



(11)

EP 2 410 243 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
25.01.2012 Bulletin 2012/04

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

(21) Application number: **11174774.7**

(22) Date of filing: **21.07.2011**

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

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(30) Priority: **21.07.2010 JP 2010164239**
06.07.2011 JP 2011149791

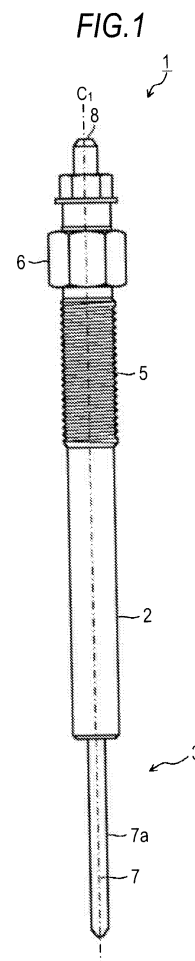
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(54) **Glow Plug**

(57) [Problem] To provide a glow plug with which it is possible to improve heat resistance and durability in comparison with a heretofore known one.

[Means for Resolution] A glow plug uses a sheathed heater with a heating coil housed in a sheath tube. The sheath tube, being formed from a nickel base alloy containing 21 to 30 percent by mass of chromium (Cr), 0.05 to 0.30 percent by mass of carbon (C), 1.0 to 2.4 percent by mass of aluminum (Al), and 0.1 to 0.3 percent by mass of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb), is such that when examining a metal structure in a circumferential transverse section of the sheath tube, the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005), and Vickers hardness is within a range of 200 to 400.



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Description

[Technical Field]

[0001] The invention relates to a glow plug used in a diesel engine.

[Background Art]

[0002] Heretofore, as a glow plug used as a diesel engine starting auxiliary or the like, one using a sheathed heater wherein a heating coil containing chromium (Cr), aluminum (Al), and the like, is enclosed in a metallic tube (a sheath tube) closed at the leading end portion has been known.

[0003] An operating temperature elevation and rapid temperature rise characteristic are required of this kind of glow plug. For this reason, heat resistance and durability have become required of the sheath tube, and the requirement can no longer be satisfied in terms of oxidation resistance by a heretofore known sheath tube using Inconel (registered trade name) 601 or the like. Also, with the heretofore known glow plug, there has been a problem in that a crack is likely to occur in the sheath tube. This is because a sheath tube of a common glow plug is such that a strip material is rolled and welded into a pipe-like form, and this pipe-like member is formed to configure the sheath tube, meaning that the strength of a welded portion of the sheath tube decreases in comparison with that of the other portion, and a crack is likely to occur in the welded portion.

[0004] Hence, a glow plug manufacturing method is proposed whereby an occurrence of a crack in the welded portion is suppressed by repeatedly carrying out transformation and heating (for example, refer to Patent Document 1). However, the effectiveness of preventing a crack occurring in the welded portion cannot be said to be sufficient even with the glow plug manufacturing method, and a further improvement in heat resistance and durability is required.

[Related Art Documents]

[Patent Documents]

[0005]

[Patent Document 1] JP-A-2009-158431

[Disclosure of the Invention]

[Problems that the Invention is to Solve]

[0006] The invention has been contrived in response to the heretofore known circumstances heretofore described. The invention has an object of providing a glow plug with which it is possible to improve heat resistance and durability in comparison with the heretofore known

one.

[Means for Solving the Problems]

[0007] According to one aspect of the glow plug of the invention, a glow plug using a sheathed heater with a heating coil housed in a sheath tube is characterized in that the sheath tube, being formed from a nickel base alloy containing 21 to 30 percent by mass of chromium (Cr), 0.05 to 0.30 percent by mass of carbon (C), 1.0 to 2.4 percent by mass of aluminum (Al), and 0.1 to 0.3 percent by mass of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb), is such that when examining a metal structure in a circumferential transverse section of the sheath tube, the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005), and Vickers hardness is within a range of 200 to 400.

[0008] With the glow plug of the invention, the sheath tube is formed from a nickel base alloy containing 21 to 30 percent by mass of chromium (Cr), 0.05 to 0.30 percent by mass of carbon (C), 1.0 to 2.4 percent by mass of aluminum (Al), and 0.1 to 0.3 percent by mass of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb). This is for the following kinds of reason.

[0009] The reason for setting the lower limit of the content of chromium (Cr) to 21 percent by mass is to secure high-temperature oxidation resistance, and the reason for setting the upper limit thereof to 30 percent by mass is to secure cold workability. That is, this is because it is no longer possible to obtain sufficient high-temperature oxidation resistance when the content of chromium (Cr) is set to less than 21 percent by mass, and it is no longer possible to obtain sufficient cold workability when the content of chromium (Cr) is set to more than 30 percent by mass.

[0010] The reason for setting the lower limit of the content of carbon (C) to 0.05 percent by mass is to secure high-temperature strength, and the reason for setting the upper limit thereof to 0.3 percent by mass is to secure cold workability and high-temperature oxidation resistance. That is, this is because it is no longer possible to obtain sufficient high-temperature strength when the content of carbon (C) is set to less than 0.05 percent by mass, and it is no longer possible to obtain sufficient cold workability or high-temperature oxidation resistance when the content of carbon (C) is set to more than 0.3 percent by mass.

[0011] The reason for setting the lower limit of the content of aluminum (Al) to 1.0 percent by mass is to secure high-temperature oxidation resistance, and the reason for setting the upper limit thereof to 2.4 percent by mass is to avoid an excessive generation of Ni_3Al . That is, this is because it is no longer possible to obtain sufficient high-temperature oxidation resistance when the content of aluminum (Al) is set to less than 1.0 percent by mass, and Ni_3Al is excessively generated when the content of aluminum (Al) is set to more than 2.4 percent by mass.

[0012] The reason for setting the lower limit of the content of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb) to 0.1 percent by mass is to secure high-temperature creep strength, and the reason for setting the lower limit thereof to 0.3 percent by mass is to secure cold workability. That is, this is because it is no longer possible to obtain sufficient high-temperature creep strength when the content of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb) is set to less than 0.1 percent by mass, and it is no longer possible to obtain sufficient cold workability when the content thereof is set to more than 0.3 percent by mass.

[0013] Also, with the glow plug of the invention, when examining the metal structure in the circumferential transverse section of the sheath tube, the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005). By making the size of the metal structure in the circumferential transverse section of the sheath tube uniform in this way, it is possible to prevent, for example, a crack from occurring in the welded portion due to a difference in the size of the metal structure between the welded portion and the other region. That is, by making the circumferential metal structure uniform, the condition in which a region high in strength and a region low in strength exist in the same circumferential plane is eliminated, and it is possible to eliminate the situation wherein the sheath tube is deformed focused on one point in response to a deformation due to thermal stress caused by heating and cooling. Because of this, it is possible to provide a glow plug of high durability and high heat resistance with which it is difficult for a crack to occur in the sheath tube.

[0014] That a variation is 2 or less in crystal grain size number according to JIS G0551 (2005) indicates that the grain size number is within a range of 1 either side of an intermediate grain size number, for example, within a range of 9 to 11. In this case, when examining the metal structure in the circumferential transverse section of the sheath tube, it is more preferable that the size of the metal structure has a variation of 0 in crystal grain size number according to JIS G0551 (2005), that is, the crystal grain size numbers are the same.

[0015] Also, the circumferential transverse section of the sheath tube indicates the transverse section of a third region wherein a second region of the sheath tube in the same position as a leading end portion of the heating coil is removed from a first region of the sheath tube in the same position as the heating coil in an axial direction (a first region of the sheath tube radially surrounding the heating coil) when looking at the glow plug from a radial direction perpendicular to the axial direction. The leading end portion of the heating coil represents a region of up to 20% of the axial length of the heating coil from the leading end of the heating coil. Then, in any transverse section of the sheath tube within the range of the third region, it is shown that the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005).

[0016] Also, with the glow plug of the invention, furthermore, the Vickers hardness (HV) of the sheath tube is within a range of 200 to 400. This is because a bend occurs in the sheath tube during the manufacturing process when the Vickers hardness of the sheath tube is less than 200, and press fit operability decreases when the hardness is more than 400.

[0017] Also, with the glow plug of the invention, it is preferable that the heretofore described size of the metal structure is set to be in a range of 7 to 12 in crystal grain size number according to JIS G0551 (2005). This is because high-temperature strength decreases when the crystal grain size is too small, and the grain boundary area decreases and grain boundary corrosion resistance performance decreases when the crystal grain size is too large. To describe with a specific crystal grain size, it is preferable that an average crystal grain size is set to be on the order of 20 μm to 100 μm .

[0018] Furthermore, with the glow plug of the invention, it is preferable that when examining the metal structure in the circumferential transverse section of the sheath tube, five carbides or more of a size of 3 μm or more exist in a visual field of a diameter of 0.1 mm. This is because crystal grains are coarsened during use, causing a grain boundary crack, when there is less carbide precipitation, and because partial carbide precipitation results in an existence of a portion low in strength in the same section, leading to a deformation or breakage of the sheath tube.

[Advantage of the Invention]

[0019] According to the invention, it is possible to provide a glow plug with which it is possible to improve heat resistance and durability in comparison with the heretofore known one.

[Brief Description of the Drawings]

[0020]

[Fig. 1] A diagram showing an outline configuration of a glow plug according to one embodiment of the invention.

[Fig. 2] A diagram showing a sectional outline configuration of the glow plug of Fig. 1.

[Fig. 3] A diagram showing a sectional outline configuration of a main portion of the glow plug of Fig. 1.

[Fig. 4] Photographs showing a metal structure in a transverse section of a sheath tube of a glow plug according to a working example.

[Fig. 5] Photographs showing a metal structure in a transverse section of a sheath tube of a glow plug according to a comparison example 1.

[Fig. 6] Photographs showing a metal structure in a transverse section of a sheath tube of a glow plug according to a comparison example 2.

[Fig. 7] Photographs showing an external appearance

ance after a durability test of the glow plug according to each of the working example and comparison examples 1 and 2.

[Mode for Carrying Out the Invention]

[0021] Hereafter, a description will be given of an embodiment, referring to the drawings, for details of the invention.

[0022] Fig. 1 is a diagram showing an overall outline configuration of a glow plug 1 according to one embodiment of the invention, and Fig. 2 is a diagram showing a longitudinal sectional outline configuration of the glow plug 1.

[0023] As shown in Figs. 1 and 2, the glow plug 1 includes a hollow cylindrical main metal shell 2 and a sheathed heater 3 mounted in the main metal shell 2.

[0024] An axial hole 4 is formed in the main metal shell 2 so as to pass therethrough in a direction of an axis C_1 . Also, a thread portion 5 for attachment to a diesel engine and a tool engagement portion 6 of hexagonal section for engaging a tool, such as a torque wrench, are formed on the outer peripheral surface of the main metal shell 2.

[0025] The sheathed heater 3 is configured by a sheath tube 7 and a central shaft 8 acting as a lead member being integrated in the direction of the axis C_1 .

[0026] As shown in Fig. 3, the sheath tube 7 is configured of a hollow cylindrical metallic tube closed at the leading end portion. In the embodiment, the sheath tube 7 is configured of a nickel base alloy containing 21 to 30 percent by mass of chromium (Cr), 0.05 to 0.30 percent by mass of carbon (C), 1.0 to 2.4 percent by mass of aluminum (Al), and 0.1 to 0.3 percent by mass of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb). For example, DIN2.4633 (alloy 602) stipulated by Deutsche Industrie Normen (DIN) corresponds to such a nickel base alloy.

[0027] Also, the sheath tube 7 is such that when examining a metal structure in a circumferential transverse section thereof, the size of the metal structure is made uniform, and the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005). The circumferential transverse section of the sheath tube 7 indicates the transverse section of a third region T_3 wherein a second region T_2 of the sheath tube in the same position as a leading end portion 9a of a heating coil 9, to be described hereafter, in Fig. 3 is removed from a first region T_1 of the sheath tube in the same position as the heating coil 9. The second region T_2 is a region corresponding to the leading end portion 9a of the heating coil 9. The leading end portion 9a of the heating coil 9 represents a region of up to 20% of a length of the heating coil 9 in the direction of the axis C_1 from the leading end of the heating coil 9 (for example, when the whole length of the heating coil is set to 10 mm, the leading end portion 9a represents a region of up to 2 mm from the leading end of the heating coil 9).

[0028] In order to manufacture the sheath tube 7

wherein the size of the metal structure in the circumferential transverse section is made uniform in this way, it is possible to use, for example, a method of manufacturing an electric resistance welded tube from a strip material and repeating a plastic working and solution treatment until the structure of a welded portion and that of the other portion become uniform, a method of manufacturing the tube from a strip material with a deep drawing, or a method of manufacturing the tube from a rod material with an extrusion molding. The plastic working may be either of a cold one or hot one. It is preferable that the size of the metal structure of the sheath tube 7 is set to be in a range of 7 to 12 in crystal grain size number according to JIS G0551 (2005).

[0029] Furthermore, the sheath tube 7 is such that the Vickers hardness (HV) thereof is set to be within a range of 200 to 400.

[0030] As shown in Fig. 3, the heating coil 9 joined to the leading end of the sheath tube 7 and a control coil 10 connected in series to the rear end of the heating coil 9 are enclosed, together with insulating powder 11 such as magnesium oxide powder, inside the sheath tube 7.

[0031] The sheath tube 7 and heating coil 9 are joined at a leading end side junction point 21. Also, the heating coil 9 and control coil 10 are joined at a rear end side junction point 22.

[0032] Furthermore, the rear end of the sheath tube 7 is sealed with respect to the central shaft 8 by annular rubber 17. In addition, the heating coil 9 is in electrical continuity with the sheath tube 7 at the leading end thereof, as heretofore described, but the outer peripheral surfaces of the heating coil 9 and control coil 10 and the inner peripheral surface of the sheath tube 7 are in a condition in which they are insulated by the insulating powder 11 being interposed therebetween.

[0033] The heating coil 9 is configured of a resistance heating wire of, for example, an iron (Fe) - chromium (Cr) - aluminum (Al) alloy. Also, the control coil 10 is configured of a resistance heating wire consisting mainly of a material with a greater temperature coefficient of electrical resistivity than that of a material of the heating coil 9, for example, Co or Ni typified by a cobalt (Co) - nickel ((Ni) - Fe alloy. A configuration is such that the heating coil 9 can generate heat by being energized and raise the surface temperature of the sheath tube 7 to a predetermined temperature, and the control coil 10 can make it difficult for an excessive temperature rise of the heating coil 9 to occur.

[0034] Also, a small diameter portion 7a housing the heating coil 9 and the like is formed in the leading end portion of the sheath tube 7, and a large diameter portion 7b larger in diameter than the small diameter portion 7a is formed on the rear end side of the sheath tube 7, by a swaging or the like. Then, by the large diameter portion 7b being pressed into and joined to a small diameter portion 4a formed in the axial hole 4 of the main metal shell 2, the sheath tube 7 is held in a condition in which it protrudes from the leading end of the main metal shell 2.

[0035] The central shaft 8, by the leading end thereof being inserted into the sheath tube 7, as well as being electrically connected to the rear end of the control coil 10, is inserted in the axial hole 4 of the main metal shell 2. The rear end of the central shaft 8 protrudes from the rear end of the main metal shell 2, and this rear end portion of the main metal shell 2 is of a structure such that an O-ring 12 made of rubber or the like, an insulating bush 13 made of a resin or the like, a holding ring 14 for preventing the insulating bush 13 dropping off, and an energizing cable connection nut 15 are fitted with the central shaft 8 in this order (refer to Fig. 2).

[0036] Next, a description will be given of a manufacturing method of the glow plug 1 configured in the way heretofore described.

[0037] Firstly, a resistance heating wire of an Fe-Cr-Al alloy is processed into a coil form, obtaining the heating coil 9.

[0038] Next, a resistance heating wire of a Co-Ni-Fe alloy or the like is processed into a coil form, obtaining the control coil 10. Then, the rear end portion of the heating coil 9 and the leading end portion of the control coil 10 are joined at the rear end side junction point 22 by an arc welding or the like.

[0039] Next, the leading end of the central shaft 8 and the heating coil 9 and control coil 10 integrated with the central shaft 8 are disposed in the hollow cylindrical sheath tube 7 which is formed to be larger in diameter than in final dimension by an amount equivalent to a machining allowance, and is not closed at the leading end. Then, the leading end portion of the sheath tube 7 is closed, and the leading end portion of the sheath tube 7 and the leading end portion of the heating coil 9 are joined at the leading end side junction point 21, by an arc welding.

[0040] Subsequently, after the sheath tube 7 has been filled with the insulating powder 11, a swaging is performed on the sheath tube 7. By so doing, as well as the sheath tube 7 having the large diameter portion 7a being formed, the sheath tube 7 is integrated with the central shaft 8, and the sheathed heater 3 is completed.

[0041] Then, the sheathed heater 3 formed in the way heretofore described is pressed into and fixed in the axial hole 4 of the main metal shell 2, and the O-ring 12, insulating bush 13, and the like, are fitted with the central shaft 8 in the rear end portion of the main metal shell 2, thereby completing the glow plug 1.

[0042] By so doing, in the embodiment, it is possible to obtain a glow plug improved in heat resistance and durability in comparison with a heretofore known one.

[0043] Fig. 4 shows photographs wherein a metal structure in a circumferential transverse section of a sheath tube 7 of a glow plug according to a working example is photographed, wherein Fig. 4(a) shows the whole of the circumferential transverse section, Fig. 4 (b) shows one portion thereof in an enlarged dimension, and Fig. 4 (c) shows the one portion in a further enlarged dimension. Also, Figs. 5 and 6 each show photographs

wherein a metal structure in a circumferential transverse section of a sheath tube of a glow plug according to each comparison example 1 and 2 is photographed, wherein Fig. 5(a) and Fig. 6(a) each show the whole of the circumferential transverse section, Fig. 5(b) and Fig. 6(b) each show one portion thereof in an enlarged dimension, and Fig. 5(c) and Fig. 6(c) each show the one portion in a further enlarged dimension.

[0044] In the working example shown in Fig. 4, the sheath tube 7 is manufactured in the following way using a nickel base alloy equivalent to DIN2. 4633 (alloy 602) stipulated by the heretofore mentioned Deutsche Industrie Normen (DIN).

[0045] Specifically, the sheath tube 7 having the small diameter portion 7a and large diameter portion 7b is formed from a strip material of DIN2. 4633 using a deep drawing. Subsequently, as the sheath tube 7 is work hardened, heat treatment is implemented at 1140°C in order to soften the sheath tube 7. By implementing the heat treatment too, the circumferential structure size of the sheath tube 7 tends to be uniform.

[0046] When examining the metal structure of the sheath tube 7 in the circumferential transverse section thereof, the size is uniform, and the crystal grain size numbers according to JIS G0551 (2005) are all 11, that is, a variation in crystal grain size number is 0.

[0047] Meanwhile, in the comparison example 1 shown in Fig. 5, the sheath tube is configured using a nickel base alloy the same as that of the working example, but in the comparison example 1, the sheath tube is configured from a pipe-like member wherein a strip material is rolled, and only a welding is performed on a welded portion.

[0048] As shown in Figs. 5 (a) and (b), in the comparison example 1, the structure size of the welded portion and that of the other region are nonuniform, and the crystal grain size number according to JIS G0551 (2005) of the welded portion is 11, while the crystal grain size number according to JIS G0551 (2005) of the other region is 8, that is, a variation in crystal grain size number is 3.

[0049] Also, in the comparison example 2, the sheath tube is configured from a pipe-like member wherein an alloy equivalent to NCF601 is used, a strip material is rolled, and only a welding is performed on a welded portion. As shown in Figs. 6(a) and (b)), in the comparison example 2, the structure size of the welded portion and that of the other region are nonuniform, the crystal grain size number according to JIS G0551 (2005) of the welded portion is 11, and the crystal grain size number according to JIS G0551 (2005) of the other region is 8. That is, a variation in crystal grain size number is 3.

[0050] Furthermore, as shown in Fig. 4(c), in the working example, when examining the metal structure in the circumferential transverse section of the sheath tube, a condition is such that five carbides or more of a size of 3 μ m or more exist in a visual field of a diameter of 0.1 mm. As opposed to this, as shown in Fig. 5(c) and Fig. 6(c), in the welded portions of the comparison examples

1 and 2, the number of carbides of a size of 3 μm or more is small, and less than five carbides exist in the visual field of a diameter of 0.1 mm.

[0051] Fig. 7 shows a comparison of external photographs of the glow plug of the working example and the glow plugs of the comparison examples 1 and 2 after a durability test has been performed thereon, wherein Fig. 7 (a) shows the working example, Fig. 7 (b) shows the comparison example 1, and Fig. 7(c) shows the comparison example 2. The durability test is carried out in the following way.

[0052] Deterioration of the sheath tube is examined by repeating an energization and de-energization of the glow plug. Specifically, the glow plug is energized in a condition in which the sheath tube is at room temperature, causing the temperature of the surface of the sheath tube to reach 1000°C in two seconds. Subsequently, after the temperature of the surface of the sheath tube has been maintained at 1050°C for three minutes, the glow plug is de-energized, and the sheath tube is cooled until the condition is attained in which the sheath tube is at room temperature. This is taken to be one cycle, the cycle is repeated 10,000 times, and a subsequent deterioration condition of the sheath tube is examined.

[0053] As shown in Fig. 7(b), in the comparison example 1, a crack occurs in the welded portion of the sheath tube due to the durability test. Also, as shown in Fig. 7 (c), in the comparison example 2, wear occurs in the leading end portion of the sheath tube due to the durability test. As opposed to this, as shown in Fig. 7(a), in the working example, no crack occurs in the welded portion of the sheath tube, and no wear of the leading end portion occurs either, due to the durability test.

[0054] As heretofore described, it can be confirmed that the glow plug of the working example wherein a variation in crystal grain size number according to JIS G0551 (2005) when examining the metal structure in the circumferential transverse section of the sheath tube is 0 is high in heat resistance and durability in comparison with the glow plugs of the comparison examples 1 and 2 wherein a variation therein is 3. Consequently, in order to obtain high heat resistance and durability, a variation in crystal grain size number according to JIS G0551 (2005) when examining the metal structure in the circumferential transverse section of the sheath tube is preferably set to 2 or less, and more preferably set to 0.

[Description of Reference Numerals and Signs]

[0055]

- 1 Glow plug
- 2 Main metal shell
- 3 Sheathed heater
- 7 Sheath tube

- 9 Heating coil
- 10 Control coil

Claims

1. A glow plug using a sheathed heater with a heating coil housed in a sheath tube, **characterized in that** the sheath tube, being formed from a nickel base alloy containing 21 to 30 percent by mass of chromium (Cr), 0.05 to 0.30 percent by mass of carbon (C), 1.0 to 2.4 percent by mass of aluminum (Al), and 0.1 to 0.3 percent by mass of one kind or more among titanium (Ti), zirconium (Zr), and niobium (Nb), is such that when examining a metal structure in a circumferential transverse section of the sheath tube, the size of the metal structure has a variation of 2 or less in crystal grain size number according to JIS G0551 (2005), and Vickers hardness is within a range of 200 to 400.
2. The glow plug according to claim 1, **characterized in that** when examining the metal structure in the circumferential transverse section of the sheath tube, the size of the metal structure is in a range of 7 to 12 in crystal grain size number according to JIS G0551 (2005).
3. The glow plug according to claim 1 or 2, **characterized in that** when examining the metal structure in the circumferential transverse section of the sheath tube, five carbides or more of a size of 3 μm or more exist in a visual field of a diameter of 0.1 mm.

FIG.1

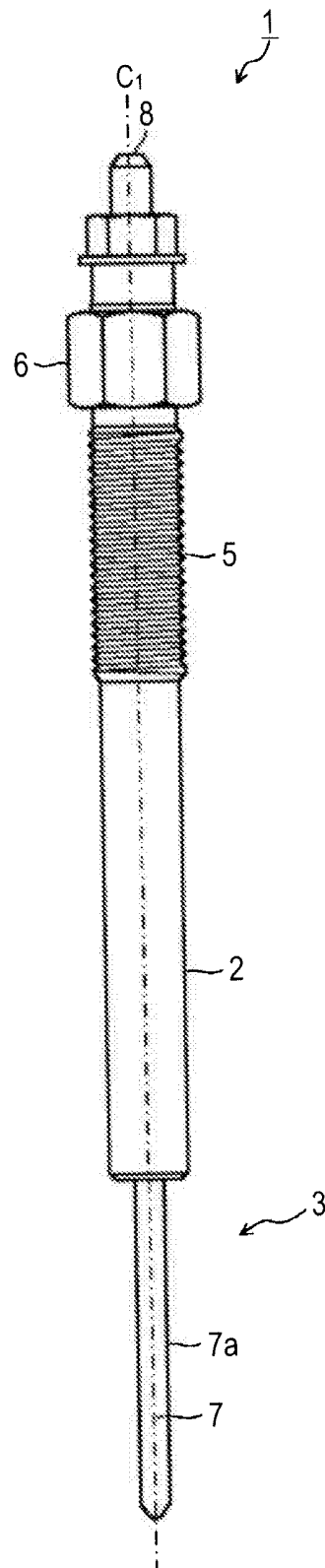


FIG.2

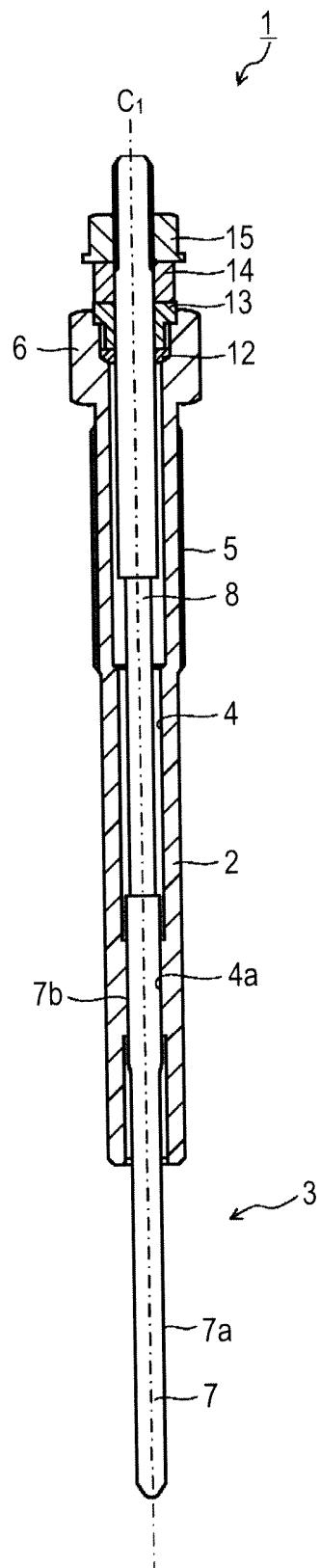


FIG.3

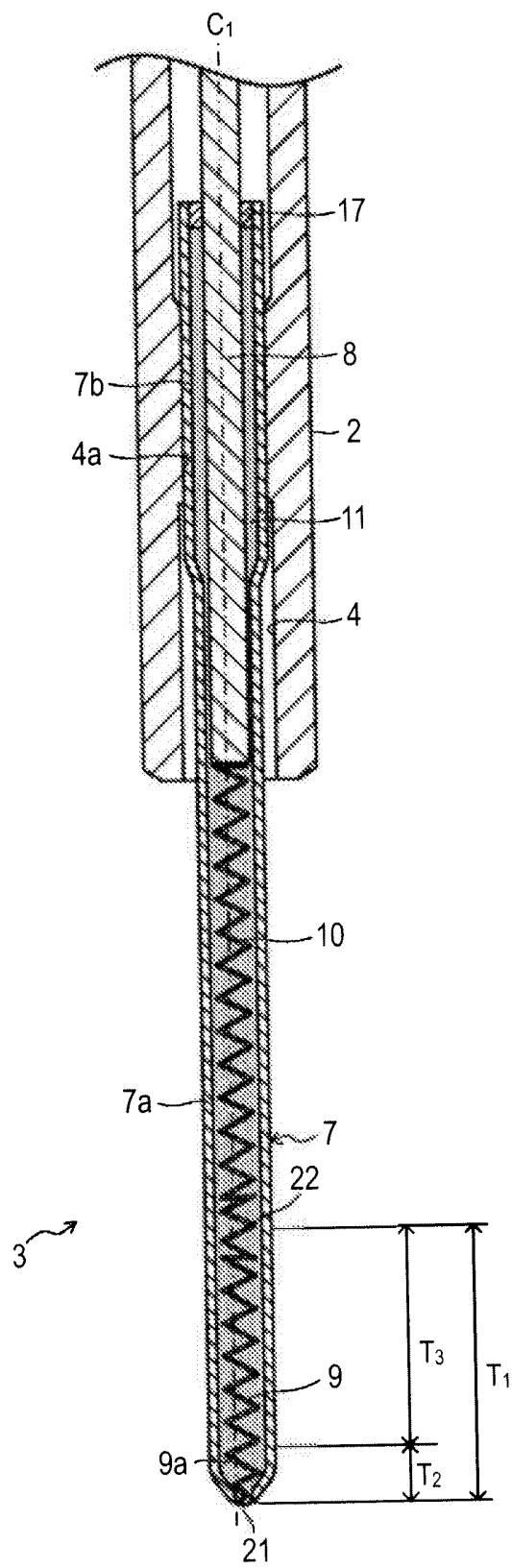


FIG.4A

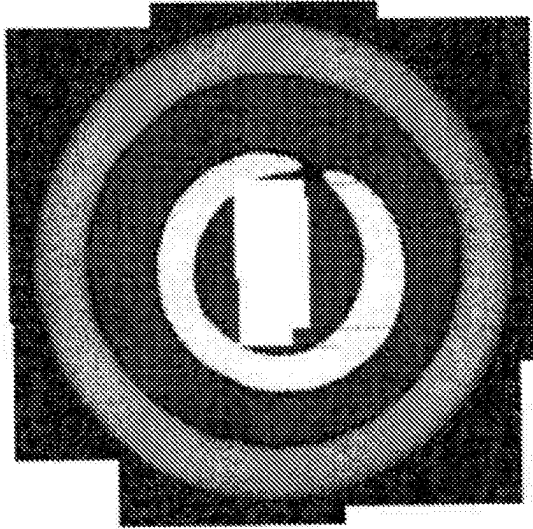
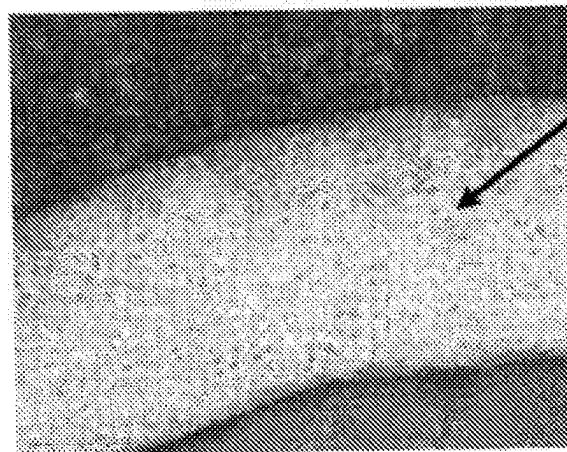


FIG.4B



GRAIN SIZE
NUMBER #11

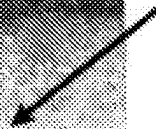
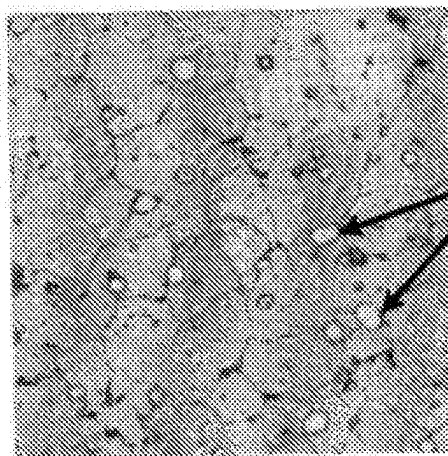


FIG.4C



CARBIDES

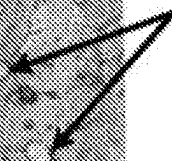


FIG.5A

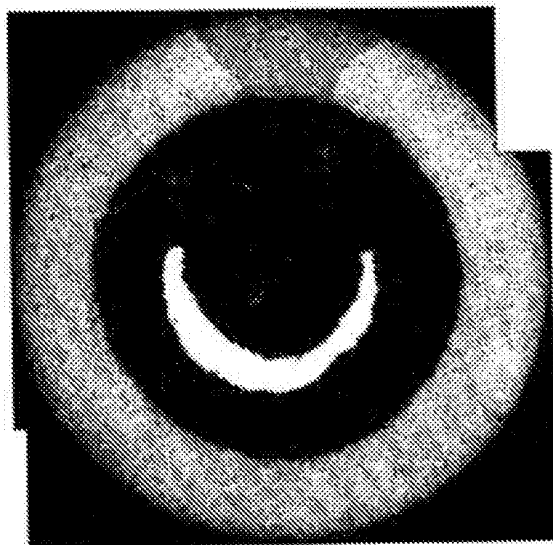


FIG.5B

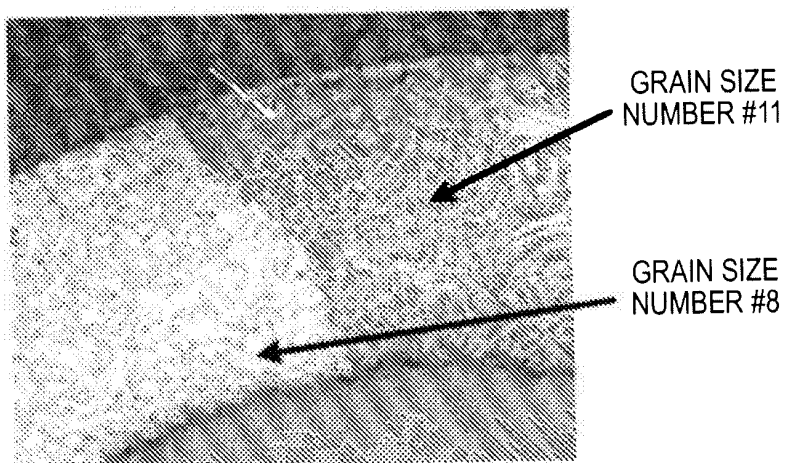


FIG.5C

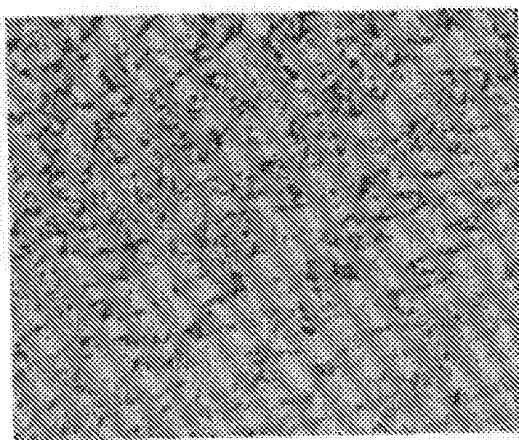


FIG.6A



FIG.6B

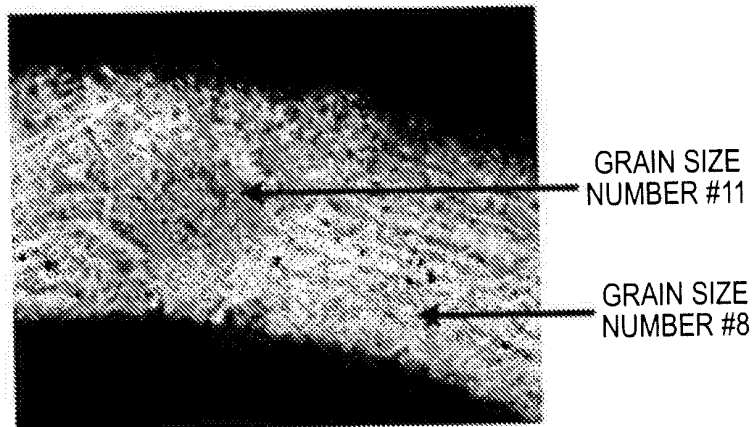


FIG.6C

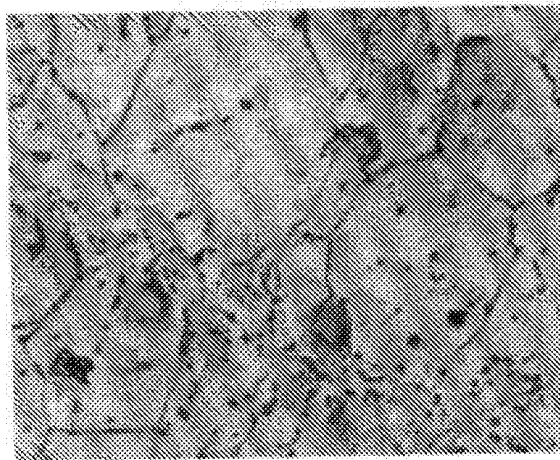


FIG.7A

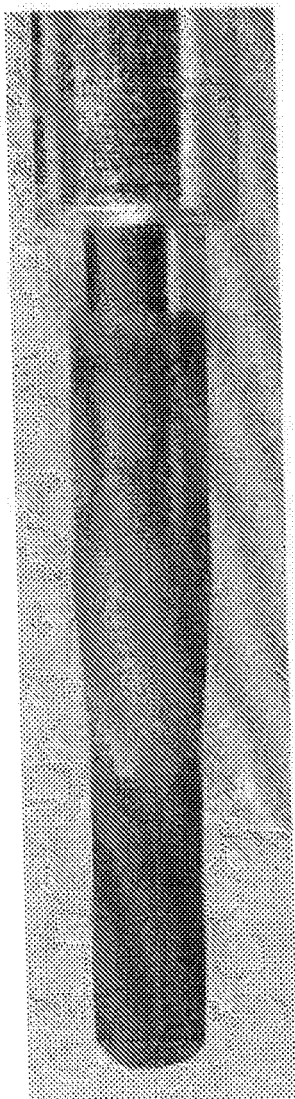


FIG.7B

CRACK OCCURS

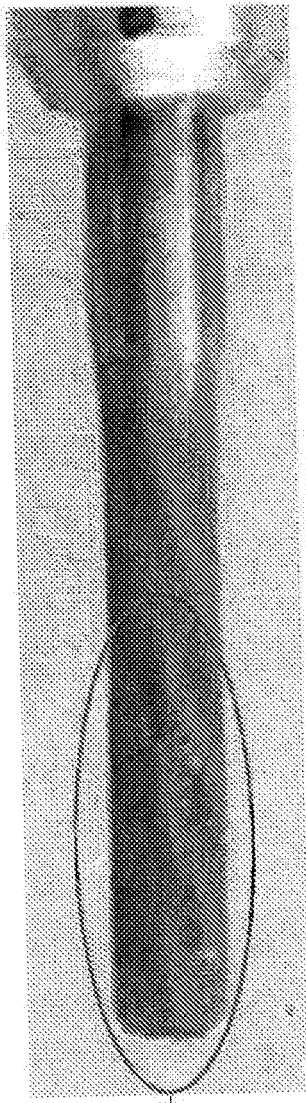


FIG.7C

LEADING END WEARS

