



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.08.2018 Bulletin 2018/32

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

(21) Application number: **18151698.0**

(22) Date of filing: **15.01.2018**

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

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(30) Priority: **03.02.2017 JP 2017018307**

(54) **GLOW PLUG**

(57) To provide a glow plug capable of restraining a temperature drop in the event of lowering applied voltage for saturating temperature, while ensuring durability and provision of higher heating-up temperature.

A rearward coil connected to the rear end of a forward coil containing W or Mo as a main component has a resistance ratio R1 lower than a resistance ratio R2 of the forward coil, where the resistance ratio R1 is the ratio of the resistance of the rearward coil at 1,000°C to the resistance of the rearward coil at 20°C, and the resistance ratio R2 is the ratio of the resistance of the forward coil at 1,000°C to the resistance of the forward coil at 20°C. A tube has a tube forward portion ranging from the forward end of the tube to a position around the axial center of the forward coil and a tube rearward portion ranging from a position around the rear end of the rearward coil to a position around the forward end of the rearward coil. The wall thickness A of the tube forward portion is 0.5 mm or more; the wall thickness B of the tube rearward portion is 0.3 mm or more; and the minimal wall thickness B1 of the tube rearward portion is smaller than the wall thickness A of the tube forward portion.

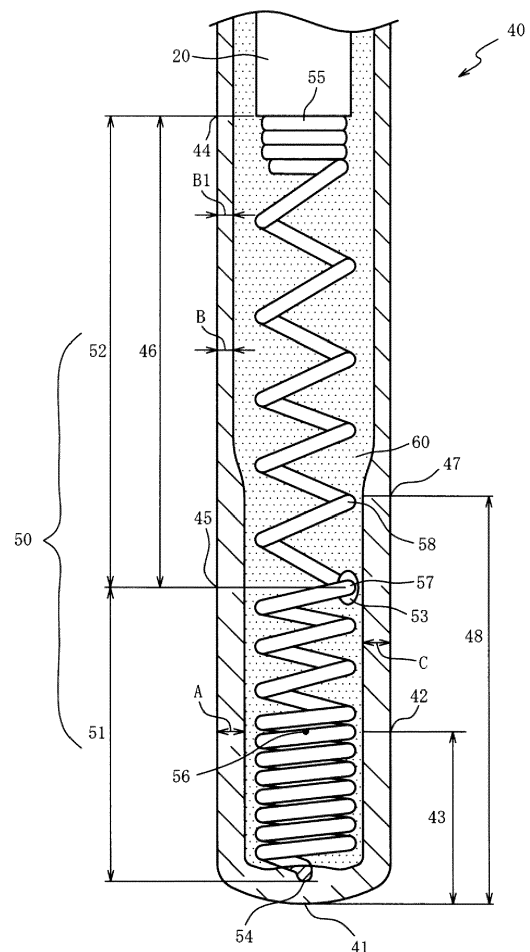


FIG. 2

Description

[Technical Field]

5 **[0001]** The present invention relates to a glow plug, particularly, a glow plug capable of providing higher heating-up temperature.

[Background Art]

10 **[0002]** A glow plug used as an auxiliary heat source in a compression-ignition-type internal combustion engine such as a diesel engine is required to provide higher heating-up temperature in the situation of tightening regulations on internal combustion engines. Patent Document 1 discloses a technique for allowing a glow plug having a coil disposed within a tube to meet the requirement to provide higher heating-up temperature. In the disclosed technique, a refractory metal containing W or Mo as a main component and having a melting point higher than those of an FeCrAl alloy and an
15 NiCr alloy is used for the coil.

[Prior Art Document]

[Patent Document]

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[0003] [Patent Document 1] International Publication No. WO2014/206847

[Summary of the Invention]

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[Problem to be Solved by the Invention]

[0004] However, since the resistance ratio of a refractory metal such as W or Mo is high as compared with the resistance ratios of an FeCrAl alloy and an NiCr alloy, the above-mentioned conventional technique involves a problem in that when a constant voltage is applied to the coil for heating up to a predetermined temperature (e.g., 1,000°C), the resistance of
30 the coil abruptly increases, resulting in an abrupt reduction in current value. The resistance ratio is "the ratio of a resistance of the coil at 1,000°C to a resistance of the coil at 20°C." The larger the value of the resistance ratio, the larger the resistance at high temperature. Since the amount of generated heat is proportional to the square of current, difficulty is involved in heating up to the predetermined temperature.

[0005] By contrast, it is conceived that a rearward coil formed of an FeCrAl alloy or an NiCr alloy and lower in resistance ratio than a refractory metal is joined to the rear end of a coil (forward coil) formed of a refractory metal. By employing such a coil structure, when voltage is applied to a coil, the forward coil and a forward side of a tube can be heated up to a predetermined temperature without involvement of an excessive increase of resistance of the entire coil.

[0006] Meanwhile, the coil heated up to the predetermined temperature needs to be saturated at around the predetermined temperature (e.g., at 1,100°C). For such saturation, the voltage applied to the coil needs to be lowered; however,
40 this causes transfer of heat from the forward side of the tube toward a rearward side of the tube lower in temperature than the forward side, potentially resulting in a transient great drop in temperature of the forward side of the tube. As a result, the combustion in an engine becomes unstable, and the emission of exhaust gas increases.

[0007] By contrast, by reducing the wall thickness of the entire tube, the heat capacity of the tube can be reduced, whereby the transfer of heat from the forward side to the rearward side of the tube can be restrained. However, reducing
45 the wall thickness of the entire tube causes oxidization wear, which results in both deformation of the tube and shortening in endurance time until formation of a through hole in the tube. As a result, durability of the tube potentially deteriorates.

[0008] The present invention has been conceived to solve the above problem, and an object of the invention is to provide a glow plug capable of restraining a temperature drop in the event of lowering applied voltage for saturating temperature, while ensuring durability and provision of higher heating-up temperature.

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[Means for Solving the Problem]

[0009] To achieve the object, a glow plug of the present invention comprises a closed-bottomed tube extending in a direction of an axial line; a forward coil and a rearward coil disposed within the tube; and an axial rod connected to a
55 rear end of the rearward coil. The forward coil is connected at its forward end to a forward end portion of the tube and contains W or Mo as a main component. The rearward coil is connected at its forward end to a rear end of the forward coil and has a resistance ratio R1 lower than a resistance ratio R2 of the forward coil, where the resistance ratio R1 is the ratio of a resistance of the rearward coil at 1,000°C to a resistance of the rearward coil at 20°C, and the resistance

ratio R2 is the ratio of a resistance of the forward coil at 1,000°C to a resistance of the forward coil at 20°C. The tube has a tube forward portion ranging from the forward end of the tube to a position around a center of the forward coil with respect to the direction of the axial line, and a tube rearward portion ranging from a position around the rear end of the rearward coil to a position around the forward end of the rearward coil. A wall thickness A of the tube forward portion is 0.5 mm or more; a wall thickness B of the tube rearward portion is 0.3 mm or more; and a minimal wall thickness B1 of the tube rearward portion is smaller than the wall thickness A of the tube forward portion.

[Effect of the Invention]

[0010] According to the glow plug described in claim 1, the forward coil containing W or Mo as a main component is connected to the forward end portion of the tube, and the rearward coil having a resistance ratio R1 lower than a resistance ratio R2 of the forward coil is connected to the rear end of the forward coil. Accordingly, even in application of a constant voltage, the forward coil containing W or Mo as a main component and a forward portion of the tube can be heated up to a predetermined temperature, whereby provision of higher heating-up temperature can be ensured.

[0011] Also, the wall thickness A of the tube forward portion is 0.5 mm or more, and the wall thickness B of the tube rearward portion is 0.3 mm or more. Accordingly, with respect to the tube rearward portion and the tube forward portion whose temperature increases as compared with the tube rearward portion, there can be restrained the shortening of endurance time until formation of a through hole in the tube and the deformation of the tube both of which are caused by oxidation wear. Therefore, durability can be ensured.

[0012] Further, the minimal wall thickness B1 of the tube rearward portion is smaller than the wall thickness A of the tube forward portion. Accordingly, the heat capacity per unit length of the tube rearward portion (a portion having the minimal wall thickness B1) can be smaller than that of the tube forward portion. As a result, when the applied voltage is lowered, the amount of heat transfer from the tube forward portion to the tube rearward portion can be restrained. Therefore, even in the event of lowering voltage applied to the coil for saturating the temperature of the coil, a drop in temperature of the forward side of the tube can be restrained.

[0013] Notably, the expression "W or Mo as a main component" means that the W or Mo content of a coil material is 50 wt% or more.

[0014] The "tube forward portion" indicates a portion of the tube which has high temperature as compared with the other portion in the event of the coil generating heat; specifically, "a portion ranging from the forward end of the tube to a position around the center of the forward coil with respect to the direction of the axial line." The "tube rearward portion" indicates a portion of the tube which is low in temperature as compared with the tube forward portion and to which heat is apt to transfer from the tube forward portion; specifically, "a portion ranging from a position around the rear end of the rearward coil to a position around the forward end of the rearward coil."

[0015] Further, "the wall thickness A of the tube forward portion" and "the wall thickness B of the tube rearward portion" indicate "the wall thickness of the entire forward portion" and "the wall thickness of the entire tube rearward portion," respectively. "The minimal wall thickness B1 of the tube rearward portion" indicates "the minimal value of the wall thickness of the entire tube rearward portion (i.e., the wall thickness B of the tube rearward portion)."

[0016] According to the glow plug described in claim 2, the wall thickness A is 0.7 mm or less, and the ratio of the wall thickness A to the minimal wall thickness B1; i.e., ratio A/B1, satisfies the relational expression $A/B1 \geq 1.11$. Since the wall thickness A is 0.7 mm or less, it is possible to prevent the heat capacity per unit length of the tube forward portion from becoming excessively large. Accordingly, in addition to provision of the effect of claim 1, there can be improved the performance of heating up the tube forward portion to a predetermined temperature in a short period of time (hereinafter, called "rapid heating-up performance").

[0017] The ratio of the wall thickness A to the wall thickness B1; i.e., A/B1, satisfies a relational expression $A/B1 \geq 1.11$. Accordingly, even when voltage applied to the coil is lowered for saturating the temperature of the coil, a drop in temperature of the forward side of the tube can be further restrained.

[0018] According to the glow plug described in claim 3, the wall thickness A is 0.56 mm or more, and the ratio A/B1 satisfies a relational expression $A/B1 \geq 1.24$. Accordingly, in addition to provision of the effect of claim 2, there can be further lengthened service life until formation of a through hole in the tube forward portion caused by oxidation wear, and there can be further restrained a drop in temperature of the forward side of the tube when voltage applied to the coil is lowered for saturating the temperature of the coil.

[0019] According to the glow plug described in claim 4, the wall thickness A is from 0.58 mm to 0.64 mm, and the ratio A/B1 satisfies a relational expression $A/B1 \geq 1.29$. Accordingly, since the heat capacity per unit length of the tube rearward portion can be further reduced as compared with that of the tube forward portion, in addition to provision of the effect of claim 3, there can be further improved restraint of a drop in temperature in the event of lowering applied voltage, durability, and rapid heating-up performance.

[0020] According to the glow plug described in claim 5, the wall thickness A is 0.62 mm or less. Accordingly, in addition to provision of the effect of claim 4, rapid heating-up performance can be further improved.

[0021] According to the glow plug described in claim 6, the tube has a wall thickness C of 0.5 mm or more as measured at a portion ranging from the forward end of the tube to a position around an end of a first turn starting from the forward end of the rearward coil. Heat generated by the forward coil is easily transmitted not only to a portion of the tube surrounding the forward coil but also to a portion of the tube surrounding the first turn of the rearward coil. By setting the wall thickness C of the portion of the tube to 0.5 mm or more, in addition to the provision of the effect of any one of claims 1 to 5, durability of the portion of the tube can be ensured.

[Brief Description of the Drawings]

[0022]

[FIG. 1] Half sectional view of a glow plug.

[FIG. 2] Enlarged sectional view showing a portion of the glow plug.

[FIG. 3] Schematic diagram showing the relation between voltage applied to the glow plug and heating-up temperature.

[Modes for Carrying out the Invention]

[0023] A preferred embodiment of the present invention will next be described with reference to the drawings. A glow plug 10 according to an embodiment of the present invention will be described with reference to FIGS. 1 and 2. FIG. 1 is a half sectional view of the glow plug 10, and FIG. 2 is an enlarged sectional view showing a portion of the glow plug 10. In FIGS. 1 and 2, the lower side of the sheet is called the forward side of the glow plug 10, and the upper side of the sheet is called the rearward side of the glow plug 10.

[0024] As shown in FIG. 1, the glow plug 10 includes an axial rod 20, a metallic shell 30, a tube 40, and a coil 50. These members are assembled along an axial line O of the glow plug 10. The glow plug 10 is an auxiliary heat source used in, for example, starting up an internal combustion engine (not shown) such as a diesel engine.

[0025] The axial rod 20 is a circular columnar conductor made of metal and is adapted to supply electric power to the coil 50. The coil 50 is electrically connected to the forward end of the axial rod 20. The axial rod 20 is inserted into the metallic shell 30 with its rear end protruding outward from the metallic shell 30.

[0026] In the present embodiment, the axial rod 20 has an externally threaded connection portion 21 formed at its rear end portion. An O-ring 22 made of insulation rubber, a tubular insulator 23 made of synthetic resin, a tubular ring 24 made of metal, and a nut 25 made of metal, from the forward side, are sequentially assembled to the rear end portion of the axial rod 20. The connection portion 21 allows connection of a connector (not shown) of a cable for supplying electric power from a power source such as battery. The nut 25 fixes a connected connector (not shown).

[0027] The metallic shell 30 is an approximately cylindrical member formed of carbon steel or the like. The metallic shell 30 has an axial hole 31 extending therethrough along the axial line O and has a threaded portion 32 formed on an outer circumferential surface thereof. The metallic shell 30 has a tool engagement portion 33 formed on the rearward side of the threaded portion 32. The axial hole 31 is a through hole through which the axial rod 20 is inserted. Since the inside diameter of the axial hole 31 is greater than the outside diameter of the axial rod 20, a gap is formed between the axial rod 20 and the axial hole 31. The threaded portion 32 is an external thread to be engaged with an internal combustion engine (not shown). The tool engagement portion 33 has such a shape (e.g., hexagonal shape) as to allow a tool (not shown) to be engaged therewith for screwing the threaded portion 32 into or unscrewing the threaded portion 32 from a threaded hole (not shown) of the internal combustion engine.

[0028] The metallic shell 30 holds the axial rod 20 via the O-ring 22 and the insulator 23 at a rear end portion of the axial hole 31. The ring 24 in contact with the insulator 23 is crimped to the axial rod 20, thereby fixing the axial position of the insulator 23. The insulator 23 electrically insulates the ring 24 and a rear end portion of the metallic shell 30 from each other. The metallic shell 30 receives the tube 40 fixed into a forward end portion of the axial hole 31.

[0029] The tube 40 is made of metal and closed at a forward end 41 thereof. The tube 40 is press-fitted into the axial hole 31 to thereby be fixed to the metallic shell 30. Examples of material for the tube 40 include heat resistant alloys such as nickel-based alloys and stainless steels.

[0030] The tube 40 receives a forward end portion of the axial rod 20 inserted therein. Since the inside diameter of the tube 40 is greater than the outside diameter of the axial rod 20, a gap is formed between the axial rod 20 and the tube 40. A seal member 26 is a cylindrical electrically insulative member held between a forward end portion of the axial rod 20 and a rear end portion of the tube 40. The seal member 26 maintains the gap between the axial rod 20 and the tube 40 and provides a seal between the axial rod 20 and the tube 40. The coil 50 is accommodated in the tube 40 along the axial line O. An insulating powder 60 is charged into the tube 40.

[0031] As shown in FIG. 2, the coil 50 has a spiral form and generates heat through energization. The coil 50 is composed of a forward coil 51 joined to a forward end 41 portion of the tube 40, and a rearward coil 52 joined to the

forward end of the axial rod 20.

[0032] The forward coil 51 is welded at a forward end 54 (the boundary between the forward coil 51 and a weld fusion zone) to a portion of the forward end 41 of the tube 40 via the weld fusion zone (not shown). A refractory metal which contains W or Mo as a main component is used as a material for the forward coil 51. These elements can be used singly as a material for the forward coil 51, or an alloy which contains either one of these elements as a main component can be used as a material for the forward coil 51. The forward coil 51 is welded at the rear end thereof to the rearward coil 52. A weld fusion zone 53 is formed between the forward coil 51 and the rearward coil 52 as a result of solidification of a molten weld metal.

[0033] The rearward coil 52 is connected in series to the forward coil 51 via the weld fusion zone 53. The rearward coil 52 is formed of an electrically conductive material having a resistance ratio R_2 lower than a resistance ratio R_1 of the forward coil 51. Examples of material for the rearward coil 52 include an FeCrAl alloy and an NiCr alloy. The rearward coil 52 is accommodated in the tube 40 along the axial line O (see FIG. 1) and is welded at a rear end 55 thereof to the forward end of the axial rod 20. The axial rod 20 is electrically connected to the tube 40 via the rearward coil 52 and the forward coil 51.

[0034] The insulating powder 60 has electric insulation and has thermal conductivity at high temperature. A space between the coil 50 and the tube 40, a space between the axial rod 20 and the tube 40, and a space surrounded by the coil 50 are filled with the insulating powder 60. The insulating powder 60 has a function of transferring heat from the coil 50 to the tube 40, a function of preventing a short circuit between the coil 50 and the tube 40, and a function of suppressing vibration of the coil 50, thereby preventing breakage thereof. Examples of the insulating powder 60 include powders of oxides such as MgO and Al_2O_3 . Powder of CaO, ZrO_2 , SiO_2 , Si, or the like can be added to powder of oxide such as MgO, Al_2O_3 , or the like. In the present embodiment, the insulating powder 60 contains MgO powder in an amount of 85% by mass to less than 100% by mass and also contains Si powder.

[0035] The tube 40 includes a tube forward portion 43 and a tube rearward portion 46. The tube forward portion 43 ranges from the forward end 41 of the tube 40 to a position 42 around a center 56 (the midpoint of a line segment connecting the position of the forward end 54 and the position of the weld fusion zone 53) of the forward coil 51 with respect to the direction of the axial line O (axial direction). The tube rearward portion 46 ranges from a position 44 around the rear end 55 of the rearward coil 52 to a position 45 around a forward end 57 (the position of the weld fusion zone 53) of the rearward coil 52. FIG. 2 shows the range of the tube forward portion 43 (from the forward end 41 of the tube 40 to the position 42) and the range of the tube rearward portion 46 (from the position 44 of the tube 40 to the position 45).

[0036] In the present embodiment, the wall thickness A of the tube forward portion 43 is 0.5 mm or more; the wall thickness B of the tube rearward portion 46 is 0.3 mm or more; and the minimal wall thickness B1 of the tube rearward portion 46 is smaller than the wall thickness A of the tube forward portion 43.

[0037] In the present embodiment, the tube forward portion 43 and the tube rearward portion 46 have the same outside diameter, and the inside diameter of the tube forward portion 43 is smaller than the inside diameter of the tube rearward portion 46 at the rear end side thereof, whereby the minimal wall thickness B1 of the tube rearward portion 46 becomes smaller than the wall thickness A of the tube forward portion 43. Also, the tube 40 has a wall thickness C of 0.5 mm or more as measured at a portion 48 ranging from the forward end 41 thereof to a position 47 around an end 58 of a first turn starting from the forward end 57 (the weld fusion zone 53) of the rearward coil 52.

[0038] Next, with reference to FIG. 3, the relation between voltage V applied to the glow plug 10 and heating-up temperature T of the glow plug 10 will be described. FIG. 3 is a schematic diagram showing the relation between voltage V and heating-up temperature T of the glow plug 10. In FIG. 3, time (seconds) is plotted along the horizontal axis; the solid line indicates heating-up temperature T; and the broken line indicates voltage V.

[0039] When voltage V is applied between the connection portion 21 and the metallic shell 30 of the glow plug 10, current I flows through the coil 50. The value of the current I is obtained by dividing the voltage V by the sum (i.e., $R_1 + R_2$) of the resistance R_1 of the forward coil 51 and the resistance R_2 of the rearward coil 52. The amount of generated heat per unit time of the forward coil 51 is $R_1 I^2$, and the amount of generated heat per unit time of the rearward coil 52 is $R_2 I^2$.

[0040] The coil 50 is designed such that the resistance R_2 of the rearward coil 52 at 20°C is greater than the resistance R_1 of the forward coil 51 at 20°C. The reason for such design is to ensure the current I (inrush current) flowing through the coil 50 at room temperature to thereby cause the coil 50 to generate heat.

[0041] Since the rearward coil 52 has the resistance ratio R_2 lower than the resistance ratio R_1 of the forward coil 51, as the temperature of the coil 50 rises as a result of generation of heat, the resistance R_1 of the forward coil 51 becomes greater than the resistance R_2 of the rearward coil 52. As a result, the amount of generated heat per unit time $R_1 I^2$ of the forward coil 51 can be greater than the amount of generated heat per unit time $R_2 I^2$ of the rearward coil 52. Since the forward coil 51 is formed of a refractory metal which contains W or Mo as a main component, the heating-up temperature T can be increased. Accordingly, the heating-up temperature T of the forward coil 51 and the tube forward portion 43 can be raised to a desired temperature (e.g., 1,000°C).

[0042] Since the wall thickness A of the tube forward portion 43 to be heated by the forward coil 51 is 0.5 mm or more, there can be restrained the shortening of endurance time until formation of a through hole in the tube forward portion

43 caused by oxidization wear. Since the tube rearward portion 46 located rearward of the tube forward portion 43 is lower in heating-up temperature than the tube forward portion 43, by setting the wall thickness B of the tube rearward portion 46 to 0.3 mm or more, it is possible to restrain the shortening of endurance time until formation of a through hole in the tube rearward portion 46 and the deformation of the tube rearward portion 46 both of which are caused by oxidization wear. Since the forward coil 51 formed of a refractory metal which contains W or Mo as a main component is apt to be oxidized, if a through hole is formed in the tube 40, the forward coil 51 is highly likely to be broken as a result of oxidation. By restraining formation of a through hole in the tube forward portion 43 and in the tube rearward portion 46 while restraining deformation of the tube rearward portion 46, breaking of the forward coil 51 caused by oxidation can be restrained, whereby durability can be improved.

[0043] After the heating-up temperature T reaches a desired temperature (herein 1,000°C), the voltage V applied to the glow plug 10 is lowered such that the heating-up temperature T becomes a saturation temperature (e.g., 1,100°C) in a stable state. Since the rearward coil 52 is smaller in the amount of generated heat than the forward coil 51, in the transition period in which the voltage V is lowered, heat moves from the forward coil 51 and the tube forward portion 43 to the rearward coil 52 and the tube rearward portion 46. As a result, the heating-up temperature T highly dependent on the forward coil 51 transiently drops by a temperature D. When the heating-up temperature T drops greatly as a result of an increase in the temperature D, combustion in an engine becomes unstable, and emission of exhaust gas increases.

[0044] In order to prevent such a problem, in the glow plug 10, the minimal wall thickness B1 of the tube rearward portion 46 is rendered smaller than the wall thickness A of the tube forward portion 43. Accordingly, the heat capacity per unit length of the tube rearward portion 46 (a portion having the minimal wall thickness B1) can be smaller than the heat capacity per unit length of the tube forward portion 43. As a result, when the voltage V is lowered for transition of the heating-up temperature T of the tube 40 to the saturation temperature, heat moving from the tube forward portion 43 to the tube rearward portion 46 can be restrained. Therefore, it is possible to restrain a temperature drop (temperature D) in the transition period during which the voltage V is lowered for saturating the heating-up temperature T. As a result, while durability and provision of higher heating-up temperature T are ensured, there can be restrained a temperature drop when the voltage V is lowered for saturating the heating-up temperature T. Therefore, the glow plug 10 assists combustion in an engine, whereby an idling operation of the engine after startup can be stabilized, and emission of exhaust gas can be reduced.

[0045] Further, preferably, the wall thickness B of at least half of the tube rearward portion 46 is smaller than the wall thickness A of the tube forward portion 43 (see FIG. 2). As a result, there can be further restrained a temperature drop when the voltage V is lowered for saturating the heating-up temperature T.

[0046] Since the glow plug 10 is designed such that the tube 40 has a wall thickness C of 0.5 mm or more as measured at the portion 48 ranging from the forward end 41 thereof to the position 47 around the end 58 of the first turn starting from the forward end (the weld fusion zone 53) of the rearward coil 52, in spite of transmission of heat generated by the forward coil 51 to the portion 48 of the tube 40, durability of the tube 40 can be ensured at the portion 48.

[0047] Since the insulating powder 60 contains Si powder, as compared with the case where the whole insulating powder 60 is MgO powder, the thermal conductivity of the insulating powder 60 can be deteriorated. As a result, since heat dissipation from the forward coil 51 resulting from heat conduction of the insulating powder 60 can be restrained, the insulating powder 60 promotes ensuring of rapid heating-up performance in inrush of current and restraint of a temperature drop in the temperature transition in heating-up of the tube forward portion 43.

[0048] The glow plug 10 is manufactured, for example, as follows. First, resistance heating wires having respective predetermined compositions are coiled to form the forward coil 51 and the rearward coil 52. Next, the forward coil 51 and the rearward coil 52 are welded together at their ends to form the coil 50. Next, the rear end 55 of the rearward coil 52 of the coil 50 is joined to the forward end of the axial rod 20.

[0049] A steel pipe having a predetermined composition is subjected to forming so as to have a diameter greater than the finished diameter of the tube 40 and to have a reduced diameter at its forward end as compared with the remaining portion, thereby yielding a tube precursor having a tapered open forward end. The coil 50 joined to the axial rod 20 is inserted into the tube precursor such that the forward end 54 of the forward coil 51 is disposed in the tapered opening portion of the tube precursor. The opening portion of the tube precursor and the forward end 54 of the forward coil 51 are fused together by welding, thereby closing a forward end portion of the tube precursor and thus yielding a heater precursor which accommodates the coil 50 therein.

[0050] Next, after the insulating powder 60 is charged into the tube 40 of the heater precursor, the seal member 26 is inserted between the axial rod 20 and a rear end opening portion of the tube 40 to seal the tube 40. Then, the tube 40 is swaged until the tube 40 has a predetermined outside diameter.

[0051] Next, the swaged tube 40 is fixedly press-fitted into the axial hole 31 of the metallic shell 30, and the O-ring 22 and the insulator 23 are fitted between the metallic shell 30 and the axial rod 20 from the rear end of the axial rod 20. The ring 24 is crimped to the axial rod 20, thereby yielding the glow plug 10.

[Examples]

[0052] The present invention will be described further in detail by way of example; however, the present invention is not limited to the example.

<Preparation of samples>

[0053] The forward coils 51 were prepared by use of wire having a diameter of 0.20 mm and formed of an alloy containing W as a main component. Similarly, the rearward coils 52 were prepared by use of wire having a diameter of 0.38 mm and formed of an NiCr alloy. The rearward coils 52 were welded to the respective forward coils 51, thereby preparing the coils 50 in which the rearward coils 52 and the forward coils 51 are connected respectively in series. The coils 50 had a resistance of 0.33 Ω at 20°C as measured by a 4-terminal method.

[0054] By use of the coils 50, glow plugs having a structure substantially the same as that of the glow plug 10 shown in FIG. 1 were manufactured by the aforementioned method, thereby yielding glow plug samples 1 to 11 shown in Table 1. Table 1 shows parameters of the samples; specifically, the maximal and minimal values of the wall thickness A of the tube forward portion 43, the maximal value and the minimal value (i.e., the minimal wall thickness B1) of the wall thickness B of the tube rearward portion 46, and the range of the ratio of the wall thickness A to the wall thickness B1.

[0055] Glow plug samples 1 to 11 had an outside diameter of the tube forward portion 43 of 3.2 mm and an outside diameter of the tube rearward portion 46 of 4.0 mm and differed in the wall thickness A of the tube forward portion 43 and the wall thickness B of the tube rearward portion 46 as a result of adjusting a swaging rate of swaging to be conducted on the tube forward portion 43 and the tube rearward portion 46. In glow plug samples 1 to 11, the insulating powder 60 was MgO powder which contained Si powder in an amount of 0.2% by mass.

[Table 1]

No.	Tube				A/B1	Rating			
	Wall thickness A (mm)		Wall thickness B (mm)			Temp. drop in temp. transition	Durability	Rapid heating-up performance	Comprehensive
			Minimal value	Maximal value					
1	0.40	0.45	0.45	0.50	0.89 - 1.00	D	A	D	
2	0.50	0.55	0.45	0.50	1.11 - 1.22	C	A	C	
3	0.56	0.61	0.45	0.56	1.24 - 1.36	B	A	B	
4	0.58	0.60	0.45	0.58	1.29 - 1.33	A	A	A	
5	0.59	0.62	0.45	0.59	1.31 - 1.38	A	A	A	
6	0.59	0.64	0.45	0.59	1.31 - 1.42	A	B	B	
7	0.65	0.70	0.45	0.65	1.44 - 1.56	A	C	C	
8	0.75	0.80	0.45	0.75	1.67 - 1.78	A	D	D	
9	0.58	0.62	0.45	0.58	1.29 - 1.38	A	A	A	
10	0.58	0.62	0.30	0.58	1.93 - 2.07	A	A	A	
11	0.58	0.62	0.25	0.58	2.32 - 2.48	A	A	D	

[0056] A PR thermocouple was joined to the surface of the tube 40 of each sample at a position located 2 mm away in the direction of the axial line O from the forward end 41 of the tube 40 to measure temperature in the vicinity of the forward end 41 of the tube 40. In place of the PR thermocouple, a radiation thermometer may be used.

[0057] The wall thickness A of the tube forward portion 43 and the wall thickness B of the tube rearward portion 46 were measured by observing, through a microscope, the sections (containing the axial line O) of the tubes 40 of samples swaged at the same swaging rates as those of samples 1 to 11.

[0058] The wall thickness A was measured at five points equally spaced along the entire length of the tube forward portion 43 in the direction of the axial line (the axial direction) (the five points consist of the position of the forward end 41, the position 42 around the center 56 of the forward coil 51 with respect to the axial direction, and three other points), thereby obtaining the maximal and minimal values of the wall thickness A from the measured values of the wall thickness A.

[0059] The wall thickness B was measured at ten points equally spaced along the entire length of the tube rearward portion 46 (the ten points consist of the position 45 around the forward end 57 of the rearward coil 52, the position 44 around the rear end 55 of the rearward coil 52, and eight other points), thereby obtaining the maximal and minimal values of the wall thickness B from the measured values of the wall thickness B.

<Temperature drop in temperature transition>

[0060] After DC voltage was applied for two seconds between the connection portion 21 and the metallic shell 30 of each sample in such a manner that the temperature of the tube 40 in the vicinity of the forward end 41 after elapse of two seconds after the application of the voltage became 1,000°C, the applied voltage was lowered. The applied voltage was a rated voltage at which the temperature of the tube 40 in the vicinity of the forward end 41 is saturated to 1,100°C. When the applied voltage was lowered, the temperature of the tube 40 transiently dropped and then increased toward the saturation temperature of 1,100°C with time (see FIG. 3). The temperature difference (temperature D shown in FIG. 3) between the highest temperature of the tube 40 and the temperature of the tube 40 in the temperature transition resulting from the lowering of applied voltage.

[0061] The samples having a temperature difference of less than 30°C were evaluated as "A: particularly excellent;" the samples having a temperature difference of 30°C to less than 50°C were evaluated as "B: excellent;" the samples having a temperature difference of 50°C to less than 80°C were evaluated as "C: good;" and the samples having a temperature difference of 80°C or more were evaluated as "D: poor." Table 1 shows the results in the column "Temperature drop in temperature transition."

<Rapid heating-up performance>

[0062] DC voltage of 11 V was applied between the connection portion 21 and the metallic shell 30 of each sample, and two seconds later, the temperature of the tube 40 in the vicinity of the forward end 41 was measured. The samples having a temperature of 950°C or higher were evaluated as "A: particularly excellent;" the samples having a temperature of 900°C to less than 950°C were evaluated as "B: excellent;" the samples having a temperature of 850°C to less than 900°C were evaluated as "C: good;" and the samples having a temperature of less than 850°C were evaluated as "D: poor." Table 1 shows the results in the column "Rapid heating-up performance."

<Durability>

[0063] After DC voltage was applied for two seconds between the connection portion 21 and the metallic shell 30 of each sample in such a manner that the temperature of the tube 40 in the vicinity of the forward end 41 after elapse of two seconds after the application of the voltage became 1,000°C, the applied voltage was lowered to a rated voltage, and the rated voltage was applied for 180 seconds. The rated voltage is a voltage at which the temperature of the tube 40 in the vicinity of the forward end 41 is saturated to 1,100°C. Subsequently, the tube 40 was air-cooled for 120 seconds until the temperature of the tube 40 in the vicinity of the forward end 41 lowered to room temperature. A test taking this procedure as one cycle was conducted for 500 hours (about 6,000 cycles). The samples were evaluated for the occurrence of breaking of the coil 50 caused by formation of a through hole in the tube 40 and for the occurrence of deformation of the tube 40.

[0064] The samples free from the occurrence of breaking of the coil 50 after the elapse of 500 hours after start of the test were evaluated as "A: particularly excellent." The samples which suffered the occurrence of breaking of the coil 50 after the elapse of 300 hours (about 3,600 cycles) to less than 500 hours after start of the test were evaluated as "B: excellent." The samples which suffered the occurrence of breaking of the coil 50 after the elapse of 100 hours (about 1,200 cycles) to less than 300 hours after start of the test were evaluated as "C: good." The samples which suffered the occurrence of breaking of the coil 50 before the elapse of 100 hours after start of the test or the occurrence of deformation of the tube 40 before elapse of 10 hours (about 120 cycles) after start of the test were evaluated as "D: poor." Table 1

shows the results in the column "Durability."

<Comprehensive evaluation>

[0065] Desirably, the glow plug satisfies high "durability," small "temperature drop in temperature transition," and high "rapid heating-up performance." Therefore, the column "Comprehensive" in Table 1 shows the lowest evaluation result of "durability" evaluation, "temperature drop in temperature transition" evaluation, and "rapid heating-up performance" evaluation.

<Results>

[0066] As shown in Table 1, sample 1 in which the wall thickness A of the tube forward portion 43 was less than 0.5 mm and sample 11 in which the minimal value (B1) of the wall thickness B of the tube rearward portion 46 was less than 0.3 mm exhibited poor durability. Since in sample 1 the wall thickness A of the tube forward portion 43 was less than 0.5 mm, a through hole was early formed in the tube forward portion 43 due to oxidization wear, resulting in breaking of the coil 50. Since in sample 11 the minimal value (B1) of the wall thickness B of the tube rearward portion 46 was less than 0.3 mm, the tube rearward portion 46 was early deformed. By contrast, samples 2 to 10 in which the wall thickness A was 0.5 mm or more and the wall thickness B was 0.3 mm or more exhibited rating A to C with respect to durability. Therefore, by setting the wall thickness A of the tube forward portion 43 to 0.5 mm or more and setting the wall thickness B of the tube rearward portion 46 to 0.3 mm or more, durability is ensured.

[0067] Sample 1 in which the wall thickness A of the tube forward portion 43 was smaller than the minimal value (B1) of the wall thickness B of the tube rearward portion 46 (i.e., $A/B1 < 1$) exhibited a large temperature drop in temperature transition. By contrast, samples 2 to 11 in which the minimal value (B1) of the wall thickness B of the tube rearward portion 46 was smaller than the maximal and minimal values of the wall thickness A of the tube forward portion 43 exhibited rating A to C with respect to a temperature drop in temperature transition. Therefore, by setting the minimal value (B1) of the wall thickness B to be smaller than the wall thickness A (maximal value), a temperature drop in temperature transition can be reduced.

[0068] Samples 1 to 7 and 9 to 11 in which the wall thickness A of the tube forward portion 43 was 0.7 mm or less were superior in rapid heating-up performance to sample 8 in which the wall thickness A was greater than 0.7 mm. Therefore, by setting the wall thickness A to 0.5 mm to 0.7 mm and setting the wall thickness B to 0.3 mm or more as in the case of samples 2 to 7, 9, and 10, rapid heating-up performance can be improved while durability is ensured. The improvement of rapid heating-up performance is conceivably for the following reason: as a result of reduction of the wall thickness A of the tube forward portion 43, the heat capacity per unit length of the tube forward portion 43 reduced; accordingly, the tube forward portion 43 was easily heated up by heating up of the forward coil 51.

[0069] Samples 2 to 7, 9, and 10 evaluated as A to C with respect to a temperature drop in temperature transition satisfied the relational expression $A/B1 \geq 1.1$. Therefore, by satisfying the relational expressions $0.5 \text{ mm} \leq A \leq 0.7 \text{ mm}$, $B \geq 0.3 \text{ mm}$, and $A/B1 \geq 1.1$, durability, a small temperature drop in temperature transition, and rapid heating-up performance can be ensured.

[0070] Of samples 2 to 7, 9, and 10, samples 3 to 7, 9, and 10 in which the wall thickness A of the tube forward portion 43 was 0.56 mm to 0.7 mm and which satisfied the relational expression $A/B1 \geq 1.24$ were evaluated as A or B with respect to a temperature drop in temperature transition and durability. Therefore, by satisfying the relational expressions $0.56 \text{ mm} \leq A \leq 0.7 \text{ mm}$ and $A/B1 \geq 1.24$, durability can be improved while a temperature drop in temperature transition is further restrained.

[0071] Of samples 3 to 7, 9, and 10, samples 4 to 6, 9, and 10 in which the wall thickness A of the tube forward portion 43 was 0.58 mm to 0.64 mm and which satisfied the relational expression $A/B1 \geq 1.29$ were evaluated as A with respect to a temperature drop in temperature transition and durability and evaluated as A or B with respect to rapid heating-up performance. Therefore, by satisfying the relational expressions $0.58 \text{ mm} \leq A \leq 0.64 \text{ mm}$ and $A/B1 \geq 1.29$, durability can be improved while a temperature drop in temperature transition is further restrained, and rapid heating-up performance can be improved.

[0072] Of samples 4 to 6, 9, and 10, samples 4, 5, 9, and 10 in which the wall thickness A of the tube forward portion 43 was 0.58 mm to 0.62 mm and which satisfied the relational expression $A/B1 \geq 1.29$ were evaluated as A with respect to all of a temperature drop in temperature transition, durability, and rapid heating-up performance. Therefore, by satisfying the relational expressions $0.58 \text{ mm} \leq A \leq 0.62 \text{ mm}$ and $A/B1 \geq 1.29$, durability can be improved while a temperature drop in temperature transition is restrained, and rapid heating-up performance can be further improved.

[0073] While the present invention has been described with reference to the above embodiment and examples, the present invention is not limited to the above embodiment and examples, but may be embodied through various improvements or modifications without departing from the spirit and scope of the invention. For example, the shape of the tube 40 is not particularly limited so long as the tube 40 assumes the form of a tube, and the section of the tube 40 taken

orthogonally to the axial line O may be circular, elliptic, polygonal, or the like.

[0074] According to the above embodiment, the tube forward portion 43 and the tube rearward portion 46 have the same outside diameter, and the tube forward portion 43 is smaller in inside diameter than the tube rearward portion 46, whereby the wall thickness A of the tube forward portion 43 becomes larger than the wall thickness B of the tube rearward portion 46. However, the present invention is not limited thereto. Needless to say, the tube forward portion 43 can be smaller in outside diameter than the tube rearward portion 46 as in the case of the above examples, or the tube forward portion 43 can be greater in outside diameter than the tube rearward portion 46.

[Description of Reference Numerals]

[0075]

10: glow plug
20: axial rod
40: tube
41: forward end
43: tube forward portion
46: tube rearward portion
51: forward coil
52: rearward coil
O: axial line

Claims

1. A glow plug (10) comprising:

a closed-bottomed tube (40) extending in a direction of an axial line (O);
a forward coil (51) and a rearward coil (52) disposed within the tube (40); and
an axial rod (20) connected to a rear end (55) of the rearward coil (52);
wherein the forward coil (51) is connected at its forward end (54) to a forward end (41) portion of the tube (40) and contains W or Mo as a main component;
the rearward coil (52) is connected at its forward end (57) to a rear end of the forward coil (51) and has a resistance ratio R1 lower than a resistance ratio R2 of the forward coil (51), where the resistance ratio R1 is the ratio of a resistance of the rearward coil (52) at 1,000°C to a resistance of the rearward coil (52) at 20°C, and the resistance ratio R2 is the ratio of a resistance of the forward coil (51) at 1,000°C to a resistance of the forward coil (51) at 20°C;
the tube (40) has

a tube forward portion (43) ranging from the forward end (41) of the tube (40) to a position (42) around a center (56) of the forward coil (51) with respect to the direction of the axial line (O), and
a tube rearward portion (46) ranging from a position around the rear end (55) of the rearward coil (52) to a position (45) around the forward end (57) of the rearward coil (52); and
a wall thickness A of the tube forward portion (43) is 0.5 mm or more, a wall thickness B of the tube rearward portion (46) is 0.3 mm or more, and a minimal wall thickness B1 of the tube rearward portion (46) is smaller than the wall thickness A of the tube forward portion (43).

2. A glow plug (10) according to claim 1, wherein
the wall thickness A is 0.7 mm or less, and
the ratio A/B1 of the wall thickness A to the minimal wall thickness B1 satisfies a relational expression $A/B1 \geq 1.11$.

3. A glow plug (10) according to claim 2, wherein
the wall thickness A is 0.56 mm or more, and
the ratio A/B1 satisfies a relational expression $A/B1 \geq 1.24$.

4. A glow plug (10) according to claim 3, wherein
the wall thickness A is from 0.58 mm to 0.64 mm, and
the ratio A/B1 satisfies a relational expression $A/B1 \geq 1.29$.

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5. A glow plug (10) according to claim 4, wherein the wall thickness A is 0.62 mm or less.
6. A glow plug (10) according to any one of claims 1 to 5, wherein the tube (40) has a wall thickness C of 0.5 mm or more as measured at a portion ranging from the forward end (41) of the tube (40) to a position (47) around an end (58) of a first turn starting from the forward end (57) of the rearward coil (52).

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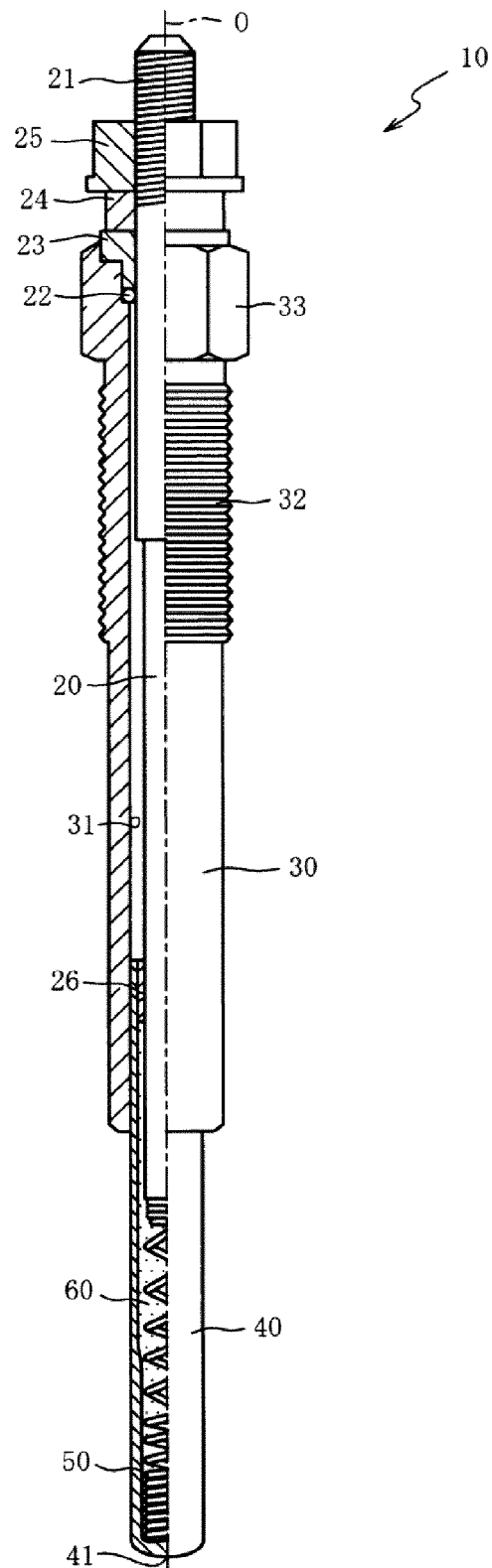


FIG. 1

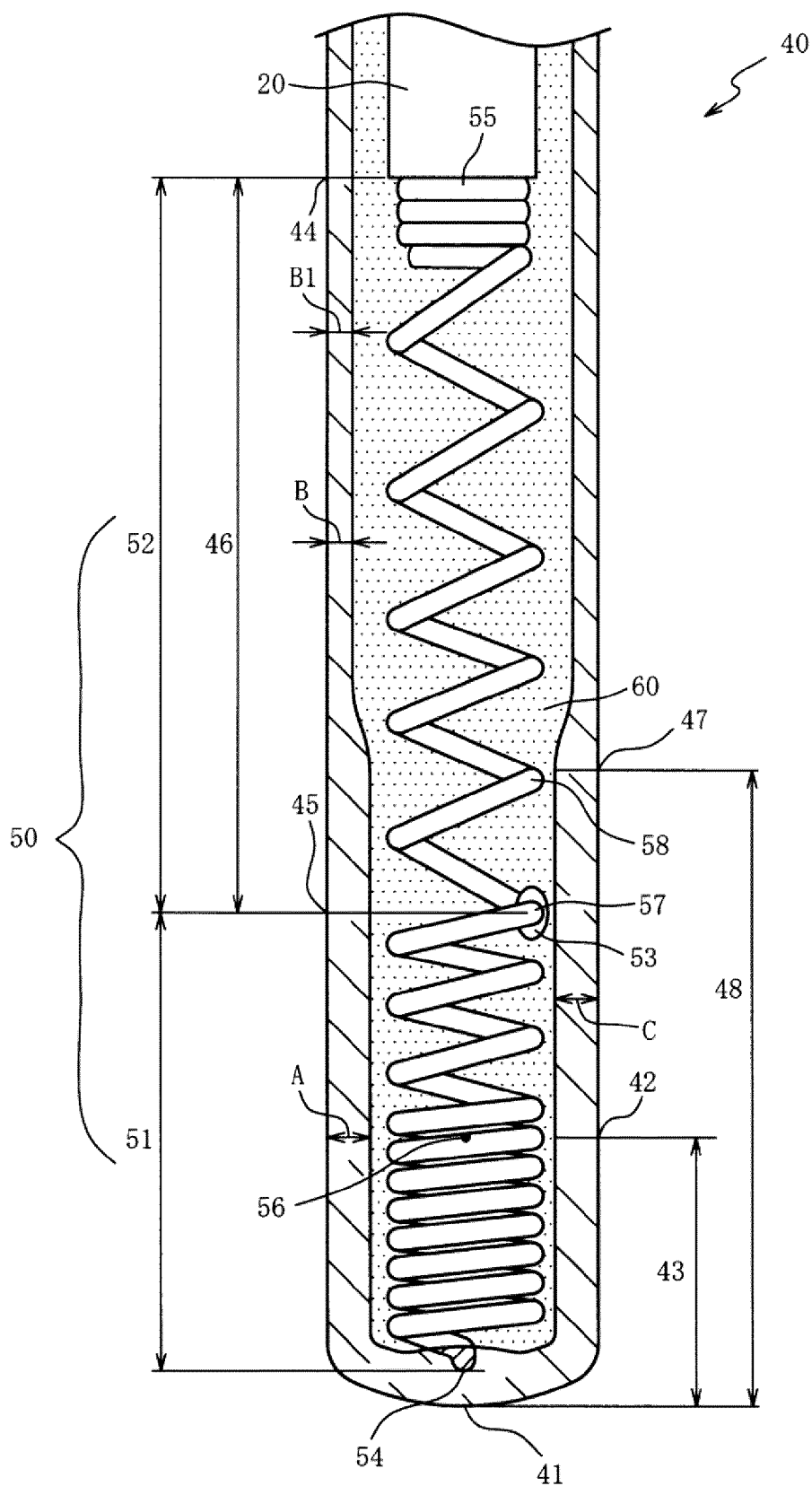


FIG. 2

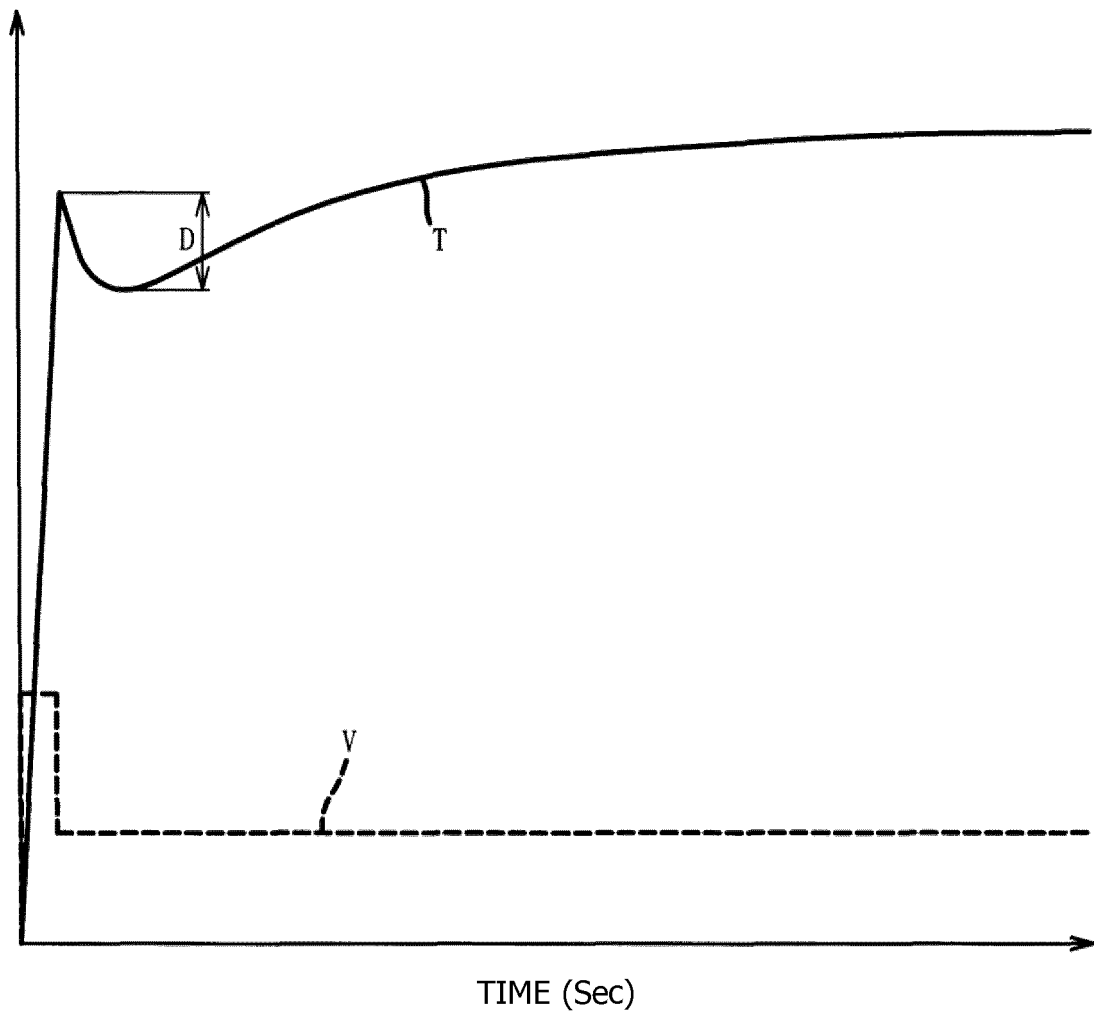


FIG. 3



EUROPEAN SEARCH REPORT

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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)
A	US 2014/361005 A1 (KASAHARA KEISUKE [JP]) 11 December 2014 (2014-12-11) * the whole document *	1-6	INV. F23Q7/00
A	EP 2 312 907 A1 (NGK SPARK PLUG CO [JP]) 20 April 2011 (2011-04-20) * the whole document *	1-6	
A	EP 2 045 526 A2 (NGK SPARK PLUG CO [JP]) 8 April 2009 (2009-04-08) * the whole document *	1-6	
A,P	EP 3 163 172 A1 (NGK SPARK PLUG CO [JP]) 3 May 2017 (2017-05-03) * the whole document *	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			F23Q
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		12 June 2018	Rodriguez, Alexander
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			

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

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014361005 A1	11-12-2014	EP 2840314 A1	25-02-2015
		JP 5584370 B2	03-09-2014
		JP W02013157223 A1	21-12-2015
		KR 20150004379 A	12-01-2015
		US 2014361005 A1	11-12-2014
		WO 2013157223 A1	24-10-2013
EP 2312907 A1	20-04-2011	EP 2312907 A1	20-04-2011
		JP 5509017 B2	04-06-2014
		JP 2011102690 A	26-05-2011
EP 2045526 A2	08-04-2009	EP 2045526 A2	08-04-2009
		JP 4870640 B2	08-02-2012
		JP 2009092291 A	30-04-2009
		US 2009090705 A1	09-04-2009
EP 3163172 A1	03-05-2017	EP 3163172 A1	03-05-2017
		JP 2017083129 A	18-05-2017

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2014206847 A [0003]