front end portion 831 is electrically connected to the heat generating coil 820 by being welded to a heat generating coil rear end portion 829 of the heat generating coil 820. The control coil rear end portion 839 is electrically connected to the center rod member 200 by being bonded to the center rod member front end portion 210 of the center rod member 200.

[0018] The insulating powder 840 is powder having an electrical insulating property. As the insulating powder 840, for example, powder of Magnesium Oxide (MgO) is employed. The insulating powder 840 is filled inside of the sheath tube 810. The insulating powder 840 electrically insulates respective clearances of the sheath tube 810, the heat generating coil 820, the control coil 830, and the center rod member 200.

[0019] The heat generating coil 820 is a coil made of a conductive material. The heat generating coil 820 is disposed at the inside of the sheath tube 810 along the axial line O direction. The heat generating coil 820 generates heat by transmission of electricity. The heat generating coil 820 includes a heat generating coil front end portion 821 and the heat generating coil rear end portion 829. The heat generating coil front end portion 821 is at the end portion on the front end side. The heat generating coil rear end portion 829 is at the end portion on the rear end side. The heat generating coil front end portion 821 is electrically connected to the sheath tube 810 by being welded to a part near the front end of the sheath tube 810.

[0020] FIG. 3 is a sectional view of near front ends of the sheath tube 810 and the heat generating coil 820 before welding the sheath tube 810 and the heat generating coil 820. The front end of the sheath tube 810 is

open before being welded with the heat generating coil 820. The heat generating coil 820 is arranged so as to penetrate an opening end of the sheath tube 810 before welding. The front end of the heat generating coil 820 before the welding extends obliquely with respect to the axial line O as illustrated in FIG. 3. Welding the sheath tube 810 and the heat generating coil 820 at the arrangements forms the part near the front end to the shape as illustrated in FIG. 2. In this embodiment, this welding is achieved by arc welding.

[0021] FIG. 4 is a sectional view of near a welded portion 850 after welding the sheath tube 810 and the heat generating coil 820. The welded portion 850 is formed such that the heat generating coil 820 and the sheath tube 810 are mixed in a melted state, and the thus-melted portion hardens. The welded portion 850 is hatched in FIG. 4. The outer surface of the welded portion 850 forms the sheath tube front end portion 811. A tube portion 860 illustrated in FIG. 4 is a remaining part excluding the welded portion 850 from the sheath tube 810. Thus, the welded portion 850 is formed by welding. In view of this, the welded portion 850 at least contains the main constituent of the heat generating coil 820 and the main constituent of the tube portion 860.

[0022] Using FIG. 4, the following describes a constituent analysis of the welded portion 850. This analysis is performed as a preparation of experiment described later. The part to be analyzed is near the boundary between the welded portion 850 and the tube portion 860.

[0023] The part to be analyzed is determined as follows. At the left side with respect to the axial line O in FIG. 4, a point A and a point B are determined. The point A is at a most front end side on the interface of the welded portion 850 and the tube portion 860. The point B is a most rear end side on the interface. Afterwards, a straight line W passing through the point A and the point B is drawn. This straight line W is not limited to the interface between the welded portion 850 and the tube portion 860. Assuming that the axial line O is the Y-axis on the XY plane, the front end side is a positive direction of the Y-axis, and the rear end side is a negative direction of the Y-axis, the left side of the axial line O corresponds to the negative direction of the X-axis.

[0024] The interface between the welded portion 850 and the tube portion 860 is, for example, determined as follows. First, a cross section near the welded portion 850 is mirror-finished. Then, electrolytic etching is performed with oxalic acid dehydrate on this cross section. Then, based on an enlarged image of this cross section, the interface between the welded portion 850 and the tube portion 860 is visually determined.

[0025] A straight line X obtained by translating a straight line W to the axial line O side by 0.3 mm is drawn. A part of the welded portion 850 along the straight line X is linearly (along the straight line X) analyzed at 10 μm -intervals. An average value of content ratios of aluminum at the respective points, which are obtained by this analysis, is calculated as a content ratio of aluminum near

the boundary. However, at a part up to 0.03 mm from the surface of the welded portion 850 is more likely to contain an oxide film. In view of this, this part is excluded from the analysis result.

[0026] Similarly, at the right side with respect to the axial line O in FIG. 4, a point C and a point D are determined. The point C is at a most front end side on the interface of the welded portion 850 and the tube portion 860. The point D is a most rear end side on the interface. Afterwards, a straight line Y passing through the point C and the point D is drawn. Furthermore, a straight line Z obtained by translating the straight line Y to the axial line O side by 0.3 mm is drawn. A part of the welded portion 850 along the straight line Z is linearly (along the straight line Z) analyzed at 10 μm -intervals. However, at a part up to 0.03 mm from the surface of the welded portion 850 is more likely to contain an oxide film. In view of this, this part is excluded from the analysis result.

[0027] The reason for determining the analysis part as described above is that these parts are likely to generate a crack. Here, the crack means a rift generated at the interface. An intermetallic compound having low toughness is likely to occur near the boundary between the welded portion 850 and the tube portion 860. Moreover, the intermetallic compound has thermal expansion characteristics different from the original metal. In addition to this, the part near the boundary is mechanically fragile. In view of this, repeated thermal expansion and thermal shrinkage may generate a crack at the interface near the boundary. This embodiment employs the above-described part as one example of the part near the boundary.

[0028] The following describes a procedure of the analysis. As the first step, using WDS of EPMA, the qualitative analysis of the welded portion 850 is performed. This analysis specifies an element contained in the welded portion 850. This analysis also specifies an element having the maximum mass% as the main constituent. The EPMA refers to an Electron Probe Micro Analyzer. The WDS refers to a Wavelength Dispersive X-ray Spectrometer.

[0029] As a second step, a measuring condition for the EPMA is determined. This is determined to enhance analysis accuracy. For example, when analyzing (detecting) an element specified as the main constituent at the first step by the amount of beam current, the measuring conditions for the EPMA includes: the amount of beam current does not cause a count loss due to incident of a large amount of X-rays and the number of measured counts of 10000 counts or more is obtained.

[0030] As a third step, the element specified at the first step is quantitatively-analyzed under the conditions determined at the second step. The above-described average value regarding the plurality of analysis target points is calculated as the content ratio of aluminum. In this analysis, the accelerating voltage was set to 20 kV, a probe current was set to $2.5 \times 10^{-8}\text{A}$, and an irradiation diameter of the beam was set to 10 μm . The main peak

is taken in for 10 seconds. Furthermore, backgrounds on respective high angle side and low angle side are taken in for five seconds. From net strength, a Count Per Second (CPS) of each element is obtained. Using this CPS and the CPS of a comparative sample (standard sample manufactured by Astimex Standards Ltd.) analyzed under the same conditions, a quantitative calculation is performed by a ZAF method. The content ratio of aluminum in this comparative sample was preliminarily analyzed. The ZAF is an acronym based on an atomic number effect (Z effect), absorption effect, and a fluorescence excitation effect. During this quantitative calculation, normalization (standardization) is performed such that the sum of the content ratio becomes 100%.

[0031] FIG. 5 is a table showing an experimental result regarding the relationship between a content ratio of aluminum and generation of a crack at the above-described part near the boundary.

[0032] For Experiment No. 1, the heat generating coil 820 formed by a material containing nickel as the main constituent and also containing chrome, but not containing aluminum was employed. In this description, the expression of "not containing aluminum" includes the case where aluminum is contained at the content ratio of around a level of an error. In the case of Experiment No. 1, the tube portion 860 formed by a material not containing aluminum (for example, SUS310S) was employed. As a result, the content ratio of aluminum of the welded portion 850 (part near the boundary of the tube portion 860 and the welded portion 850) in Experiment No. 1 was 0.00 mass%.

[0033] In the cases of Nos. 2 to 10, the heat generating coil 820 formed by a material containing iron as the main constituent and also containing chrome and aluminum was employed. Furthermore, the tube portion 860 formed by Alloy 602 was employed. Alloy 602 means a DIN2.4633 alloy specified by Deutsche Industrie Normen (DIN) at the time of this application. The Alloy 602 has the content ratio of chrome of 24 mass% or more to 26 mass% or less and the content ratio of aluminum is 1.8 mass% or more to 2.4 mass% or less. Consequently, the content ratio of aluminum of the welded portion 850 (part near the boundary between the welded portion 850 and the tube portion 860) became 3.00 to 5.50 mass%. The content ratio of aluminum of the welded portion 850 (part near the boundary of the welded portion 850 and the tube portion 860) was changed by adjusting the front end shape of the heat generating coil 820 before melting and the content ratio of aluminum contained in the heat generating coil 820.

[0034] As an experiment determining durability, in the case where thermal shock was repeatedly applied as a load, whether a crack occurred in the welded portion 850 or not was confirmed. As the load of the thermal shock, heating and cooling were conducted on the glow plug 10 by 8000 cycles. The heating was conducted for 20 seconds such that the surface of the glow plug 10 became 1150°C. The cooling was conducted for 60 seconds un-

der the condition that the glow plug 10 was reduced by 149°C after one second from the start of cooling. These values as experimental conditions were all illustrative and therefore may be changed for reproductive experiment.

5 For example, a temperature width lowered after one second from the start of cooling may be 139 to 159°C. A surface temperature of the glow plug 10 in the heating may be 1140 to 1160°C.

[0035] As illustrated in FIG. 5, Experiment Nos. 1 to 6 did not generate a crack. Experiment Nos. 7 to 10 generated a crack. Accordingly, the content ratio of aluminum in the welded portion 850 (part near the boundary between the welded portion 850 and the tube portion 860) is preferable to be less than 5.00 mass% and more preferable to be 4.95 mass% or less.

[0036] Furthermore, to minimize generation of the intermetallic compound from aluminum and another metal (for example, Ni_3Al , which is a compound of aluminum and nickel contained in Alloy 602), the smaller the content ratio of aluminum in the welded portion 850 (part near the boundary of the welded portion 850 and the tube portion 860) is, the more preferable the content ratio is. This content ratio is, for example, preferable to be 2.00 mass% or less and more preferable to be 1.00 mass% or less.

[0037] The following describes constituent analysis targeting the part near the surface of the welded portion 850. The constituent analysis targeting the part near the surface is performed to analyze mass% of respective aluminum, chrome, and iron. The part subject to this analysis is hatched in FIG. 6. FIG. 6 is, similar to FIG. 4, a sectional view near the welded portion 850. The part to be the analysis target is the part of the welded portion 850 where a depth from the surface is in a range of 0.03 mm to 0.5 mm. Here, the depth direction is approximately vertical direction to the surface as illustrated in FIG. 6. The reason for removing the range up to 0.03 mm is, as described above, to remove the oxide film from the analysis target. The content ratio of aluminum at each of the predetermined number of points (for example, 10 points) selected from the part to be analyzed is obtained. The average value of the content ratios is calculated as the average content ratio of aluminum near the surface. Similarly, the average content ratio of chrome and iron are calculated. The analysis targeting the respective points is performed by the same method as the method for the first to the third steps, which is described as the analysis near the boundary. However, the irradiation diameter of the beam was changed to 100 μm . The analysis target points may be selected, for example, randomly. The analysis target points may also be selected such that the analysis target points are dispersed as much as possible.

[0038] FIG. 7 is a table showing an experimental result examining the relationship between the average content ratios of aluminum and chrome near the surface of the welded portion 850 and the oxidative consumption. Here, the oxidative consumption means that due to repeated thermal loads, the surface of the welded portion 850 is peeled off, falls, and is thinned. The condition of thermal

load is the same as the already-described condition as an experiment regarding the crack. FIG. 7 also shows compositions of the heat generating coil 820 and the tube portion 860 employed to achieve the average content ratios of aluminum and chrome regarding the respective experiment Nos. The "residual" in the compositions of the heat generating coil 820 and the tube portion 860 means a trace additive and impurities. The impurities mean, for example, carbon, silicon, titanium, manganese or the like.

[0039] The evaluation A on the oxidative consumption shown in FIG. 7 means that a thickness of the part thinned due to the oxidative consumption (hereinafter referred to as a "wearing rate") is less than 0.05 mm. The evaluation B means that the wearing rate is 0.05 mm or more to less than 0.10 mm. The evaluation C means that the wearing rate is 0.10 mm or more to less than 0.15 mm. The evaluation D means that the wearing rate is 0.15 mm or more to less than 0.20 mm. As shown in FIG. 7, when the average content ratio of aluminum was 2.5 mass% or less (Experiment Nos. 11 to 37), the evaluation on the oxidative consumption was C or higher. In contrast to this, when the average content ratio of aluminum was 2.6 mass% (Experiment No. 38), the evaluation on the oxidative consumption was D. Accordingly, the average content ratio of aluminum near the surface of the welded portion 850 is preferable to be 2.5 mass% or less.

[0040] As described above, the reason for the average content ratio of aluminum affects the oxidative consumption is as follows. The oxide film of aluminum has an action of securing the oxide film of chrome to a base material. Accordingly, in the case where the oxide film of aluminum is too thick, if the thermal load is repeatedly applied and peels off the oxide film of aluminum, the oxide film of chrome is also peeled off. As described above, the reason for the evaluation of Experiment No. 38 being D was considered as follows. Since the average content ratio of aluminum was too high, 2.6 mass%, the generated oxide film of aluminum was too thick. In contrast to this, in the case where the average content ratio of aluminum was 2.5 mass% or less, since the generated oxide film of aluminum was not too thick, the evaluation of C or higher was obtained. Furthermore, the average content ratio of aluminum is preferable to be less from the viewpoint of the oxidative consumption. The average content ratio of aluminum is, for example, preferable to be 1.2 mass% or less.

[0041] On the other hand, if the average content ratio of aluminum is 0.03 mass% or less (Experiment No. 39), since the content of aluminum suppressing invasion of nitrogen is too little, nitrogen invades the inside of the sheath tube 810. Nitrogen invaded the inside of the sheath tube 810 causes nitriding of the heat generating coil 820, resulting in degrade of the durability of the heat generating coil 820. Accordingly, the average content ratio of aluminum is preferable to be a value greater than 0.03 mass% (for example, 0.04 mass% or more) from the viewpoint of the durability of the heat generating coil

820. Note that Experiment No. 39 obtained the evaluation of A from the viewpoint of the oxidative consumption. However, by analysis using the above-described WDS of EPMA, nitriding of the heat generating coil 820 was confirmed. Nitriding of the heat generating coil 820 possibly degrades the durability. Accordingly, the evaluation of Experiment No. 39 was B.

[0042] As shown in FIG. 7, when the average content ratio of aluminum was 0.04 mass% or more to 2.5 mass% or less and the average content ratio of chrome was 10 mass% or more to 40 mass% or less, (Experiment Nos. 11 to 37), the evaluation was C or higher. Accordingly, the average content ratio of chrome near the surface of the welded portion 850 is preferable to be 10 mass% or more to 40 mass% or less.

[0043] As shown in FIG. 7, when the average content ratio of aluminum was 0.04 mass% or more to 2.5 mass% or less and the average content ratio of chrome was 15 mass% or more to 30 mass% or less (Experiment Nos. 13 to 33), the evaluation was B or higher. Accordingly, the average content ratio of chrome near the surface of the welded portion 850 is preferable to be 15 mass% or more to 30 mass% or less.

[0044] As shown in FIG. 7, where the average content ratio of aluminum was 0.04 mass% or more to 2.5 mass% or less and the average content ratio of chrome was 15 mass% or more to 21 mass% or less (Experiment Nos. 13 to 18), the evaluation was A. Accordingly, the average content ratio of chrome near the surface of the welded portion 850 is preferable to be 15 mass% or more to 21 mass% or less.

[0045] As described above, the reason for the average content ratio of chrome affects the oxidative consumption is as follows. An alloy containing chrome and aluminum forms an oxide film where an oxide of the chrome is formed on the surface. If the thermal load is repeatedly applied, as described above, the oxide film is repeatedly generated and peeled off, thus rapidly accelerating the oxidative consumption. In view of this, it is preferable that the oxide film be not thick too much. In the case where the average content ratio of chrome is within the above-described appropriate range, the oxide film is formed so as not to be thick too much and further is formed minutely. In view of this, the oxidative consumption is suppressed.

[0046] The average content ratios of iron of Experiment Nos. 11 to 21, 23, and 25 to 38 were 17 mass% or more to 21 mass% or less (not shown). In the case where the average content ratio of iron is 17 mass% or more to 21 mass% or less, this prevents or suppresses the aggregated iron being exposed on the surface in association with the oxidative consumption. When the aggregated iron is exposed on the surface, the aggregated iron is rapidly oxidized. This locally accelerates the oxidative consumption. Therefore, iron is preferable not to be aggregated at the welded portion. To achieve this, as described above, the average content ratio of iron is preferable to be 17 mass% or more to 21 mass% or less.

[0047] In Experiment No. 23, the heat generating coil

820 contains aluminum while the sheath tube 810 does not contain aluminum. In Experiment Nos. 22 and 24, the heat generating coil 820 does not contain aluminum while the sheath tube 810 contains aluminum. In Experiment Nos. 22 and 24, the main constituent of the heat generating coil 820 is nickel.

[0048] As the material of the tube portion 860, a nickel base alloy is employed. However, in Experiment Nos. 16, 17, 20 to 22, 24, 26, and 27, as the material of the tube portion 860, INCONEL 601 (INCONEL is a registered trademark) may be employed. Further, in Experiment Nos. 18, 19, 25, 29, 30, and 38, an Alloy 602 may be employed as the material of the tube portion 860.

[0049] The techniques of the present invention are not limited to the above-described embodiments. The techniques of the present invention may be practiced in various forms without departing from its spirit and scope. For example, to solve a part of or all of the above-described problems, or to achieve a part of or all of the above-described effects, the technical features in the embodiments corresponding to the technical features in the respective embodiments described in SUMMARY may be, as necessary, replaced or combined. If the technical feature is not described as essential in the description, it can be deleted as necessary. As another embodiment in the present invention, for example, the following embodiments are illustrative.

[0050] FIG. 8 illustrates shapes of the sheath tube 810 and a heat generating coil 820a before welding the sheath tube 810 and the heat generating coil 820a as another embodiment. The heat generating coil 820a substitutes for the heat generating coil 820 in the embodiment. The front end of the heat generating coil 820a, as illustrated in FIG. 8, extends almost parallel to the axial line O.

[0051] FIG. 9 illustrates shapes of the sheath tube 810 and a heat generating coil 820b before welding the sheath tube 810 and the heat generating coil 820b as yet another embodiment. The heat generating coil 820b substitutes for the heat generating coil 820 in the embodiment. The front end of the heat generating coil 820b, as illustrated in FIG. 9, is formed such that the part projecting from the opening end is closely coiled. Besides, the shape of the heat generating coil before welding may have a different shape from the heat generating coils illustrated in FIG. 3, FIG. 8, and FIG. 9.

[0052] The method for analyzing the content ratio of aluminum in the welded portion is not limited to the methods described in the embodiments. The method may change an apparatus used for the analysis. The part to be analyzed may be changed. For example, the part where a crack is likely to be generated is selected, and the part may be set as an analysis target. For example, the part where aluminum is aggregated most may be selected as the part where a crack is likely to be generated. For example, an observer may select the part where aluminum is aggregated most, based on an image illustrating a distribution of the content ratio of aluminum. This

magnification of the image, for example, may be 30. The number of measurement points and an interval of the measurement points may be changed appropriately for appropriate evaluation on durability.

[0053] In the present invention, the welded portion means the tube portion extending in an axial direction and disposed at the outer circumference of the heating unit, and a part that contains at least the main constituent of the tube portion and the main constituent of the heating unit and blocks the front end of the tube portion. The welded portion is not limited to a part manufactured by welding.

[0054] The foregoing detailed description has been presented for the purposes of illustration and description. Many modifications and variations are possible in light of the above teaching. It is not intended to be exhaustive or to limit the subject matter described herein to the precise form disclosed. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims appended hereto.

Claims

1. A glow plug, comprising:

a heating unit that generates heat by transmission of electricity; and
a sheath tube including a tube portion and a welded portion, the tube portion being disposed at an outer circumference of the heating unit and extending in an axial line direction, the welded portion containing at least a main constituent of the tube portion and a main constituent of the heating unit and closing a front end of the tube portion, wherein
in a range of 0.03 mm or more to 0.5 mm or less from a surface of the welded portion to an inside of the surface, an average content ratio of aluminum is 2.5 mass% or less.

2. The glow plug according to claim 1, wherein at least one of the tube portion and the heating unit contains aluminum.

3. The glow plug according to claim 2, wherein the heating unit contains aluminum.

4. The glow plug according to any one of claims 1 to 3, wherein
in the range of 0.03 mm or more to 0.5 mm or less, an average content ratio of chrome is 10 mass% or more to 40 mass% or less.

5. The glow plug according to claim 4, wherein
in the range of 0.03 mm or more to 0.5 mm or less,
an average content ratio of chrome is 15 mass% or
more to 30 mass% or less. 5
6. The glow plug according to claim 5, wherein
in the range of 0.03 mm or more to 0.5 mm or less,
an average content ratio of chrome is 15 mass% or
more to 21 mass% or less. 10
7. The glow plug according to any one of claims 1 to 6,
wherein
the tube portion contains aluminum at a content ratio
of more than 1.7 mass%. 15
8. The glow plug according to claim 7, wherein
the tube portion contains chrome at a content ratio
of 24 mass% or more to 26 mass% or less and con-
tains aluminum at a content ratio of 1.8 mass% or
more to 2.4 mass% or less. 20
9. The glow plug according to any one of claims 1 to 8,
wherein
a main constituent of the heating unit is nickel. 25
10. The glow plug according to any one of claims 1 to 9,
wherein
the welded portion contains aluminum at a content
ratio of less than 5 mass% at a part near a boundary
with the tube portion. 30
11. The glow plug according to any one of claims 1 to
10, wherein
in the range of 0.03 mm or more to 0.5 mm or less,
an average content ratio of aluminum is 1.2 mass% 35
or less.
12. The glow plug according to any one of claims 1 to
11, wherein
in the range of 0.03 mm or more to 0.5 mm or less, 40
an average content ratio of aluminum is 0.04 mass%
or more.
13. The glow plug according to any one of claims 1 to
12, wherein 45
in the range of 0.03 mm or more to 0.5 mm or less,
an average content ratio of iron is 17 mass% or more
to 21 mass% or less.

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FIG. 1

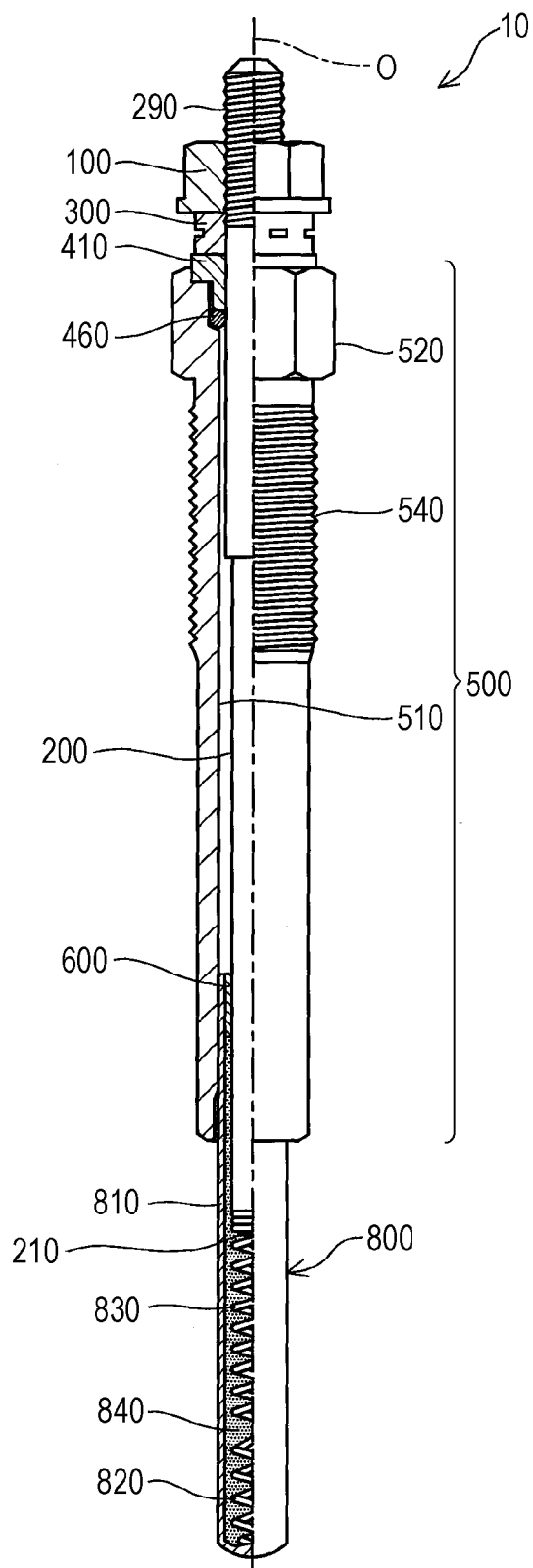


FIG. 2

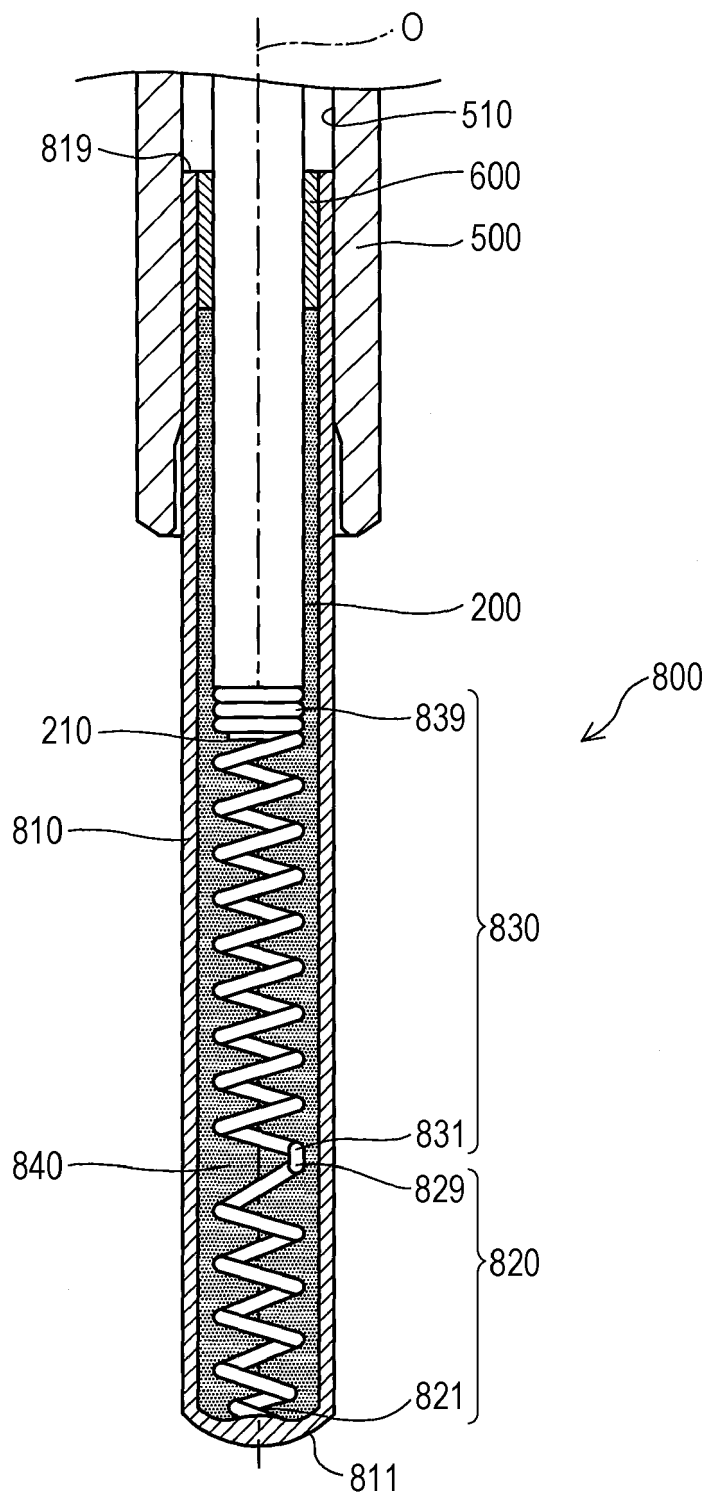


FIG. 3

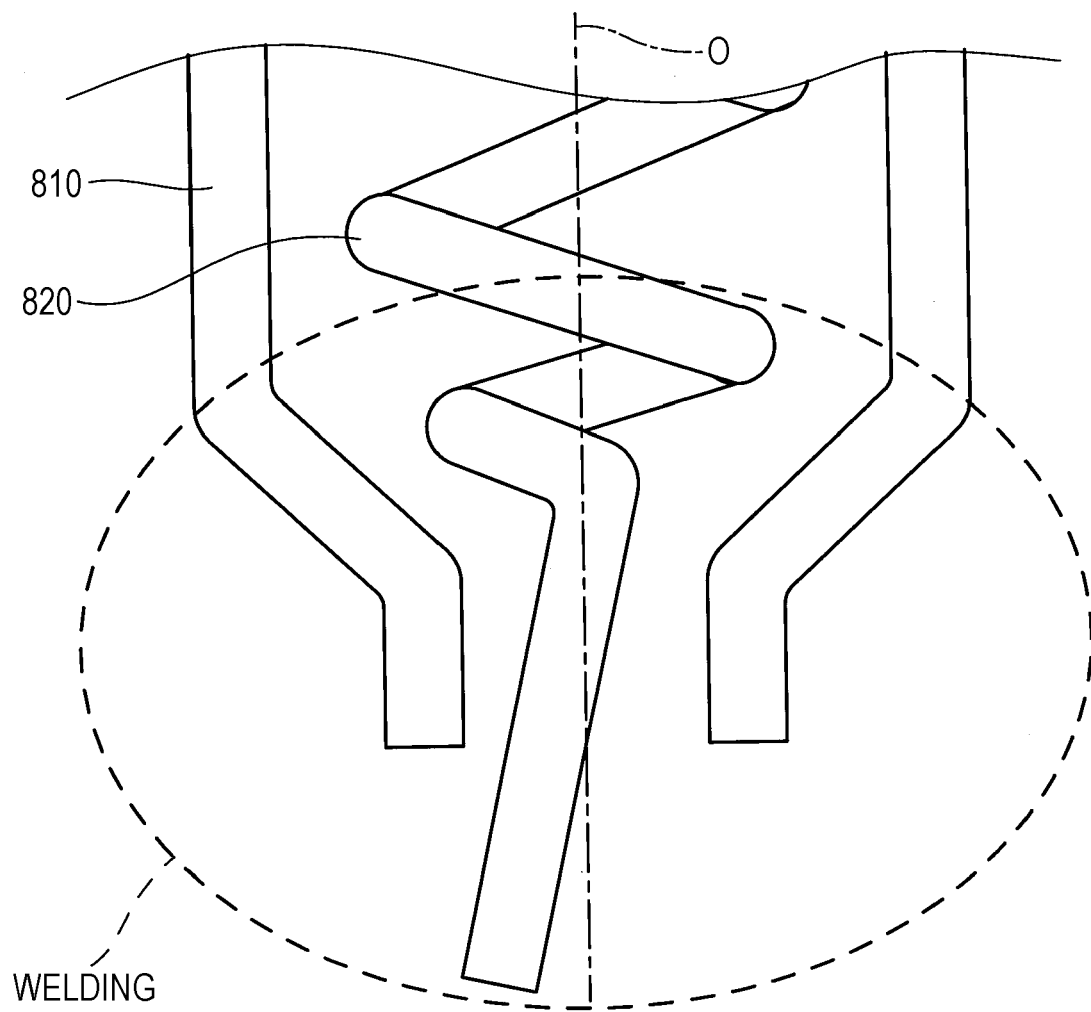
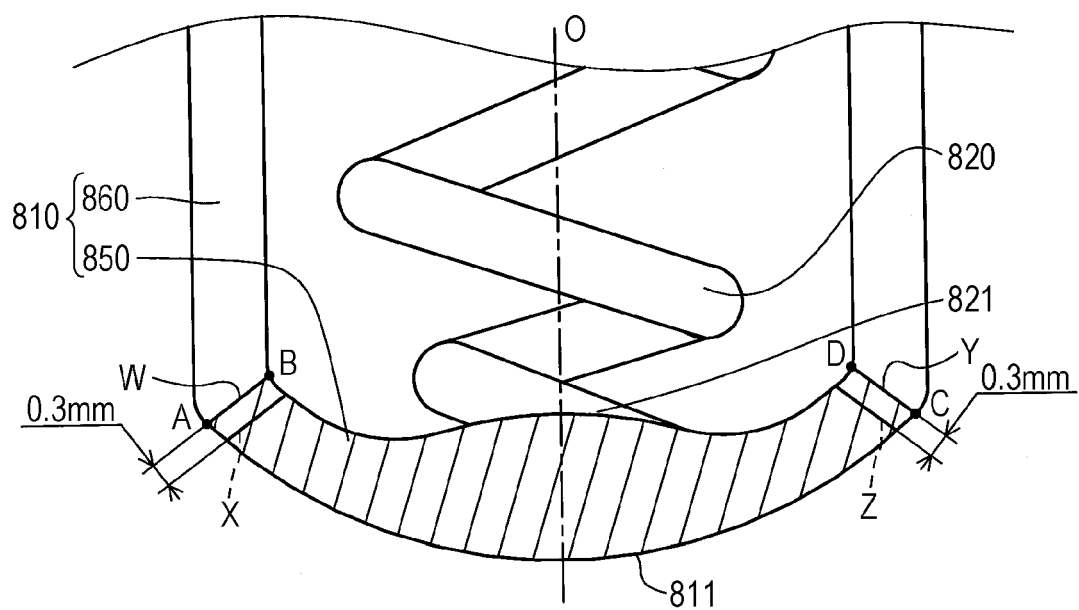


FIG. 4**FIG. 5**

EXPERIMENT No.	Al CONTENT RATIO NEAR BOUNDARY (mass%)	COMPOSITION OF HEAT GENERATING COIL	CRACK
1	0.00	Ni-Cr	NO
2	3.00	Fe-Cr-Al	NO
3	4.50	Fe-Cr-Al	NO
4	4.80	Fe-Cr-Al	NO
5	4.90	Fe-Cr-Al	NO
6	4.95	Fe-Cr-Al	NO
7	5.00	Fe-Cr-Al	YES
8	5.10	Fe-Cr-Al	YES
9	5.30	Fe-Cr-Al	YES
10	5.50	Fe-Cr-Al	YES

FIG. 6

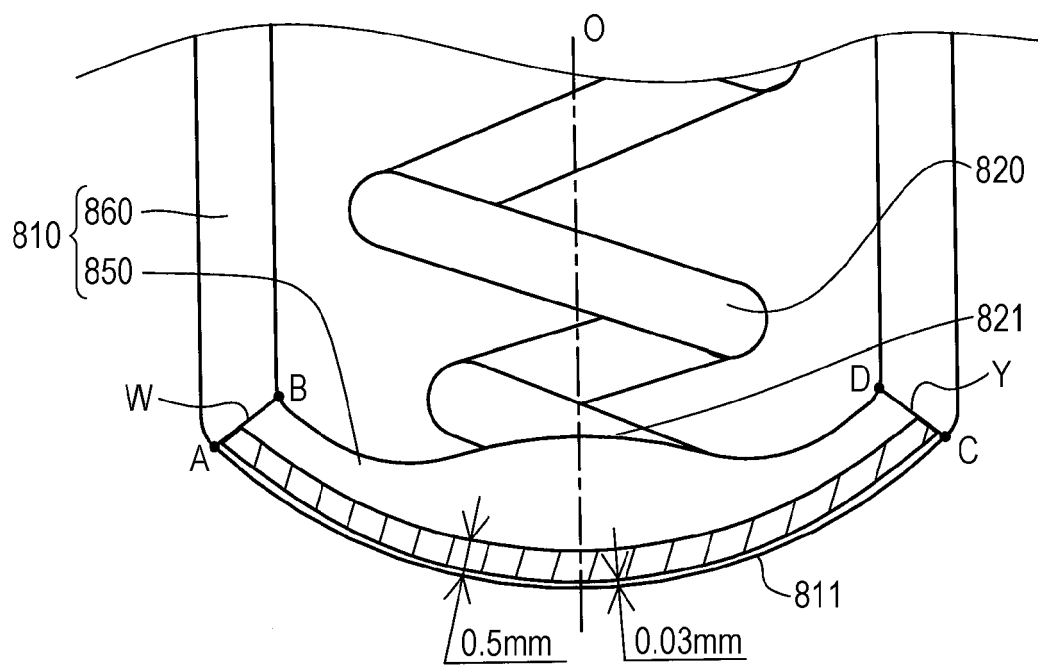


FIG. 7

No.	COMPOSITION OF WELDED PORTION (mass%)		COMPOSITION OF HEAT GENERATING COIL (mass%)					COMPOSITION OF TUBE PORTION (mass%)					OXIDATIVE CONSUMPTION
	Al	Cr	Al	Cr	Fe	Ni	RESIDUAL	Al	Cr	Fe	Ni	RESIDUAL	
11	0.04	10	3	19	77.8	–	0.2	0.04	13.8	15.1	70.96	0.1	C
12	2.00	14	5.1	12.5	82.1	–	0.3	1.3	13.8	15.1	69.7	0.1	C
13	0.04	15	3	19	77.8	–	0.2	0.04	15.6	15.1	69.16	0.1	A
14	2.00	16	5.1	16.4	78.2	–	0.3	1.3	15.6	15.1	67.9	0.1	A
15	0.04	18	3	19	77.8	–	0.2	0.04	23.8	15.1	60.96	0.1	A
16	2.00	18	5.1	20.5	74.1	–	0.3	1.3	23.8	15.1	59.7	0.1	A
17	0.04	21	3	25.9	70.9	–	0.2	1.3	23.8	15.1	59.7	0.1	A
18	2.50	21	5.1	22.5	72.1	–	0.3	2.1	25.9	9.8	62.1	0.1	A
19	1.40	23.8	7.5	25.9	66.4	–	0.2	2.1	25.9	9.8	62.1	0.1	B
20	0.04	24	3	25.9	70.9	–	0.2	1.3	23.8	15.1	59.7	0.1	B
21	0.05	24	3	25.9	70.9	–	0.2	1.3	23.8	15.1	59.7	0.1	B
22	0.09	24	–	20	–	79.9	0.1	1.3	23.8	15.1	59.7	0.1	B
23	0.70	24	7.5	25.9	66.4	–	0.2	–	23.8	16.4	59.7	0.1	B
24	1.05	24	–	20	–	79.9	0.1	1.3	23.8	15.1	59.7	0.1	B
25	1.60	24	7.5	25.9	66.4	–	0.2	2.1	25.9	9.8	62.1	0.1	B
26	1.75	24	7.5	25.9	66.4	–	0.2	1.6	23.8	15.1	59.4	0.1	B
27	1.80	24	7.5	25.9	66.4	–	0.2	1.7	23.8	15.1	59.3	0.1	B
28	1.85	24	7.5	25.9	66.4	–	0.2	1.8	23.8	15.1	59.2	0.1	B
29	2.15	24	7.5	25.9	66.4	–	0.2	2.1	25.9	9.8	62.1	0.1	B
30	2.20	24	7.8	22.5	69.4	–	0.3	2.2	25.9	9.8	62	0.1	B
31	2.50	24	5.1	22.5	72.1	–	0.3	2.7	25.5	9.8	61.9	0.1	B
32	0.04	30	1	25.9	72.9	–	0.2	1.3	30.9	15.1	52.6	0.1	B
33	2.50	30	5.1	22.5	72.1	–	0.3	2.3	30.9	9.8	56.9	0.1	B
34	0.04	35	2	25.9	71.9	–	0.2	1.3	35.4	15.1	48.1	0.1	C
35	2.50	35	5.1	22.5	72.1	–	0.3	2.3	35.4	9.8	52.4	0.1	C
36	0.04	40	3	25.9	70.9	–	0.2	1.3	41.6	15.1	41.9	0.1	C
37	2.50	40	5.1	22.5	72.1	–	0.3	2.1	41.6	9.8	46.4	0.1	C
38	2.60	24	5.7	22.5	71.5	–	0.3	2.3	25.9	9.8	61.9	0.1	D
39	0.03	24	–	20.0	–	79.9	0.1	0.04	13.8	15.1	70.96	0.1	B

FIG. 8

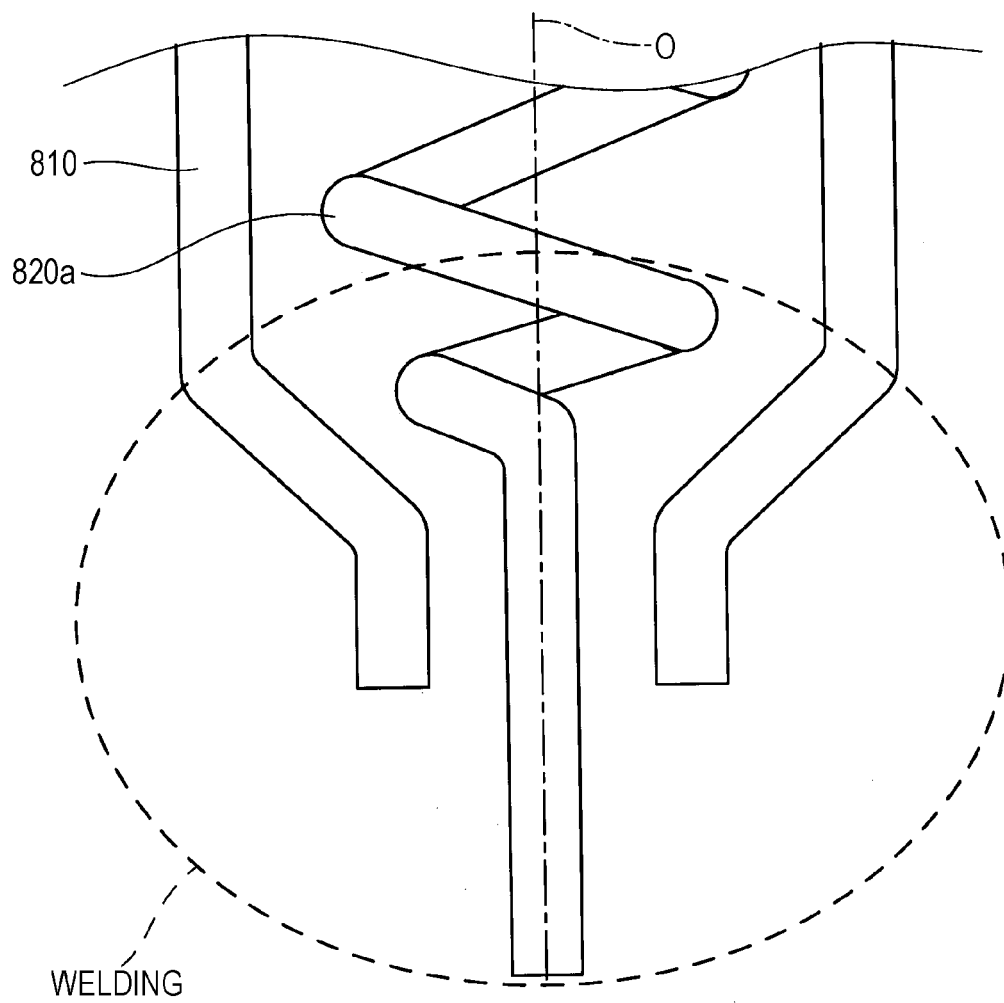
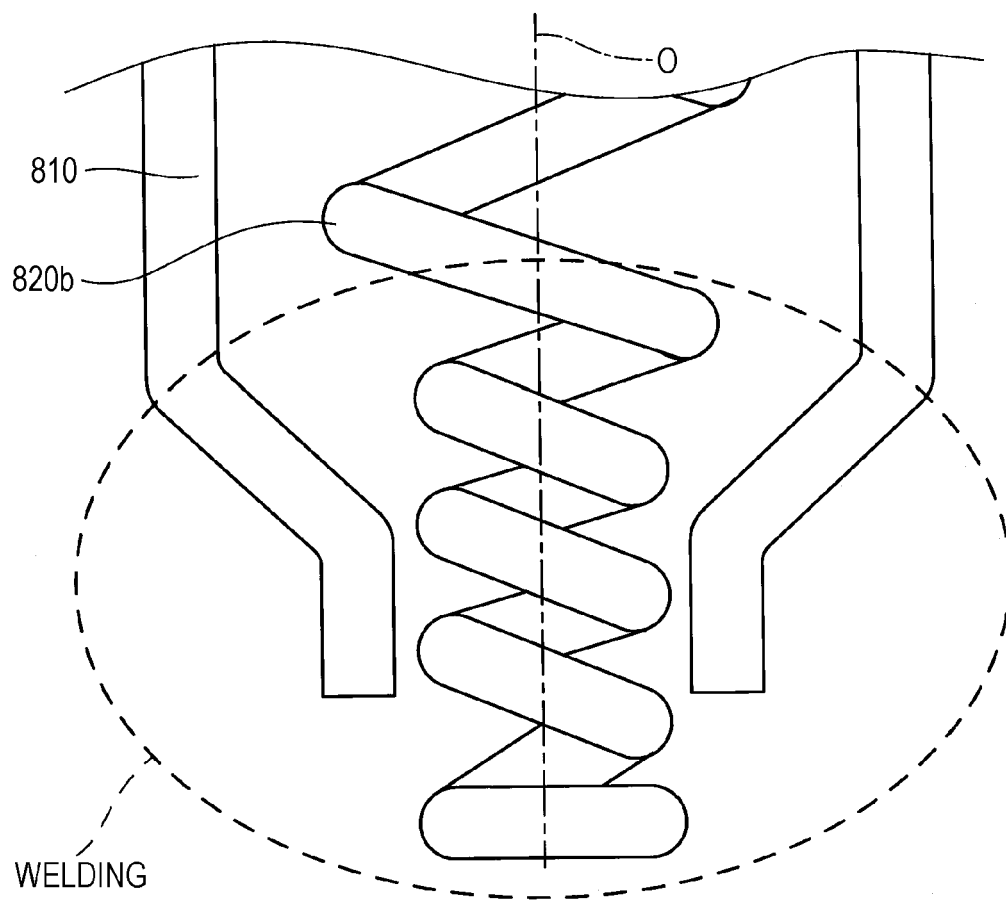


FIG. 9





EUROPEAN SEARCH REPORT

Application Number
EP 14 19 1865

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X	EP 2 410 243 A2 (NGK SPARK PLUG CO [JP]) 25 January 2012 (2012-01-25) * paragraphs [0007], [0011], [0033] * * figure 3 *	1,2,7, 10-12	
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			F23Q
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 10 March 2015	Examiner Vogl, Paul
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