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(54) **GLOW PLUG**

(57) [Objective] To provide a glow plug that can realize increase in heating temperature and ensure rapid temperature rising property, and that can suppress temperature decrease when an applied voltage is lowered in order to saturate the temperature.

[Means for Solution] This glow plug includes: a front end coil connected to the front end of a tube and containing W or Mo as a principal component; and a rear end coil connected to the rear end of the front end coil. A resistance ratio which is the ratio of a resistance value at 1000°C of the front end coil relative to a resistance value at 20°C of the front end coil is greater than a resistance ratio which is the ratio of a resistance value at 1000°C of the rear end coil relative to a resistance value at 20°C of the rear end coil. Relative to the resistance value at 20°C between the front end of the tube and the rear end of the front end coil, the proportion of the resistance value at 20°C between a position of the front end coil at 4 mm from the front end of the tube toward the rear side in the axis direction and the front end of the tube is 55% to 80%.

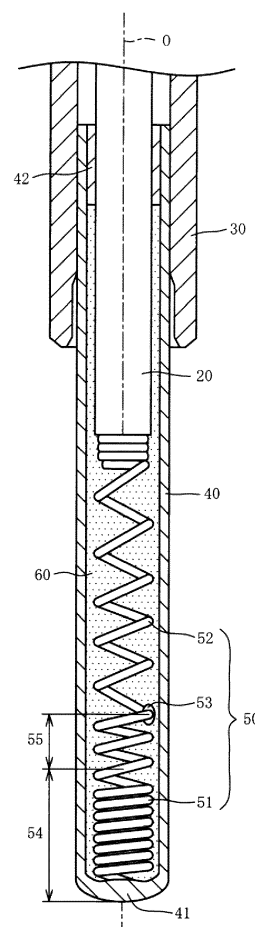


FIG. 2

Description

[0001] The present invention relates to a glow plug, and in particular, to a glow plug that can realize increase in heating temperature.

[Background Art]

[0002] A glow plug is used as an auxiliary heat source of an internal combustion engine such as a compression ignition-type diesel engine. In order to improve startability of the internal combustion engine, the glow plug is required to have a property of raising the temperature thereof to a predetermined temperature in a short time period (hereinafter, referred to as "rapid temperature rising property"). In addition, with regulations on internal combustion engines becoming increasingly stringent, the glow plug is also required to have increased heating temperature. Patent Document 1 discloses a technology in which, in order to meet the demand for increasing the heating temperature, in a glow plug having a coil joined to the front end of a center rod, a heat resistant metal of which principal component is W or Mo that has a higher melting point than a FeCrAl alloy or a NiCr alloy is used for the coil.

[Prior Art Document]

[Patent Document]

[0003] [Patent Document 1] International Publication WO 2014/206847

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0004] However, a resistance ratio of the heat resistant metal such as W or Mo is greater than a resistance ratio of the NiCr alloy. Thus, in the conventional technology, if a constant voltage is applied to the coil in order to raise the temperature to a predetermined temperature, the resistance of the coil abruptly increases and the current value abruptly decreases. Here, the resistance ratio is the "ratio of the resistance value at 1000°C of a coil relative to the resistance value at 20°C of the coil", and the greater the value of the resistance ratio is, the greater the resistance value at a high temperature is. Since the heat generation amount is proportional to the square of the current value, there is a problem that the temperature is difficult to be raised to a predetermined temperature in a short time period, and that the rapid temperature rising property is not realized.

[0005] In contrast to this, it is conceivable to cause the rear side of a coil (front end coil) made from a heat resistant metal to be joined to a rear end coil made from a FeCrAl alloy or a NiCr alloy that has a resistance ratio smaller than the resistance ratio of a heat resistant metal. With this, without excessively increasing the resistance value of the entirety of the coil, it is possible to raise the temperature of the front end coil to a predetermined temperature, and to ensure the rapid temperature rising property.

[0006] However, when the applied voltage is lowered in order to saturate the temperature of the coil of which temperature has been raised to the predetermined temperature, heat of the coil is transferred to the rear end coil, and the temperature of the front end coil readily decreases to a great extent temporarily. This causes problems of unstable combustion of the engine and increased emission of exhaust gas.

[0007] The present invention has been made in order to solve the above-described problems. An object of the present invention is to provide a glow plug that can suppress temperature decrease when the applied voltage is lowered in order to saturate the temperature, while ensuring increased heating temperature and the rapid temperature rising property.

[Means for Solving the Problems]

[0008] In order to achieve this object, a glow plug of the present invention includes: a center rod made of metal and extending in an axis direction; a coil electrically connected to a front end of the center rod; and a tube made of metal and having a front end which is closed, the tube housing the coil and a front side of the center rod and having the coil electrically connected thereto. The coil has: a front end coil electrically connected to the front end of the tube and containing W or Mo as a principal component thereof; and a rear end coil electrically connected to a rear end of the front end coil. A resistance ratio R1 and a resistance ratio R2 satisfy relationship of $R1 > R2$, the resistance ratio R1 being a ratio of a resistance value at 1000°C of the front end coil relative to a resistance value at 20°C of the front end coil, the resistance ratio R2 being a ratio of a resistance value at 1000°C of the rear end coil relative to a resistance value at 20°C of the rear end coil. Then, relative to a resistance value at 20°C between the front end of the tube and the rear

end of the front end coil, a proportion of a resistance value at 20°C between a position of the front end coil at 4 mm from the front end of the tube toward a rear side in the axis direction and the front end of the tube is 55% to 80%.

[Effects of the Invention]

[0009] In the glow plug according to a first aspect, relative to the resistance value at 20°C between the front end of the tube and the rear end of the front end coil, the proportion of the resistance value at 20°C between the front end of the tube and a position of the front end coil at 4 mm from the front end of the tube toward the rear side in the axis direction is 55% to 80%. Thus, the heat generation amount of the portion up to 4 mm of the front end coil can be made greater than the heat generation amount of the other portion of the front end coil. Therefore, the temperature of the portion up to 4 mm of the front end coil can be rapidly raised, and thus, the rapid temperature rising property can be ensured.

[0010] The other portion of the front end coil generates heat in accordance with the proportion of the resistance value (20% to 45%). Thus, when the applied voltage is lowered, the amount of heat that is transferred from the portion up to 4 mm of the front end coil to the rear side can be suppressed. Thus, temperature decrease when the applied voltage is lowered in order to saturate the temperature can be suppressed.

[0011] It should be noted that "W or Mo as a principal component" means that the total content of W or Mo relative to the entire content of the coil material is not less than 50 wt%.

[0012] In the glow plug according to a second aspect, the resistance value between the front end of the tube and the rear end of the front end coil is not greater than 0.13 Ω. Thus, in addition to the effect obtained by the first aspect, it is possible to ensure the value of current flowing in the front end coil, without applying an extremely large voltage to the coil, and to cause the front end coil to generate heat.

[0013] In the glow plug according to a third aspect, the front end coil has a uniform composition from the front end thereof to the rear end thereof, and a pitch at the front side of the front end coil is smaller than a pitch at the rear side of the front end coil. Accordingly, in addition to the effect obtained by the first or second aspect, the structure of the front end coil can be simplified.

[0014] In the glow plug according to a fourth aspect, a resistance value at 20°C between the front end of the tube and the rear end of the rear end coil is not greater than 0.36 Ω. Thus, the value of current, at the time of rush, that flows in the front end coil can be sufficiently ensured. Since the heat generation amount of the front end coil can be ensured, the rapid temperature rising property can be ensured in addition to the effect obtained by any of the first to third aspects.

[0015] In the glow plug according to a fifth aspect, the length in the axis direction from the front end of the tube to the rear end of the front end coil is not less than 6 mm and not greater than 11 mm. Therefore, in addition to the effect obtained by any of the first to fourth aspects, the proportion of the resistance value of the portion up to 4 mm of the front end coil can be easily set.

[0016] In the glow plug according to a sixth aspect, the outer diameter of the tube from the front end of the tube to a position at 4 mm from the front end of the tube toward the rear side in the axis direction is not greater than 3.5 mm. Thus, the heat capacity in the vicinity of the front end of the tube in which the front end coil is disposed can be prevented from being extremely large. As a result, in addition to the effect obtained by the first to fifth aspects, the rapid temperature rising property can be easily ensured.

[Brief Description of the Drawings]

[0017]

[FIG. 1] Diagram of a glow plug with a half side thereof shown in a cross-section.

[FIG. 2] Partial enlarged cross-sectional view of the glow plug.

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

[Modes for Carrying Out the Invention]

[0018] Hereinafter, preferable embodiments of the present invention will be described with reference to attached drawings. A glow plug 10 according to one embodiment of the present invention is described with reference to FIG. 1 and FIG. 2. FIG. 1 is a diagram of the glow plug 10 with a half side thereof shown in a cross section. FIG. 2 is a partial enlarged cross-sectional view of the glow plug 10. In FIG. 1 and FIG. 2, the lower side of the drawing sheet is referred to as the front side of the glow plug 10, and the upper side of the drawing sheet is referred to as the rear side of the glow plug 10.

[0019] As shown in FIG. 1, the glow plug 10 includes a center rod 20, a metal shell 30, a tube 40, and a coil 50. These members are assembled along an axis O of the glow plug 10. The glow plug 10 is an auxiliary heat source to be used at the time of starting an internal combustion engine (not shown), including, for example, a diesel engine.

[0020] The center rod 20 is a metal conductor having a columnar shape, and serves as a member for supplying electric power to the coil 50. The coil 50 is electrically connected to the front end of the center rod 20. The center rod 20 is inserted in the metal shell 30, with the rear end thereof protruding from the metal shell 30.

[0021] In the present embodiment, a connecting portion 21 composed of an external thread is formed at the rear end of the center rod 20. An O-ring 22 made of insulating rubber, an insulator 23 which is a tubular member made of synthetic resin, a ring 24 which is a tubular member made of metal, and a nut 25 made of metal are assembled to the rear end of the center rod 20 in this order from the front side. The connecting portion 21 is a portion to which a connector (not shown) of a cable that supplies electric power from a power source such as a battery is connected. The nut 25 is a member for fixing the connected connector (not shown).

[0022] The metal shell 30 is a substantially cylindrical member formed from carbon steel or the like. The metal shell 30 has an axial hole 31 penetrated therethrough along the axis O, and has a thread portion 32 formed on the outer peripheral surface thereof. In the metal shell 30, a tool engagement portion 33 is formed at the rear side relative to the thread portion 32. The axial hole 31 is a through hole in which the center rod 20 is inserted. Since the inner diameter of the axial hole 31 is greater than the outer diameter of the center rod 20, a void is formed between the center rod 20 and the axial hole 31. The thread portion 32 is an external thread fitted to an internal combustion engine (not shown). The tool engagement portion 33 is a portion having a shape (e.g., a hexagonal shape) engageable with a tool (not shown) that is used to fit or remove the thread portion 32 to or from a threaded hole (not shown) of the internal combustion engine.

[0023] The metal shell 30 holds the center rod 20 through the O-ring 22 and the insulator 23 at the rear side of the axial hole 31. As a result of the ring 24 being crimped to the center rod 20 with the insulator 23 in contact with the ring 24, the position, in the axial direction, of the insulator 23 is fixed. The rear side of the metal shell 30 and the ring 24 are insulated from each other by the insulator 23. The metal shell 30 has the tube 40 fixed at the front side thereof in the axial hole 31.

[0024] The tube 40 is a metal tubular body having a front end 41 which is closed. The tube 40 is fixed to the metal shell 30 by being press-fitted into the axial hole 31. Examples of the material of the tube 40 include heat resistant alloys such as a nickel-based alloy and stainless steel.

[0025] The front side of the center rod 20 is inserted in the tube 40. Since the inner diameter of the tube 40 is greater than the outer diameter of the center rod 20, a void is formed between the center rod 20 and the tube 40. A sealing member 42 is a cylindrical insulating member sandwiched between the front side of the center rod 20 and the rear end of the tube 40. The sealing member 42 maintains the interval between the center rod 20 and the tube 40, and seals the space between the center rod 20 and the tube 40. The coil 50 is housed in the tube 40 along the axis O. An insulating powder 60 is filled in the tube 40.

[0026] As shown in FIG. 2, the coil 50 is formed in a spiral shape and generates heat by current being applied thereto. The coil 50 includes: a front end coil 51 joined to the front end 41 of the tube 40; and a rear end coil 52 joined to the front end of the center rod 20.

[0027] The front end of the front end coil 51 is joined to the front end 41 of the tube 40 by welding. The front end coil 51 is formed from a high-melting-point metal containing W or Mo as a principal component. An elementary substance of either of these elements, or an alloy using either of these elements as a principal component can be used as the front end coil 51. The rear end of the front end coil 51 is joined to the rear end coil 52 by welding. A melt portion 53 which is a weld metal melted during the welding and solidified is formed between the front end coil 51 and the rear end coil 52.

[0028] The rear end coil 52 is a member connected in series to the front end coil 51 through the melt portion 53. The rear end coil 52 is formed from a conductive material that has a resistance ratio R2 smaller than a resistance ratio R1 of the front end coil 51. Examples of the material of the rear end coil 52 include a FeCrAl alloy, and a NiCr alloy. The rear end coil 52 is housed in the tube 40 along the axis O, and the rear end of the rear end coil 52 is joined to the front end of the center rod 20 by welding. The center rod 20 is electrically connected to the tube 40 through the rear end coil 52 and the front end coil 51.

[0029] The insulating powder 60 is a powder that has electrical insulation property and that has thermal conductivity under high temperature. The insulating powder 60 is filled between the coil 50 and the tube 40, between the center rod 20 and the tube 40, and inside the coil 50. The insulating powder 60 has a function of causing heat to be transferred from the coil 50 to the tube 40, a function of preventing short circuit between the coil 50 and the tube 40, and a function of making the coil 50 less liable to vibrate thereby preventing disconnection. Examples of the insulating powder 60 include oxide powders such as MgO powder and Al₂O₃ powder. In addition to the oxide powders such as MgO powder and Al₂O₃ powder, powders such as CaO or ZrO₂ powder and SiO₂ or Si powder can be added. In the present embodiment, the insulating powder 60 contains an MgO powder by not less than 85 mass% and less than 100 mass% relative to the total mass of the insulating powder 60, and also contains an Si powder.

[0030] The front end coil 51 is composed of: a first portion 54 extending from the front end 41 of the tube 40 to a position separated by 4 mm from the front end 41 of the tube 40 toward the rear side in the axis O direction; and a second portion 55 extending from the rear end (the position separated by 4 mm from the front end 41 of the tube 40 toward the rear side in the axis O direction) of the first portion 54 to the melt portion 53. In the front end coil 51, the

resistance value at 20°C between the front end 41 of the tube 40 and the rear end (the melt portion 53) of the front end coil 51 is set to be not greater than 0.13 Ω . It should be noted that the resistance value is a value measured by a four-terminal method.

[0031] In the front end coil 51, relative to the resistance value at 20°C between the front end 41 of the tube 40 and the rear end (the melt portion 53) of the front end coil 51, the proportion of the resistance value at 20°C of the first portion 54 is set to 55% to 80%, and the proportion of the resistance value at 20°C of the second portion 55 is set to 20% to 45%.

[0032] In the coil 50, the resistance value at 20°C between the front end 41 of the tube 40 and the rear end (the welded portion between the rear end coil 52 and the center rod 20) of the rear end coil 52 is set to be not greater than 0.36 Ω . In the present embodiment, the resistance value at 20°C between the front end 41 of the tube 40 and the rear end of the rear end coil 52 is set to be not less than 0.29 Ω .

[0033] In the front end coil 51, the length in the axis O direction from the front end 41 of the tube 40 to the melt portion 53, that is, the entire length obtained by adding the length in the axis O direction of the first portion 54 and the length in the axis O direction of the second portion 55, is set to be not less than 6 mm and not greater than 11 mm.

[0034] In the present embodiment, the front end coil 51 has a uniform composition from the front end 41 to the melt portion 53 except the front end 41 of the tube 40 and the weld metal of the melt portion 53, and the proportions of the resistance values of the first portion 54 and the second portion 55 are set by making the pitch at the front side of the front end coil 51 smaller than the pitch at the rear side of the front end coil 51. Accordingly, the structure of the front end coil 51 can be simplified.

[0035] It should be noted that the means for setting the proportions of the resistance values of the first portion 54 and the second portion 55 is not limited to the means for adjusting the pitch of the front end coil 51. Examples of another means for setting the proportions of the resistance values include: means for making the wire diameter at the front side of the front end coil 51 smaller than the wire diameter at the rear side thereof; and means for producing the front end coil 51 by joining in series two coils made of materials having different specific resistances at 20°C and then joining the coil having the higher specific resistance to the front end 41 of the tube 40. Also in these cases, the resistance value at the front side of the front end coil 51 can be made higher than the resistance value at the rear side thereof, and thus, the proportion of the resistance value of the first portion 54 can be made greater than the proportion of the resistance value of the second portion 55.

[0036] Next, with reference to FIG. 3, the relationship between voltage V applied to the glow plug 10 and heating temperature T of the glow plug 10 is described. FIG. 3 is a schematic diagram showing the relationship between the voltage V and the heating temperature T of the glow plug 10. In FIG. 3, the horizontal axis represents time (seconds), the solid line indicates the heating temperature T, and the broken line indicates the voltage V.

[0037] When the voltage V is applied between the connecting portion 21 of the glow plug 10 and the metal shell 30, current I obtained by dividing the voltage V by the sum $R_1 + R_2$ of a resistance value R_1 of the front end coil 51 and a resistance value R_2 of the rear end coil 52 flows in the coil 50. The heat generation amount of the front end coil 51 per unit time is $R_1 \cdot I^2$, and the heat generation amount of the rear end coil 52 per unit time is $R_2 \cdot I^2$.

[0038] Since the resistance value R_1 at 20°C of the front end coil 51 is not greater than 0.13 Ω , the current I that flows in the front end coil 51 at the time of heat generation can be ensured without extremely increasing the voltage that is applied between the connecting portion 21 and the metal shell 30. Thus, the heat generation amount of the front end coil 51 can be ensured. It should be noted that, in the coil 50, the resistance value R_2 at 20°C of the rear end coil 52 is set to a value greater than the resistance value R_1 at 20°C of the front end coil 51 (specifically, not less than 0.06 Ω). This is for ensuring the current I (rush current) flowing in the coil 50 at normal temperature, to cause the coil 50 to generate heat.

[0039] Since the rear end coil 52 has the resistance ratio R_2 which is smaller than the resistance ratio R_1 of the front end coil 51, the resistance value R_1 of the front end coil 51 becomes greater than the resistance value R_2 of the rear end coil 52 in association with temperature rise due to heat generation by the coil 50. As a result, the heat generation amount $R_1 \cdot I^2$ per unit time of the front end coil 51 can be made greater than the heat generation amount $R_2 \cdot I^2$ per unit time of the rear end coil 52.

[0040] Since the front end coil 51 is formed from a high-melting-point metal containing W or Mo as a principal component, the heating temperature T can be increased. In the glow plug 10, the proportion of the resistance value at 20°C of the first portion 54 in the front end coil 51 relative to the resistance value R_1 at 20°C of the front end coil 51 is 55% to 80%, and thus, the heat generation amount of the first portion 54 can be made greater than the heat generation amount of the second portion 55. Thus, the heating temperature T of the first portion 54 can be rapidly raised to a desired temperature (e.g., 1000°C), and the rapid temperature rising property can be ensured.

[0041] After the heating temperature T has reached the desired temperature (here, 1000°C), the voltage V applied to the glow plug 10 is lowered in order to bring the heating temperature T to a saturation temperature (e.g., 1100°C) realized during stable operation. Since the heat generation amount of the rear end coil 52 is smaller than the heat generation amount of the front end coil 51, during transition in which the voltage V is lowered, heat of the front end coil 51 is transferred to the rear end coil 52. As a result, the heating temperature T highly depending on the front end coil 51

temporarily decreases by a temperature D. If the temperature D increases and the heating temperature T greatly decreases, combustion of the engine becomes unstable, and emission of exhaust gas is increased.

[0042] In order to prevent this, in the glow plug 10, the proportion of the resistance value at 20°C of the second portion 55 in the front end coil 51 is set to 20% to 45%. The second portion 55 generates heat in accordance with the proportion (20% to 45%) of the resistance value thereof relative to that of the front end coil 51. Thus, the amount of heat can be suppressed that is to be transferred from the first portion 54 to the second portion 55 when the voltage V is lowered for making transition to the saturation state. Accordingly, the temperature decrease (temperature D) during transition in which the voltage V is lowered in order to saturate the heating temperature T can be suppressed. As a result, while the heating temperature T is increased and the rapid temperature rising property is ensured, temperature decrease at the time when the voltage V is lowered in order to saturate the heating temperature T can be suppressed. Therefore, the glow plug 10 can assist combustion of the engine and stabilize idling operation of the started engine, and in addition, can reduce emission of exhaust gas.

[0043] In the glow plug 10, since the resistance value at 20°C between the front end 41 of the tube 40 and the rear end of the rear end coil 52 (i.e., the resistance value at 20°C of the coil 50) is set to be not greater than 0.36 Ω, the value of current flowing in the front end coil 51 can be ensured. Since the heat generation amount of the front end coil 51 can be ensured, the rapid temperature rising property can be ensured.

[0044] In the glow plug 10, at the time of rush, the first portion 54 of the front end coil 51 rapidly generates heat due to application of voltage, and further, temperature decrease of the first portion 54 during transition to the saturation state can be suppressed. Therefore, power saving of the glow plug 10 can be realized.

[0045] Since the resistance value at 20°C between the front end 41 of the tube 40 and the rear end of the rear end coil 52 (i.e., the resistance value at 20°C of the coil 50) is set to be not less than 0.29 Ω, the value of current at the time of rush can be regulated. As a result, an extremely large rush current can be prevented from flowing in a controller (not shown) that controls the glow plug 10, and thus, the controller can be protected.

[0046] In order to suppress rush current that flows in the controller, it is understood that a protective resistance can be provided separately from the glow plug 10. In a case where the protective resistance is provided, the resistance value at 20°C of the glow plug 10 may not be necessarily set to be not less than 0.29 Ω. However, if the resistance value at 20°C of the glow plug 10 is set to be not less than 0.29 Ω, the protective resistance can be omitted, and thus, the number of components can be reduced, accordingly.

[0047] In the front end coil 51, the length in the axis O direction from the front end 41 of the tube 40 to the melt portion 53, that is, the entire length obtained by adding the length in the axis O direction of the first portion 54 and the length in the axis O direction of the second portion 55, is set to be not less than 6 mm and not greater than 11 mm. Accordingly, the developed length of the front end coil 51 can be set appropriately. As a result, while the resistance value of the front end coil 51 is prevented from becoming extremely large, the proportion of the resistance value of the first portion 54 relative to the resistance value of the front end coil 51 can be easily set.

[0048] Since the insulating powder 60 contains an Si powder, the thermal conductivity of the insulating powder 60 can be decreased when compared with a case where the entirety of the insulating powder 60 is an MgO powder. As a result, heat dissipation of the first portion 54 due to heat conduction of the insulating powder 60 can be suppressed. Thus, by causing heat generation from the front end 41 of the tube 40, the insulating powder 60 helps ensuring the rapid temperature rising property at the time of rush and suppressing the temperature decrease during transition.

[0049] The glow plug 10 is produced in the following manner, for example. First, a resistance heating wire having a predetermined composition is processed into a coil shape, and from the coil-shaped resistance heating wire, the front end coil 51 and the rear end coil 52 are produced. Next, end portions of the front end coil 51 and the rear end coil 52 are joined together by welding, to form the coil 50. Next, the rear end coil 52 in the coil 50 is joined to the front end of the center rod 20.

[0050] Meanwhile, a metal steel pipe having a predetermined composition is formed such that the diameter thereof is larger than the final dimension of the tube 40, and such that a front end of the metal steel pipe has a diameter smaller than the diameters of other portions, whereby a tapered-off tube precursor having an open front end is produced. The coil 50 integrated with the center rod 20 is inserted in the tube precursor, and the front end of the coil 50 is disposed in the tapered-off opening portion of the tube precursor. The opening portion of the tube precursor and the front end portion of the coil 50 are melted by welding to close the front end portion of the tube precursor, whereby a heater precursor having the coil 50 housed therein is formed.

[0051] Then, after the insulating powder 60 is filled in the tube 40 of the heater precursor, the sealing member 42 is inserted between the opening portion at the rear end of the tube 40 and the center rod 20, so as to seal the tube 40. Next, swaging is performed on the tube 40 until the tube 40 has a predetermined outer diameter.

[0052] Next, the tube 40 having been subjected to the swaging is fixed by being press-fitted into the axial hole 31 of the metal shell 30, and the O-ring 22 and the insulator 23 are fitted between the metal shell 30 and the center rod 20 from the rear end of the center rod 20. The center rod 20 is crimped with the ring 24, whereby the glow plug 10 is obtained.

[Examples]

[0053] The present invention is further described in detail by use of Example. However, the present invention is not limited to this Example.

<Creation of samples 1 to 10>

[0054] By use of a wire having a diameter of $\phi 0.20$ mm and made of an alloy containing tungsten as a principal component, and with the numbers of turn times, the pitch, and the entire length thereof adjusted, front end coils 51 were created that each had an entire length of 6 mm to 11 mm, and that had various proportions of the resistance values at 20°C of the first portion 54 and the second portion 55. Similarly, by use of a wire made of a NiCr alloy, various rear end coils 52 were created. Various coils 50 in which the rear end coil 52 and the front end coil 51 were connected in series were each created by joining the rear end coil 52 to the front end coil 51 by welding.

[0055] By use of the coils 50, glow plugs each having a structure similar to that of the glow plug 10 shown in FIG. 1 were produced in the manner as described above, whereby the glow plugs of samples 1 to 10 shown in Table 1 were obtained. In the glow plugs of samples 1 to 10, an MgO powder containing an Si powder by 0.2 mass% was used as the insulating powder 60.

[0056] In the glow plugs of samples 1 to 10, the outer diameter of the tube 40 was set to be not greater than $\phi 3.5$ mm (that is, the outer diameter of the portion, outside the first portion 54 of the coil 50, of the tube 40 (the portion from the front end 41 of the tube 40 to the position at 4 mm from the front end 41 of the tube 40 toward the rear side) was set to be not greater than $\phi 3.5$ mm).

[Table 1]

No	Proportion of resistance value		Resistance value of front end coil (Ω)	Evaluation		
	First portion (%)	Second portion (%)		Temperature at the time of rush	Temperature decrease during transition	Overall
1	90	10	0.13	excellent	poor	poor
2	85	15	0.13	excellent	poor	poor
3	80	20	0.13	excellent	good	good
4	70	30	0.13	very good	good	good
5	60	40	0.13	very good	very good	very good
6	55	45	0.13	good	very good	good
7	50	50	0.13	poor	excellent	poor
8	45	55	0.13	poor	excellent	poor
9	55	45	0.14	poor	very good	poor
10	55	45	0.15	poor	very good	poor

[0057] A PR thermocouple was joined at a position on the surface of the tube 40 separated by 2 mm in the axis O direction from the front end 41 of the tube 40 of each sample, and the temperature in the vicinity of the front end 41 of the tube 40 was measured. It should be noted that a radiation thermometer may be used instead of the PR thermocouple.

<Temperature at the time of rush>

[0058] DC voltage of 11 V was applied between the connecting portion 21 and the metal shell 30 of each sample, and the temperature in the vicinity of the front end 41 of the tube 40 after two seconds from the application of the voltage was measured. As evaluation, a sample in which the temperature was not less than 900°C was determined as "excellent", a sample in which the temperature was not less than 850°C and less than 900°C was determined as "very good", a sample in which the temperature was not less than 800°C and less than 850°C was determined as "good", and a sample in which the temperature was less than 800°C was determined as "poor". The results are shown in the column "Tem-

perature at the time of rush" of Table 1.

<Temperature decrease during transition>

[0059] DC voltage was applied for two seconds between the connecting portion 21 and the metal shell 30 of each sample such that the temperature in the vicinity of the front end 41 of the tube 40 after two seconds from the application of the voltage became 1000°C, and then, the applied voltage was lowered. The applied voltage at this time was set to a rated voltage at which the temperature in the vicinity of the front end 41 of the tube 40 became saturated at 1100°C. When the applied voltage was lowered, the temperature of the tube 40 temporarily decreased, and with a lapse of time, rose toward the saturation temperature of 1100°C (see FIG. 3). The difference between the maximum temperature of the tube 40 during rapid temperature rise and the temperature of the tube 40 during transition in which the applied voltage was lowered (the temperature D shown in FIG. 3) was measured.

[0060] As evaluation, a sample in which the temperature difference was less than 30°C was determined as "excellent", a sample in which the temperature difference was not less than 30°C and less than 50°C was determined as "very good", and a sample in which the temperature difference was not less than 50°C and less than 80°C was determined as "good", and a sample in which the temperature difference was not less than 80°C was determined as "poor". The results are shown in the column "Temperature decrease during transition" in Table 1.

<Overall evaluation>

[0061] A glow plug that can realize both a high "temperature at the time of rush" and a small "temperature decrease during transition" is required. Thus, the lower one of the evaluation of "temperature at the time of rush" and the evaluation of "temperature decrease during transition" was entered in the column of "Overall" in Table 1.

<Measurement of resistance value>

[0062] The tube 40 of each sample in which the temperature measurement had been finished was cut to be opened in the axis O direction, the insulating powder 60 filled in the tube 40 was removed, and the coil 50 in a state where both ends thereof were joined to the front end 41 of the tube 40 and the center rod 20 was exposed. By a four-terminal method, the resistance value at 20°C of each of the following portions (1) to (4) was measured: (1) the front end coil 51 between the front end 41 of the tube 40 and the melt portion 53; (2) the first portion 54 between the front end 41 of the tube 40 and the position separated by 4 mm in the axis O direction from the front end 41 of the tube 40; (3) the second portion 55 between the position separated by 4 mm in the axis O direction from the front end 41 of the tube 40 and the melt portion 53; and (4) the coil 50 between the front end 41 of the tube 40 and the rear end (the front end of the center rod 20) of the rear end coil 52.

[0063] After the measurement of the resistance value, the proportion of the resistance value at 20°C of the first portion 54 and the proportion of the resistance value at 20°C of the second portion 55, relative to the resistance value at 20°C between the front end 41 of the tube 40 and the rear end (melt portion 53) of the front end coil 51, were obtained. The results are shown in Table 1. It should be noted that the resistance value at 20°C of the coil 50 of each of all the samples was 0.33 Ω.

<Result>

[0064] As shown in Table 1, among samples 1 to 8 in which the resistance value of the front end coil 51 was 0.13 Ω, samples 1 and 2 in which the proportion of the resistance value of the first portion 54 exceeded 80% and the proportion of the resistance value of the second portion 55 was less than 20% satisfied the evaluation criteria for the temperature at the time of rush, but did not satisfy the evaluation criteria for the temperature decrease during transition. In samples 1 and 2, the heat generation amount of the second portion 55 was small. Thus, it was speculated that, when the applied voltage was lowered, the amount of heat of the first portion 54 temporarily reduced due to heat conduction from the first portion 54 to the second portion 55, whereby the temperature of the tube 40 decreased.

[0065] Samples 7 and 8 in which the proportion of the resistance value of the first portion 54 was less than 55% and the proportion of the resistance value of the second portion 55 exceeded 45% satisfied the evaluation criteria for the temperature decrease during transition but did not satisfy the evaluation criteria for the temperature at the time of rush. Thus, it was speculated that, since the proportion of the resistance value of the first portion 54 was small in samples 7 and 8, the heat generation amount necessary for rapid temperature rise of the first portion 54 was not ensured.

[0066] In contrast to this, samples 3 to 6 in which the proportion of the resistance value of the first portion 54 was 55% to 80% and the proportion of the resistance value of the second portion 55 was 20% to 45% satisfied the evaluation criteria for the temperature at the time of rush and the temperature decrease during transition. It was speculated that

samples 3 to 6 were able to ensure the heat generation amount necessary for rapid temperature rise of the first portion 54, and in addition, were able to suppress the amount of heat transferred from the first portion 54 to the second portion 55.

[0067] In samples 9 and 10, the proportion of the resistance value of the first portion 54 was 55% and the proportion of the resistance value of the second portion 55 was 45%, but samples 9 and 10 did not satisfy the evaluation criteria for the temperature at the time of rush. It is speculated that, since the resistance value of the front end coil 51 exceeded 0.13 Ω in samples 9 and 10, the current value necessary for rapid temperature rise of the front end coil 51 was not ensured by the DC voltage of 11 V that was applied in this Example.

[0068] Therefore, it has been clarified that by setting the proportion of the resistance value of the first portion 54 to 55% to 80%, it is possible to suppress temperature decrease during transition while ensuring the rapid temperature rising property. Further, it has been clarified that by setting the resistance value of the front end coil 51 to be not greater than 0.13 Ω , it is possible to ensure the heat generation amount by application of DC voltage of 11 V. Furthermore, it has been revealed that if the outer diameter of the portion, of the tube 40, from the front end 41 of the tube 40 to the position at 4 mm from the front end 41 of the tube 40 toward the rear side is set to be not greater than $\phi 3.5$ mm, the heat capacity in the vicinity of the front end 41 of the tube 40 can be prevented from being extremely large, and the rapid temperature rising property can be ensured.

<Creation of samples 11 to 14>

[0069] Front end coils 51 were created in a manner similar to that for sample 3. Various rear end coils 52 were created by use of a wire made of a NiCr alloy. Various coils 50 in which the rear end coil 52 and the front end coil 51 were connected in series were each created by joining the rear end coil 52 to the front end coil 51 by welding. The numbers of turn times of the rear end coil 52 was adjusted, whereby the resistance value at 20°C of the coil 50 was adjusted. The method for measuring the resistance value was the same as that described with regard to samples 1 to 10, and the resistance value was measured after the temperature measurement for each sample was finished.

[0070] By use of these coils 50, glow plugs each having a structure similar to that of the glow plug 10 shown in FIG. 1 were produced in the manner as described above, whereby the glow plugs of samples 11 to 14 shown in Table 2 were obtained. In the glow plugs of samples 11 to 14, an MgO powder containing an Si powder by 0.2 mass% was used as the insulating powder 60.

[Table 2]

No	Proportion of resistance value		Resistance value of front end coil (Ω)	Resistance value of coil (Ω)	Evaluation
	First portion (%)	Second portion (%)			Temperature at the time of rush
11	80	20	0.13	0.29	excellent
12	80	20	0.13	0.32	very good
13	80	20	0.13	0.35	very good
14	80	20	0.13	0.36	good

[0071] A PR thermocouple was joined at a position on the surface of the tube 40 separated by 2 mm in the axis O direction from the front end 41 of the tube 40 of each sample, and the temperature in the vicinity of the front end 41 of the tube 40 was measured. It should be noted that a radiation thermometer may be used instead of the PR thermocouple.

<Temperature at the time of rush>

[0072] DC voltage of 11 V was applied between the connecting portion 21 and the metal shell 30 of each sample, and the temperature in the vicinity of the front end 41 of the tube 40 after two seconds from the application of the voltage was measured. As evaluation, a sample in which the temperature was not less than 950°C was determined as "excellent", a sample in which the temperature was not less than 900°C and less than 950°C was determined as "very good", and a sample in which the temperature was not less than 850°C and less than 900°C was determined as "good". The results are shown in the column "temperature at the time of rush" in Table 2.

<Result>

[0073] As shown in Table 2, it was confirmed that, in samples 11 to 14 in which the resistance value at 20°C of the coil 50 (between the front end 41 of the tube 40 and the rear end of the rear end coil 52) was not less than 0.29 Ω and not greater than 0.36 Ω, the temperature became higher in accordance with decrease in the resistance value, and the rapid temperature rising property was improved. It is speculated that this is because the value of current at the time of rush that flows in the front end coil 51 becomes large in accordance with decrease in the resistance value at 20°C of the coil 50. As a result, the heat generation amount of the front end coil 51 at the time of rush can be increased, and thus, it is speculated that the rapid temperature rising property can be improved.

[0074] Although the present invention has been described on the basis of the embodiment and Example, the present invention is not limited to the above embodiment and Example at all. It is easily understood that various improved modifications can be made without departing from the gist of the present invention. For example, the shape of the tube 40 is not limited in particular as long as the shape is tubular, and the shape thereof in cross-section perpendicular to the axis O may be circular, elliptical, polygonal, or the like. In addition, the wire diameter and the diameter of the coil 50, and the thickness and the diameter of the tube 40 can be set as appropriate in consideration of the heat capacity, etc. of the coil 50 and the tube 40.

[0075] In the embodiment, a case has been described in which the entirety of the tube 40 has a uniform outer diameter except the portion of the front end 41. However, the present invention is not limited thereto. For example, it is of course possible to employ a tube 40 having a varied diameter in which the outer diameter of the portion, inside the metal shell 30, of the tube 40 is made larger than the outer diameter at the position at 4 mm from the front end 41 of the tube 40 toward the rear side. If the tube 40 having a varied diameter in which the outer diameter at the front side is small is employed, the heat capacity at the front end 41 side of the tube 40 can be reduced. Thus, the rapid temperature rising property can be easily ensured.

[0076] In addition, since the rear side of the tube 40 at which the outer diameter is greater than at the front end 41 side is press-fitted in the metal shell 30, the inner diameter of the metal shell 30 need not be made small in accordance with the outer diameter at the front end 41 side of the tube 40. In addition, the front end of the center rod 20 is inserted into the rear side of the tube 40, the diameter of the center rod 20 need not be made small in accordance with the inner diameter of the rear side of the tube 40. That is, the outer diameter of the center rod 20 and the inner diameter of the metal shell 30 can be set irrespectively of the outer diameter at the front end 41 side of the tube 40, and thus, the degrees of freedom in design of the center rod 20 and the metal shell 30 can be ensured.

[Description of Reference Numerals]

[0077]

10: glow plug
 20: center rod
 40: tube
 41: front end
 50: coil
 51: front end coil
 52: rear end coil
 54: first portion (portion)
 O: axis

Claims

1. Aglow plug (10) comprising:

a center rod (20) made of metal and extending in an axis (O) direction;
 a coil (50) electrically connected to a front end of the center rod (20); and
 a tube (40) made of metal and having a front end which is closed, the tube (40) housing the coil (50) and a front side of the center rod (20) and having the coil (50) electrically connected thereto, wherein
 the coil (50) has: a front end coil (51) electrically connected to the front end (41) of the tube (40) and containing W or Mo as a principal component thereof; and a rear end coil (52) electrically connected to a rear end (53) of the front end coil (51),
 a resistance ratio R1 and a resistance ratio R2 satisfy relationship of $R1 > R2$, the resistance ratio R1 being a

ratio of a resistance value at 1000°C of the front end coil (51) relative to a resistance value at 20°C of the front end coil (51), the resistance ratio R2 being a ratio of a resistance value at 1000°C of the rear end coil (52) relative to a resistance value at 20°C of the rear end coil (52), and
 relative to a resistance value at 20°C between the front end (41) of the tube (40) and the rear end (53) of the front end coil (51), a proportion of a resistance value at 20°C between a position of the front end coil (51) at 4 mm from the front end (41) of the tube (40) toward a rear side in the axis (O) direction and the front end (41) of the tube (40) is 55% to 80%.

2. The glow plug (10) according to claim 1, wherein the resistance value between the front end (41) of the tube (40) and the rear end (53) of the front end coil (51) is not greater than 0.13 Ω.
3. The glow plug (10) according to claim 1 or 2, wherein the front end coil (51) has a uniform composition from a front end thereof to the rear end (53) thereof, and a pitch at a front side of the front end coil (51) is smaller than a pitch at a rear side of the front end coil (51).
4. The glow plug (10) according to any one of claims 1 to 3, wherein a resistance value at 20°C between the front end (41) of the tube (40) and a rear end of the rear end coil (52) is not greater than 0.36 Ω.
5. The glow plug (10) according to any one of claims 1 to 4, wherein a length in the axis (O) direction from the front end (41) of the tube (40) to the rear end (53) of the front end coil (51) is not less than 6 mm and not greater than 11 mm.
6. The glow plug (10) according to any one of claims 1 to 5, wherein an outer diameter of the tube (40) from the front end (41) of the tube (40) to a position at 4 mm from the front end (41) of the tube (40) toward the rear side in the axis (O) direction is not greater than 3.5 mm.

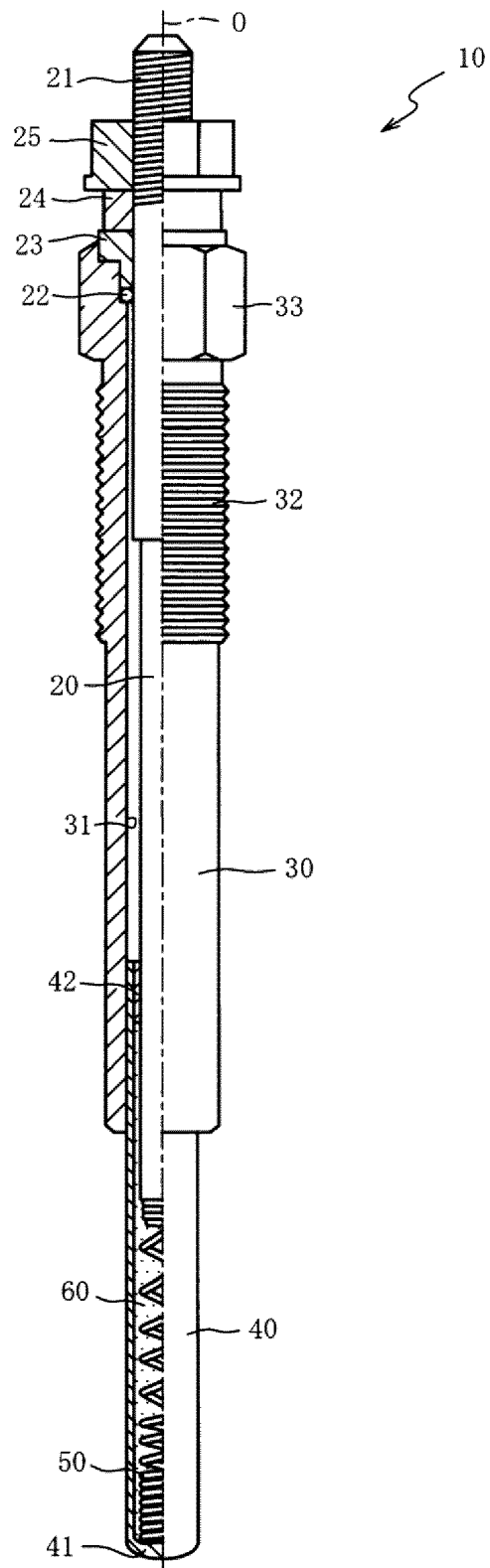


FIG. 1

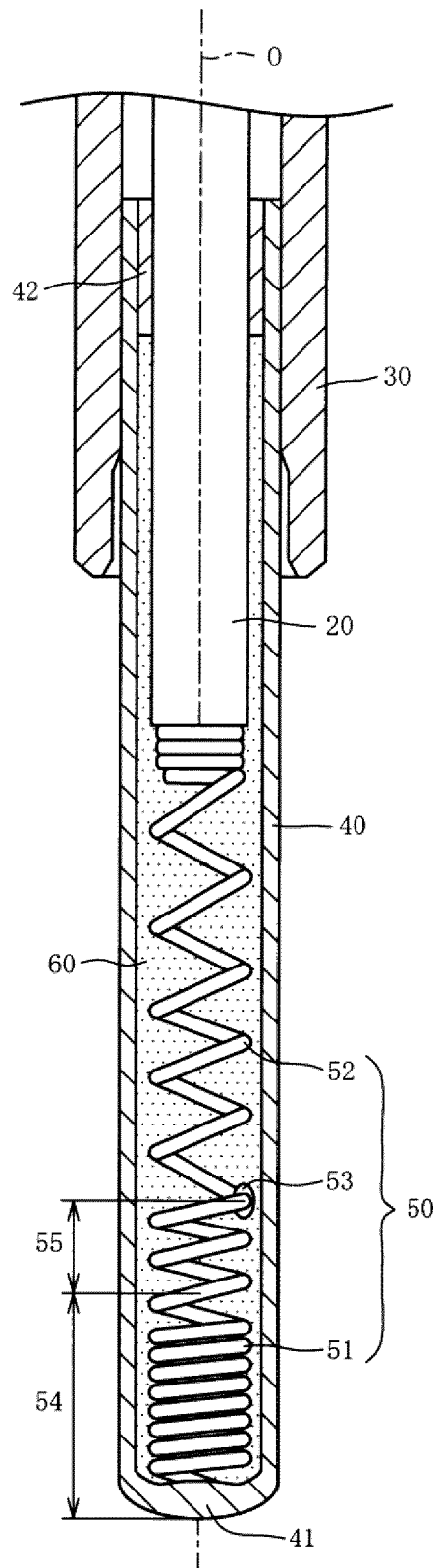


FIG. 2

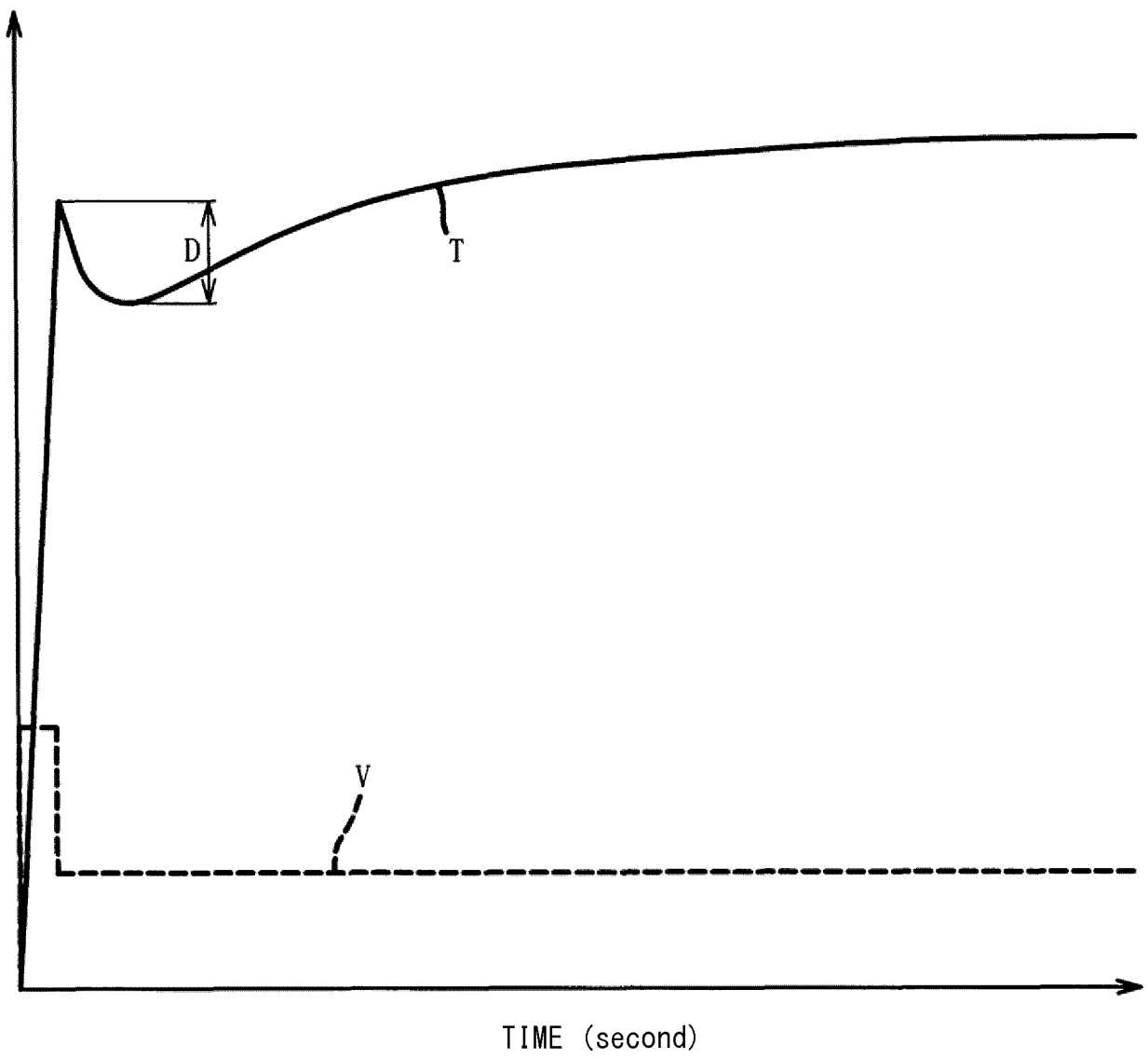


FIG. 3



EUROPEAN SEARCH REPORT

 Application Number
 EP 17 20 0876

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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)
Y	US 2004/206742 A1 (DUBA DAVID E [US]) 21 October 2004 (2004-10-21) * paragraphs [0024], [0025], [0035]; figure 4 *	1-6	INV. F23Q7/00
Y	EP 2 587 156 A1 (NGK SPARK PLUG CO [JP]) 1 May 2013 (2013-05-01) * paragraphs [0077], [0102] - [0106], [0125]; figures 4,6,7 *	1-6	
Y	EP 2 136 142 A1 (NGK SPARK PLUG CO [JP]) 23 December 2009 (2009-12-23) * paragraph [0048] *	6 1	
A	WO 2009/079530 A2 (FEDERAL MOGUL IGNITION CO [US]; HOFFMAN JOHN [US]; GORETTI SANDRO [IT]) 25 June 2009 (2009-06-25) * paragraph [0037]; figure 3 *	1-6	
A	EP 0 392 180 A1 (BOSCH GMBH ROBERT [DE]) 17 October 1990 (1990-10-17) * column 5, line 5 - line 27; figure 1 *	1-6	TECHNICAL FIELDS SEARCHED (IPC) F23Q
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25 April 2018	Examiner Mougey, Maurice
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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 EPO FORM 1503 03.02 (P04C01)

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

EP 17 20 0876

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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25-04-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004206742 A1	21-10-2004	NONE	
EP 2587156 A1	01-05-2013	DE 102011077239 A1 EP 2587156 A1 JP 5255706 B2 JP WO2011162074 A1 WO 2011162074 A1	22-12-2011 01-05-2013 07-08-2013 19-08-2013 29-12-2011
EP 2136142 A1	23-12-2009	CN 101365912 A EP 2136142 A1 US 2009314761 A1 WO 2008126171 A1	11-02-2009 23-12-2009 24-12-2009 23-10-2008
WO 2009079530 A2	25-06-2009	CN 101896772 A EP 2229557 A2 JP 2011506910 A KR 20100098702 A US 2009184101 A1 WO 2009079530 A2	24-11-2010 22-09-2010 03-03-2011 08-09-2010 23-07-2009 25-06-2009
EP 0392180 A1	17-10-1990	DE 3911506 A1 EP 0392180 A1 JP 2793004 B2 JP H02293523 A	11-10-1990 17-10-1990 03-09-1998 04-12-1990

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2014206847 A [0003]