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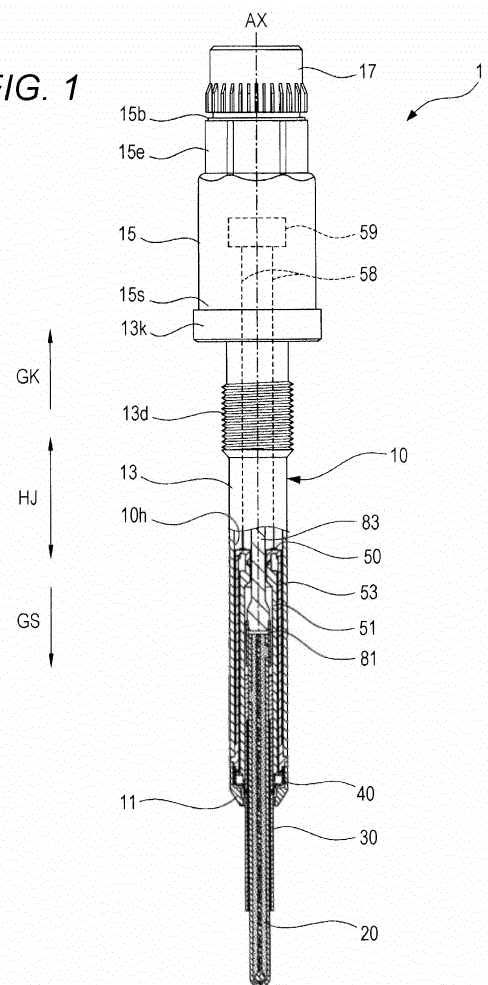
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(54) **GLOW PLUG WITH PRESSURE SENSOR**

(57) A glow plug with a pressure sensor 1 includes an outer cylinder 30 arranged and held inside a metal shell 10. The outer cylinder 30 has inner part 33 arranged inside the metal shell 10 and a projection part 31 projecting from the metal shell 10. A ceramic heater 20 is held by the outer cylinder 30 so as to be displaceable in the axial line direction HJ together with the outer cylinder 30. Further, the outer cylinder inner part 33 of the outer cylinder 30 has a heater holding part 35 for holding the ceramic heater 20 therein. The outer cylinder projection part 31 of the outer cylinder 30 surrounds the ceramic heater 20 provided therein in a loose-fit manner.

FIG. 1



Description

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a glow plug with a pressure sensor.

2. Related Art

[0002] Conventionally, as a glow plug used for assisting ignition of a diesel engine, there has been known a glow plug with a pressure sensor which also has a function of sensing a combustion pressure. This glow plug with a pressure sensor (hereinafter, also simply referred to as a glow plug) is mounted to an engine head such that a heater is exposed in a combustion chamber. This can facilitate the ignition of the fuel. In addition, the heater is subjected to the combustion pressure (combustion gas pressure) inside the combustion chamber. The resultant displacement of the heater is sensed by a sensor unit having a piezoelectric device, a strain sensor (gage), or the like. This glow plug includes, for example, a cylindrical metal shell, a metallic outer cylinder held on the front end side of this metal shell, a bar-shaped ceramic heater held by the outer cylinder, and the sensor unit. Among them, the ceramic heater and the outer cylinder are arranged to be displaceable in the axial line direction according to the combustion pressure. The displacement of the ceramic heater is sensed by the sensor unit.

[0003] It is noted that, in the conventional glow plug, the entire outer cylinder is fixed evenly to the ceramic heater along its axial line direction by press-fit, brazing, or the like. For example, WO2013/099226A1 discloses such a glow plug (see FIG. 1 and its related description of WO2013/099226A1).

SUMMARY

[0004] When the entire outer cylinder holds the ceramic heater evenly along its axial line direction by press-fit, however, a press-fitted part of the outer cylinder is long. This requires a large press-fit load at the press-fit, which results in poor press-fit properties. On the other hand, when the entire outer cylinder holds the ceramic heater evenly along its axial line direction by brazing, a brazed portion is long. This causes an increased cost.

[0005] Thus, the inventors have considered a glow plug having the following outer cylinder. That is, while the front-end-side portion of the outer cylinder holds the ceramic heater by press-fit, brazing, or the like, the rear-end-side portion of the outer cylinder does not hold the ceramic heater. That is, the outer cylinder is spaced apart from the ceramic heater.

[0006] This glow plug causes the following problems. When the glow plug is mounted to the engine head, a front end part (a heater front end part) of the ceramic

heater and an outer cylinder projection part of the outer cylinder are exposed in the combustion chamber, respectively. The temperature is therefore higher on the respective front end sides of the ceramic heater and the outer cylinder. The outer cylinder is made of metal. Therefore, when exposed to high temperature, the outer cylinder is thermally-expanded largely as compared to the ceramic heater. Thus, there is a concern that the front-end-side portion of the outer cylinder initially fixed to the ceramic heater by press-fit is thermally-expanded largely and thus the diameter of the front-end-side portion increases, which causes a gap between the inner circumferential surface of the outer cylinder and the outer circumferential surface of the ceramic heater. Alternatively, there is a concern that, even if the front-end-side portion of the outer cylinder is initially fixed to the ceramic heater by brazing, melting of the brazing material similarly causes a gap between the inner circumferential surface of the outer cylinder and the outer circumferential surface of the ceramic heater. This causes a concern that the combustion gas flows through this gap into the rear end side of the outer cylinder of the glow plug.

[0007] An object of the present disclosure is to provide a glow plug with a pressure sensor in which a ceramic heater is held by an outer cylinder reliably with a low cost and which is able to suppress the inflow of combustion gas up to a rear end side of the outer cylinder through a gap between an inner circumferential surface of the cylinder and an outer circumferential surface of the ceramic heater when the plug is used.

[0008] A glow plug with a pressure sensor according to an aspect of the present disclosure to solve the above problems includes: a cylindrical metal shell having an axial hole extending in an axial line direction; a cylindrical metallic outer cylinder having an outer cylinder hole inner part arranged in the axial hole of the metal shell, and an outer cylinder projection part projecting toward a front end side in the axial line direction from a front end of the metal shell; a bar-shaped ceramic heater made of ceramics, held by the outer cylinder, having a heater front end part projecting toward the front end side in the axial line direction from a front end of the outer cylinder, and held by the metal shell to be displaceable in the axial line direction together with the outer cylinder; and a sensor unit configured to sense displacement of the ceramic heater. The outer cylinder hole inner part of the outer cylinder has a heater holding part holding the ceramic heater therein, and the outer cylinder projection part of the outer cylinder surrounds the ceramic heater provided therein in a loose-fit manner.

[0009] In the glow plug with the pressure sensor according to the present disclosure, the outer cylinder hole inner part of the outer cylinder has the heater holding part for holding the ceramic heater therein. On the other hand, the outer cylinder projection part of the outer cylinder surrounds the ceramic heater provided therein in a loose-fit manner. Therefore, for example, when the heater holding part holds the ceramic heater by press-fit, the

press-fitted part of the outer cylinder (i.e., the heater holding part) is shorter than that in the case where the entire outer cylinder holds the ceramic heater evenly along the axial line direction. Thus, the press-fit load is small, which allows for favorable press-fit properties. Further, when the heater holding part holds the ceramic heater by brazing, the brazed portion can be shorter than that in the case where the entire outer cylinder holds the ceramic heater evenly along the axial line direction. This allows for reduced cost.

[0010] In addition, the heater holding part of the outer cylinder is arranged in the axial hole of the metal shell. Therefore, the heater holding part is less likely to be exposed to high temperature when the plug is used, as compared to the outer cylinder projection part projecting from the metal shell. Thus, for example, when the heater holding part holds the ceramic heater by press-fit, it can be suppressed that the gap is generated between the inner circumferential surface of the heater holding part and the outer circumferential surface of the ceramic heater due to large thermal expansion of the heater holding part. Further, when the heater holding part holds the ceramic heater by brazing, it can be suppressed that the gap is generated between the inner circumferential surface of the heater holding part and the outer circumferential surface of the ceramic heater due to melting of the brazing material by high temperature. Therefore, it can be suppressed that the combustion gas flows into the rear end side of the outer cylinder through the gap between the inner circumferential surface of the outer cylinder and the outer circumferential surface of the ceramic heater.

[0011] Incidentally, as for the form of the "heater holding part", the entire outer cylinder hole inner part may serve as the heater holding part, or only a part of the outer cylinder hole inner part extending in the axial line direction may serve as the heater holding part. Furthermore, in the latter case, a plurality of heater holding parts can be provided in the outer cylinder hole inner part. In addition, when only a part of the outer cylinder hole inner part extending in the axial line direction serves as the heater holding part, at least any one of the front end side and the rear end side of the heater holding part in the outer cylinder hole inner part surrounds the ceramic heater in a loose-fit manner instead of holding the ceramic heater.

[0012] Further, in order that the ceramic heater is held by the "heater holding part", the ceramic heater may be held by press-fitting in the outer cylinder. Alternatively, the ceramic heater may be held by crimping the outer cylinder inward in the radial direction after inserting the ceramic heater into the outer cylinder in a loose-insertion manner. Further, the ceramic heater may be held by brazing a brazing material filled in the gap between the outer cylinder and the ceramic heater after inserting the ceramic heater into the outer cylinder in a loose-insertion manner.

[0013] The outer cylinder projection part "surrounds in

a loose-fit manner" the ceramic heater provided therein, which means that the outer cylinder projection part surrounds the ceramic heater inside thereof such that the outer cylinder projection part and the ceramic heater inside thereof are relatively movable in the axial line direction instead of that the outer cylinder projection part holds the ceramic heater inside thereof. A specific example may be an outer cylinder projection part that surrounds but is spaced apart from the ceramic heater inside thereof. Another example may be an outer cylinder projection part that is only in contact with the ceramic heater inside thereof without holding the ceramic heater.

[0014] The "outer cylinder" may have a metal layer on its inner circumferential surface, such as a plating layer mainly including Au, Ag, Cu, Ni, or the like.

[0015] The "ceramic heater" can be a ceramic heater having a heating resistor integrated with a ceramic base member made of insulating ceramics, for example. More specifically, a ceramic heater having a heating resistor embedded inside a ceramic base member can be exemplified. Another example may be a ceramic heater having a heating resistor exposed outside a ceramic base member. Further, the heating resistor can be a heating resistor made of conductive ceramics, metal such as W (tungsten), or the like, for example.

[0016] The "sensor unit" can be a sensor unit configured with use of a displacement sensor such as a strain sensor (strain gage), a semiconductor strain gage having a piezoresistor, and a piezoelectric device and a member adapted to transfer the displacement of the ceramic heater to the displacement sensor, for example.

[0017] The above-described glow plug with the pressure sensor further includes a cylindrical metallic holding member arranged in the axial hole, held by the metal shell, and holding the outer cylinder and the ceramic heater therein to allow the displacement. The outer cylinder hole inner part of the outer cylinder may have a heater spacing part spaced apart from the ceramic heater provided therein on at least one of the front end side and a rear end side of the heater holding part in the axial line direction, and the holding member may be welded to the heater spacing part of the outer cylinder hole inner part of the outer cylinder.

[0018] When the holding member is welded to the heater holding part of the outer cylinder hole inner part, the heat generated during the welding is transferred to the ceramic heater. Thus, a failure such as a crack in the ceramic heater, a breakage of the ceramic heater, or the like is easily caused.

[0019] In contrast, in the present glow plug with the pressure sensor, the heater spacing part spaced apart from the ceramic heater of the outer cylinder hole inner part is provided. The holding member is welded to this heater spacing part. Thus, the heat generated during the welding is less likely to be transferred to the ceramic heater. This can suppress the failure such as the crack in the ceramic heater, the breakage of the ceramic heater, or the like. As a result, the glow plug with high reliability can

be obtained.

[0020] It is noted that the location where the "holding member" is welded to the "heater spacing part" can be properly selected. For example, the holding member may be welded to the front end portion of the heater spacing part. Alternatively, the holding member may be welded to the rear end portion of the heater spacing part. Alternatively, the holding member may be welded to a position that is spaced apart from both of the front end and the rear end of the heater spacing part (for example, a middle portion of the heater spacing part).

[0021] Further, the "holding member" may be welded to the "heater spacing part" of the outer cylinder over its entire circumference in the circumferential direction, or may be welded at multiple points with gaps provided in the circumferential direction.

[0022] Further, the "holding member" may be held directly by the metal shell. The holding member may be held by the metal shell indirectly via other members. Further, the holding member may be fixed to the metal shell and the like over its entire circumference in the circumferential direction, or may be fixed at multiple points with gaps provided in the circumferential direction. The technique for fixing the holding member to the metal shell and the like may be welding, brazing, crimping, or the like.

[0023] In order to provide a function as a seal member to the "holding member", however, the holding member may be welded to the outer cylinder over the entire circumference and further welded or brazed to the metal shell and the like over the entire circumference. In this case, the seal member is able to divide an annular space between the inner circumferential surface of the metal shell and the outer circumferential surface of the outer cylinder in an airtight manner in the axial line direction.

[0024] Further, the "holding member" may be, for example, a holding member having an outer cylinder side-part welded to the outer cylinder, a metal shell side-part located on the rear end side of the outer cylinder side-part in the axial line direction and held by the metal shell and the like, and a middle deformable part located between them and being deformable due to the displacement in the axial line direction of the ceramic heater and the outer cylinder. Further, in contrast to the above, it may be a holding member having an outer cylinder side-part, a metal shell side-part located on the front end side of the outer cylinder side-part, and a middle deformable part. Furthermore, the middle deformable part may be, for example, a middle deformable part having an annular plate-like diaphragm (a thin film) or a bellows.

[0025] Further, in the above-described glow plug with the pressure sensor, the outer cylinder hole inner part of the outer cylinder may have the heater spacing part that is continuous to the outer cylinder projection part and that surrounds the ceramic heater to be spaced apart from the ceramic heater on the front end side of the heater holding part in the axial line direction, and the holding member may be welded to the heater spacing part at a position that is spaced apart from the heater holding part

toward the front end side in the axial line direction on the front end side of a position held by the metal shell in the axial line direction.

[0026] When the engine mounted with the glow plug is operated, the combustion gas with a high temperature and a high pressure repeatedly reaches the holding member through the gap between a glow hole and both of the heater front end part and outer cylinder projection part. In response, the holding member thermally-expands instantaneously and its dimension in the axial line direction increases. That is, the holding member extends in the axial line direction. With this expansion, the outer cylinder and the ceramic heater held by the holding member are displaced in the axial line direction. This displacement due to the thermal expansion is added to the displacement of the ceramic heater that is caused by the combustion pressure. This may cause deterioration in the sensing accuracy for the combustion pressure. More specifically, with use of a holding member welded to the outer cylinder at a more front end-side position in the axial line direction than a position held by the metal shell, the heated holding member expands so as to cause the outer cylinder and the ceramic heater to move to the front end side. As a result, an unnecessary variation (a variation in the direction by which the displacement and the increase of the pressure appear to be smaller) is added to the displacement of the ceramic heater that is caused by the combustion pressure.

[0027] In contrast, in the above-described glow plug with the pressure sensor, the part of the holding member located on the front end side along the axial line direction with respect to the position where the holding member is held (directly or indirectly) by the metal shell is welded to the part of the heater spacing part of the outer cylinder hole inner part which is spaced apart from the heater holding part toward the front end side in the axial line direction. When exposed in the combustion gas, the holding member thermally-expands and extends toward the front end side in the axial line direction, as described above. On the other hand, the combustion gas also reaches the part between the outer cylinder projection part of the outer cylinder surrounding but spaced apart from the ceramic heater and the heater spacing part continuing thereto, and the ceramic heater. Therefore, they also thermally-expand and extend toward the front end side in the axial line direction. That is, of the heater spacing part, the portion lying to the heater holding part from the part where the holding member is welded also thermally-expands and extends toward the front end side in the axial line direction. Therefore, at the same time when the holding member extends toward the front end side due to the combustion gas, the portion of the heater spacing part lying to the heater holding part from the part where the holding member is welded also extends toward the front end side. Thereby, the displacement of the outer cylinder and the ceramic heater due to the extension of the holding member is partially offset. In such a way, the unnecessary variation of the outer cylinder and the ce-

ramic heater (the variation by which the displacement and the increase of the pressure appear to be smaller) is less likely to be added to the displacement of the ceramic heater that is caused by the combustion pressure. This allows for favorable sensing accuracy for the combustion pressure.

[0028] It is noted that the holding member may be held by the metal shell indirectly via another member without limited to the case of being held directly by the metal shell as described above. When the holding member is held directly by the metal shell, the position in the axial line direction of a part of the holding member that is fixed to the metal shell (for example, the welded portion of the holding member) corresponds to the above-described "position where the holding member is held by the metal shell". Further, when the holding member is held by the metal shell indirectly via another member, the position in the axial line direction of a part of the holding member that is fixed to the other member (for example, the welded portion of the holding member) corresponds to the above-described "position where the holding member is held by the metal shell".

BRIEF DESCRIPTION OF DRAWINGS

[0029]

FIG. 1 is a partially broken vertical sectional view of a glow plug with a pressure sensor according to an embodiment;

FIG. 2 is an enlarged vertical sectional view in which a portion in the vicinity of a heater front end part and an outer cylinder projection part of the glow plug with the pressure sensor according to the embodiment is enlarged;

FIG. 3 is an enlarged vertical sectional view in which a portion in the vicinity of a holding member, an outer cylinder hole inner part, and a heater rear end part of the glow plug with the pressure sensor according to the embodiment is enlarged;

FIG. 4 is an enlarged vertical sectional view in which a portion in the vicinity of the heater rear end part, a connection ring, and a center shaft front end part of the glow plug with the pressure sensor according to the embodiment is enlarged; and

FIG. 5 is a view for describing the movement of the holding member, the outer cylinder, and the ceramic heater when heated by combustion gas.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0030] In the following detailed description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order

to simplify the drawing.

[0031] An embodiment of the present invention will be described below by referring to the drawings. FIG. 1 to FIG. 4 illustrate a glow plug with a pressure sensor 1 (hereinafter also simply referred to as a glow plug 1) according to the embodiment. It is noted that, in FIG. 1 to FIG. 4, the direction along an axial line AX of the glow plug 1 and a metal shell 10 thereof is defined as an axial line direction HJ. In the axial line direction HJ, the side on which a ceramic heater 20 is arranged (the lower side in the drawings) is defined as a front end side GS and the side opposite thereto (the upper side of the drawings) is defined as a rear end side GK.

[0032] The glow plug 1 is mounted to an engine head such that the ceramic heater 20 and an outer cylinder 30 are exposed inside a combustion chamber of a diesel engine (not illustrated). The glow plug 1 is utilized to sense a combustion pressure (combustion gas pressure) inside the combustion chamber in addition to facilitating ignition of the fuel. The glow plug 1 includes the metal shell 10, the ceramic heater 20, the outer cylinder 30, a holding member 40, a sensor unit 50, and the like.

[0033] The metal shell 10 is a cylindrical metallic member (specifically, made of carbon steel) having an axial hole 10h penetrating therethrough in the axial line direction HJ. The metal shell 10 includes a cylindrical front end cap member 11 located on the front end side GS, a cylindrical rear end cap member 15 located on the rear end side GK, and a cylindrical metal shell body member 13 located between them and extending in the axial line direction HJ (see FIG. 1). A rear end part 11k of the front end cap member 11 and a front end part 13s of the metal shell body member 13 are joined (specifically, welded) to each other via a later-described flange part 53c of a sensor support member 53 (see FIG. 3). Further, a rear end part 13k of the metal shell body member 13 and a front end part 15s of the rear end cap member 15 are directly jointed (specifically, welded) to each other (see FIG. 1).

[0034] A diameter of the front end part 11s of the front end cap member 11 (see FIG. 3) is tapered toward the front end side GS. A tapered outer circumferential surface 11sm of the front end part 11s is pressed against a seating portion of a plug hole when the glow plug 1 is mounted to an engine head (not illustrated). Thereby, airtightness in the combustion chamber is ensured. Further, a mounting part 13d having external threads for mounting the glow plug 1 to the engine head is provided to the rear end side GK portion (see FIG. 1) of the metal shell body member 13. Further, a tool engagement part 15e is provided to the rear end side GK portion of the rear end cap member 15. The tool engagement part 15e has a hexagonal cross-section. When the glow plug 1 is mounted to the engine head, a tool is engaged to the tool engagement part 15e. Further, a sealing cylindrical rubber member 17 projecting to the rear end side GK with respect to the rear end 15b of the rear end cap member 15 is arranged in the rear end cap member 15.

[0035] Next, the ceramic heater 20 will be described. The ceramic heater 20 is a heater made of ceramics. The ceramic heater 20 has a round bar shape with a diameter (d1) of 3.1 mm extending in the axial line direction HJ. The front end of the ceramic heater 20 is machined into a semispherically curved surface. Specifically, in the ceramic heater 20, a heating resistor 27 made of conductive ceramics (specifically, silicon nitride ceramics containing tungsten carbide as a conductive component) is embedded inside a ceramic base member 26 made of insulating ceramics (specifically, silicon nitride ceramics).

[0036] The heating resistor 27 includes a heating part 27c, a pair of lead parts 27d and 27e, and a pair of electrode extraction parts 27f and 27g. The heating part 27c (see FIG. 2) is arranged in the front end side GS and bent in a U-shape. The heating part 27c is heated at a high temperature through energization. Further, the pair of lead parts 27d and 27e (see FIG. 2 to FIG. 4) are connected to both ends of the heating part 27c and extend in parallel to each other toward the rear end side GK. Further, the pair of lead parts 27d and 27e is connected at its rear end side GK to the pair of electrode extraction parts 27f and 27g (see FIG. 3 and FIG. 4). The pair of electrode extraction parts 27f and 27g are exposed to an outer circumferential surface 26m of the ceramic base member 26. One electrode extraction part 27g is located on the rear end side GK of the other electrode extraction part 27f.

[0037] The ceramic heater 20 is held by the outer cylinder 30. Specifically, a heater front end part 21 (see FIG. 2) of the ceramic heater 20 projects to the front end side GS with respect to a front end 31a of the outer cylinder 30. A heater rear end part 23 (see FIG. 3 and FIG. 4) of the ceramic heater 20 projects to the rear end side GK with respect to a rear end 33b of the outer cylinder 30. A heater middle part 22 (see FIG. 2 to FIG. 4) is held by the outer cylinder 30 between the heater front end part 21 and the heater rear end part 23. Further, the ceramic heater 20 is held by the metal shell 10 so as to be displaceable in the axial line direction HJ together with the outer cylinder 30 as described later.

[0038] The heater rear end part 23 of the ceramic heater 20 is connected to a center shaft member 83 (see FIG. 4) via a connection ring 81 (see FIG. 3 and FIG. 4). The connection ring 81 is a cylindrical metallic member (specifically, made of stainless steel) extending in the axial line direction HJ. The connection ring 81 is arranged inside of a later-described displacement transmission member 51 and the sensor support member 53 in the radial direction within the axial hole 10h of the metal shell 10. The heater rear end part 23 of the ceramic heater 20 is press-fitted in a portion on the front end side GS of the connection ring 81. On the other hand, a fitting part 83sa of a center shaft front end part 83s of the center shaft member 83 is press-fitted in a portion on the rear end side GK of the connection ring 81. Thereby, one electrode extraction part 27g of the ceramic heater 20 is electrically connected to the center shaft member 83 via the con-

nection ring 81.

[0039] The center shaft member 83 is a round bar-shaped metallic member (specifically, made of stainless steel) extending in the axial line direction HJ. The center shaft member 83 is inserted through the axial hole 10h of the metal shell 10 so as to be spaced apart from the metal shell 10. Further, the portion on the front end side GS of the center shaft member 83 is arranged inside of the later-described displacement transmission member 51 and the sensor support member 53 in the radial direction and spaced apart from them. The center shaft member 83 includes a center shaft front end part 83s and a center shaft body part 83c. The center shaft front end part 83s is located on the front end side GS and has a larger diameter. The center shaft body part 83c has a smaller diameter than the center shaft front end part 83s and extends toward the rear end side GK from the center shaft front end part 83s. The connection ring 81 is press-fitted in the fitting part 83sa on the front end side GS of the center shaft front end part 83s as described above.

[0040] Next, the outer cylinder 30 will be described. The outer cylinder 30 (see FIG. 2 to FIG. 4) is a cylindrical metallic member extending in the axial line direction HJ. Specifically, the outer cylinder 30 includes a metallic outer cylinder body member 37 (specifically, made of stainless steel) and a metallic layer 38 made of an Au plating layer formed on the inner circumferential surface of the outer cylinder body member 37. The outer diameter of the outer cylinder 30 is uniform along over the axial line direction HJ. On the other hand, the outer cylinder 30 has a stepped shape such that its inner diameter is larger at the portion on the front end side GS and smaller at the portion on the rear end side GK. Specifically, an outer diameter d2 of the outer cylinder 30 is 4.1 mm. Further, an inner diameter d3 of the portion (an outer cylinder projection part 31 and a heater spacing part 34 described later) on the front end side GS of the outer cylinder 30 is 3.3 mm. On the other hand, when the outer cylinder 30 is fixed to the heater by press-fit, the inner diameter (equal to the diameter d1 of the ceramic heater 20) of the portion (a heater holding part 35 described later) on the rear end side GK of the outer cylinder 30 is 3.1 mm, which is smaller than the inner diameter d3 by 0.2 mm.

[0041] The outer cylinder 30 is held by the metal shell 10 so as to be displaceable together with the ceramic heater 20 in the axial line direction HJ. Specifically, the outer cylinder projection part 31 (see FIG. 2) projects to the front end side GS with respect to the front end 11sa of the metal shell 10. The outer cylinder hole inner part 33 (see FIG. 3 and FIG. 4) is arranged inside the axial hole 10h of the metal shell 10. In this way, the outer cylinder 30 is held by the metal shell 10 via the holding member 40, the displacement transmission member 51, the sensor support member 53, and the like described later so as to be displaceable in the axial line direction HJ.

[0042] On the other hand, the outer cylinder 30 holds the heater middle part 22 of the ceramic heater 20 by press-fit. Specifically, the outer cylinder projection part

31 of the outer cylinder 30 surrounds the ceramic heater 20 but is spaced apart from the ceramic heater 20 inside thereof. As described above, the inner diameter d3 of the outer cylinder projection part 31 is 3.3 mm, while the diameter d1 of the ceramic heater 20 is 3.1 mm. Therefore, a clearance SA of 0.1 mm is formed over the entire circumference between an inner circumferential surface 31n of the outer cylinder projection part 31 and an outer circumferential surface 20m of the ceramic heater 20.

[0043] Meanwhile, the outer cylinder hole inner part 33 of the outer cylinder 30 includes the heater spacing part 34 continuing to the outer cylinder projection part 31 located on the front end side GS thereof, and the heater holding part 35 located on the rear end side GK thereof. The heater spacing part 34 surrounds the ceramic heater 20 but is spaced apart from the ceramic heater 20 inside thereof. Specifically, as described above, the inner diameter d3 of the heater spacing part 34 is 3.3 mm that is the same as the above-described inner diameter d3 of the outer cylinder projection part 31. On the other hand, the diameter d1 of the ceramic heater 20 is 3.1 mm. Therefore, a clearance SB of 0.1 mm is formed over the entire circumference also between an inner circumferential surface 34n of the heater spacing part 34 and the outer circumferential surface 20m of the ceramic heater 20.

[0044] Incidentally, the holding member 40 described later is welded to the heater spacing part 34. The holding member 40 is welded to the weld part 34c of the heater spacing part 34. Further, a front-end-side part 34s of the heater spacing part 34 is located on the front end side GS of the weld part 34c and is continuous to the outer cylinder projection part 31. A rear-end-side part 34k of the heater spacing part 34 is located on the rear end side GK of the weld part 34c and is continuous to the heater holding part 35.

[0045] Meanwhile, the heater holding part 35 holds the ceramic heater 20 therein by press-fit. Further, in the heater holding part 35, one electrode extraction part 27f of the ceramic heater 20 is in contact with the metallic layer 38 of the outer cylinder 30, and therefore the electrode extraction part 27f and the outer cylinder 30 are electrically connected to each other.

[0046] Next, the holding member 40 will be described. The holding member 40 (see FIG. 3) is a cylindrical metallic member (specifically, made of stainless steel). The holding member 40 is arranged in an annular space KA between the inner circumferential surface of the metal shell 10 (specifically, an inner circumferential surface 11n of the front end cap member 11) and an outer circumferential surface 30m of the outer cylinder 30. The holding member 40 is held at a position W1 in the axial line direction HJ by the later-described sensor support member 53. The holding member 40 is held by the metal shell 10 through the sensor support member 53. Furthermore, the holding member 40 holds the outer cylinder 30 at a position W2 on the front end side GS of the position W1.

[0047] Specifically, the holding member 40 includes an

outer cylinder side-part 41, a metal shell side-part 45, and a middle deformable part 43 located between them. The outer cylinder side-part 41 of the holding member 40 is shaped in a cylinder and located on the front end side GS. The holding member 40 holds the outer cylinder 30 therein. Specifically, the outer cylinder side-part 41 is welded to the weld part 34c of the heater spacing part 34 of the outer cylinder 30 over the entire circumference in the circumferential direction at the position W2, which is on the front end side GS of the position W1, along the axial line direction HJ. Further, the metal shell side-part 45 is shaped in a cylinder having a larger diameter than the outer cylinder side-part 41 and located on the rear end side GK. The metal shell side-part 45 is held by the metal shell 10 via the later-described sensor support member 53. Specifically, the metal shell side-part 45 is welded to a support front end part 53s of the sensor support member 53 over the entire circumference in the circumferential direction so as to be externally fitted thereto at the above-described position W1. Furthermore, the sensor support member 53 is welded to the metal shell 10 over the entire circumference in the circumferential direction, as described later. Therefore, the metal shell side-part 45 of the holding member 40 is fixed to the metal shell 10 indirectly by welding.

[0048] In this way, the holding member 40 causes the metal shell 10 to hold the outer cylinder 30 and the ceramic heater 20. Further, the holding member 40 functions as a seal member that divides the annular space KA between the inner circumferential surface 11n of the front end cap member 11 of the metal shell 10 and the outer circumferential surface 30m of the outer cylinder 30 in an airtight manner in the axial line direction HJ. This can suppress that the combustion gas flowing in the annular space KA from the front end side GS of the glow plug 1 flows into the rear end side GK of the outer cylinder 30 through the annular space KA.

[0049] Furthermore, the middle deformable part 43 of the holding member 40 deforms in response to the displacement of the ceramic heater 20 and the outer cylinder 30 in the axial line direction HJ. Specifically, the middle deformable part 43 forms an annular plate-like diaphragm (a thin film). The deformation of the middle deformable part 43 allows for the displacement of the ceramic heater 20 and the outer cylinder 30 in the axial line direction HJ.

[0050] The holding member 40 electrically connects the outer cylinder 30 and the metal shell 10 to each other. Therefore, one electrode extraction part 27f of the ceramic heater 20 is electrically connected to the metal shell 10 via the outer cylinder 30 and the holding member 40. Further, the holding member 40 functions as a heat transmission member, by which the heat of the ceramic heater 20 is dispersed to the engine head via the metal shell 10.

[0051] Next, the sensor unit 50 will be described. The sensor unit 50 includes a displacement transmission member 51, the sensor support member 53, a diaphragm member 55, a sensor element 57, a pair of wiring 58, and

an integrated circuit 59. The displacement transmission member 51 (see FIG. 3 and FIG. 4) is a cylindrical metallic member (specifically, made of stainless steel) extending in the axial line direction HJ. The displacement transmission member 51 is located inside of the sensor support member 53 in the radial direction, and on the rear end side GK of the holding member 40 within the axial hole 10h of the metal shell 10. The displacement transmission member 51 is welded to the outer cylinder 30 over the entire circumference in the circumferential direction at a position W3 in the axial line direction HJ. On the other hand, the diaphragm member 55 is connected to the rear end side GK of the displacement transmission member 51.

[0052] The sensor support member 53 (see FIG. 3 and FIG. 4) is a cylindrical metallic member (specifically, made of stainless steel) extending in the axial line direction HJ. The sensor support member 53 is located outside of the displacement transmission member 51 in the radial direction within the axial hole 10h of the metal shell 10. The sensor support member 53 includes a cylindrical support front end part 53s, a flange part 53c located on the rear end side GK thereof and having a larger diameter, and a cylindrical support body part 53k extending toward the rear end side GK from the flange part 53c. The metal shell side-part 45 of the holding member 40 is welded to the support front end part 53s so as to cover the support front end part 53s, as described above. Further, the flange part 53c is welded to the metal shell 10 so as to be held between the rear end part 11k of the front end cap member 11 and the front end part 13s of the metal shell body member 13 of the metal shell 10. Further, the diaphragm member 55 is connected to the rear end side GK of the support body part 53k.

[0053] The diaphragm member 55 (see FIG. 4) is a metallic member (specifically, made of stainless steel). The sensor element 57 is joined on a main surface of the diaphragm member 55 on the rear end side GK. The sensor element 57 is a semiconductor strain gage having a piezoresistor. The resistance of the sensor element 57 changes in response to the bending of the diaphragm member 55. Further, the integrated circuit 59 is arranged inside the rear end cap member 15 of the metal shell 10 as illustrated by a dashed line in FIG. 1. The integrated circuit 59 is connected to the sensor element 57 via the pair of wiring 58 cabled from the sensor element 57 to the rear end side GK. The integrated circuit 59 utilizes the resistance of the sensor element 57 to output an electrical signal to the outside.

[0054] As described above, in the glow plug with the sensor 1 according to the embodiment, the outer cylinder hole inner part 33 of the outer cylinder 30 has the heater holding part 35 for holding the ceramic heater 20 therein. Meanwhile, the outer cylinder projection part 31 of the outer cylinder 30 surrounds but is spaced apart from the ceramic heater 20 provided therein. Thus, the press-fitted portion of the outer cylinder 30 (that is, the heater holding part 35) is shorter than that in the case where the entire

outer cylinder 30 holds the ceramic heater 20 evenly along the axial line direction HJ. Therefore, the press-fit load is reduced and thus favorable press-fit properties is obtained.

[0055] In addition, the heater holding part 35 of the outer cylinder 30 is arranged inside the axial hole 10h of the metal shell 10. Therefore, the heater holding part 35 is less likely to be subjected to high temperature in use as compared to the outer cylinder projection part 31 projecting from the metal shell 10. This can suppress the occurrence of the gap between the inner circumferential surface 35n of the heater holding part 35 and the outer circumferential surface 20m of the ceramic heater 20 due to large thermal expansion of the heater holding part 35. Therefore, this can suppress the inflow of the combustion gas into the rear end side GK of the outer cylinder 30 through the gap between the inner circumferential surface 30n of the outer cylinder 30 and the outer circumferential surface 20m of the ceramic heater 20.

[0056] Furthermore, in the present embodiment, the heater spacing part 34 spaced apart from the ceramic heater 20 is provided in the outer cylinder hole inner part 33 of the outer cylinder 30, and the holding member 40 is welded to the heater spacing part 34. Thus, the heat generated during the welding is less likely to be transferred to the ceramic heater 20 as compared to the case where the holding member 40 is welded to the heater holding part 35. This can suppress the failure such as a crack in the ceramic heater 20, a breakage of the ceramic heater 20, or the like. As a result, the glow plug 1 with high reliability can be obtained.

[0057] Further, in the present embodiment, the holding member 40 is welded, at the front end side GS of the position W1 where the holding member 40 is held by the metal shell 10 via the sensor support member 53, to the position W2, which is spaced apart from the heater holding part 35 to the front end side GS, of the heater spacing part 34 of the outer cylinder hole inner part 33. When exposed to the combustion gas, the holding member 40 thermally-expands and extends toward the front end side GS in the axial line direction. This displacement is represented as $\Delta a1$ (see FIG. 5). Meanwhile, the combustion gas also reaches the portion between: the outer cylinder projection part 31 of the outer cylinder 30 surrounding but spaced apart from the ceramic heater 20 and the heater spacing part 34 continuing to the outer cylinder projection part 31 of the outer cylinder 30; and the ceramic heater 20. Therefore, the ceramic heater 20, the outer cylinder projection part 31, and the heater spacing part 34 also extend toward the front end side GS due to the thermal expansion. That is, of the heater spacing part 34, a portion 34ka (a part of the rear end side-part 34k in the axial line direction HJ) from the position W2 where the holding member 40 is welded to the position W3 where the displacement transmission member 51 is welded also extends toward the front end side GS due to the thermal expansion. This displacement is represented as $\Delta a2$.

[0058] Therefore, at the same time when the holding member 40 extends toward the front end side GS due to the combustion gas (displacement $\Delta a1$), the portion 34ka of the heater spacing part 34 from the position W2 where the holding member 40 is welded to the position W3 where the displacement transmission member 51 is welded also extends toward the front end side GS (displacement $\Delta a2$). Thereby, the displacement (displacement $\Delta a3$) of the outer cylinder 30 and the ceramic heater 20 due to the extension of the holding member 40 is partially offset. This results in displacement $\Delta a3 = \Delta a1 - \Delta a2$. In such a way, the unnecessary variation of the outer cylinder 30 and the ceramic heater 20 (the variation by which the displacement and the increase of the pressure appear to be smaller) is less likely to be added to the displacement of the ceramic heater 20 that is caused by the combustion pressure, so that favorable sensing accuracy for the combustion pressure can be obtained.

[0059] Although the present invention has been described above with reference to the embodiment, the present invention is not limited to the above-described embodiment and of course can be appropriately modified for any application without departing from its spirit.

[0060] For example, in the embodiment, the heater holding part 35 of the outer cylinder 30 and the ceramic heater 20 are fixed by press-fit. However, the fixing technique is not limited thereto. For example, the heater holding member of the outer cylinder and the ceramic heater may be fixed by brazing.

[0061] Further, in the embodiment, the outer cylinder projection part 31 of the outer cylinder 30 surrounding but spaced apart from the ceramic heater 20 is exemplified. However, the embodiment is not limited thereto. The outer cylinder projection part may not hold the ceramic heater, but the outer cylinder projection part and the ceramic heater may simply be in contact with each other.

[0062] Further, in the embodiment, the portion of the outer cylinder hole inner part 33 of the outer cylinder 30 on the front end side GS of the heater holding part 35 corresponds to the heater spacing part 34 surrounding but spaced apart from the ceramic heater 20. However, the portion on the front end side GS of the heater holding part is not limited thereto. For example, the portion of the outer cylinder hole inner part of the outer cylinder on the front end side GS of the heater holding part may not hold the ceramic heater, but the portion of the outer cylinder hole inner part of the outer cylinder on the front end side GS of the heater holding part and the ceramic heater may simply be in contact with each other. However, the heater spacing part 34 surrounding but spaced apart from the ceramic heater 20 as in the embodiment is more preferable because the heat generated when the holding member 40 is welded to the outer cylinder 30 is less likely to be transferred to the ceramic heater 20 as described above.

[0063] The foregoing detailed description has been presented for the purposes of illustration and description. Many modifications and variations are possible in light

of the above teaching. It is not intended to be exhaustive or to limit the subject matter described herein to the precise form disclosed. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims appended hereto.

Claims

1. A glow plug with a pressure sensor 1, comprising:
 - a cylindrical metal shell 10 having an axial hole 10h extending in an axial line direction HJ;
 - a cylindrical metallic outer cylinder 30 having an outer cylinder hole inner part 33 arranged in the axial hole 10h of the metal shell 10, and an outer cylinder projection part 31 projecting toward a front end side GS in the axial line direction HJ from a front end 11sa of the metal shell 10;
 - a bar-shaped ceramic heater 20 made of ceramics, held by the outer cylinder 30, having a heater front end part 21 projecting toward the front end side GS in the axial line direction HJ from a front end 31a of the outer cylinder 30, and held by the metal shell 10 to be displaceable in the axial line direction HJ together with the outer cylinder 30; and
 - a sensor unit 50 configured to sense displacement of the ceramic heater 20, wherein the outer cylinder hole inner part 33 of the outer cylinder 30 has a heater holding part 35 holding the ceramic heater 20 therein, and the outer cylinder projection part 31 of the outer cylinder 30 surrounds the ceramic heater 20 provided therein in a loose-fit manner.
2. The glow plug with the pressure sensor 1 according to claim 1, further comprising
 - a cylindrical metallic holding member 40 arranged in the axial hole 10h, held by the metal shell 10, and holding the outer cylinder 30 and the ceramic heater 20 therein to allow the displacement, wherein the outer cylinder hole inner part 33 of the outer cylinder 30 has a heater spacing part 34 spaced apart from the ceramic heater 20 provided therein on at least one of the front end side GS and a rear end side GK of the heater holding part 35 in the axial line direction HJ, and the holding member 40 is welded to the heater spacing part 34 of the outer cylinder hole inner part 33 of the outer cylinder 30.
3. The glow plug with the pressure sensor 1 according

to claim 2, wherein

the outer cylinder hole inner part 33 of the outer cylinder 30 has the heater spacing part 34 that is continuous to the outer cylinder projection part 31 and that surrounds the ceramic heater 20 to be spaced
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apart from the ceramic heater 20 on the front end side GS of the heater holding part 35 in the axial line direction HJ, and

the holding member 40 is welded to the heater spacing part 34 at a position W2 that is spaced apart from
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the heater holding part 35 toward the front end side GS in the axial line direction HJ on the front end side GS of a position W1 held by the metal shell 10 in the axial line direction HJ.

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FIG. 1

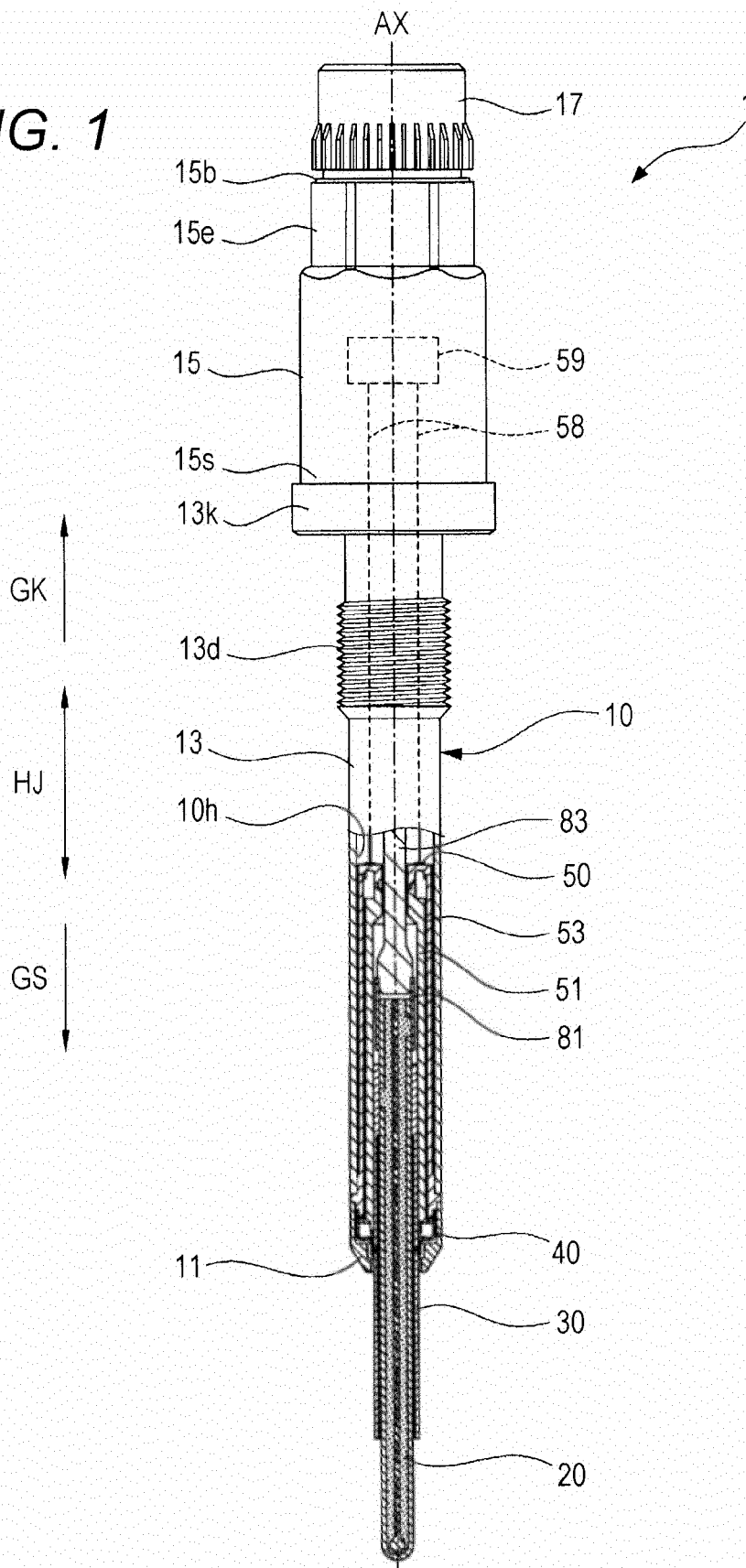


FIG. 2

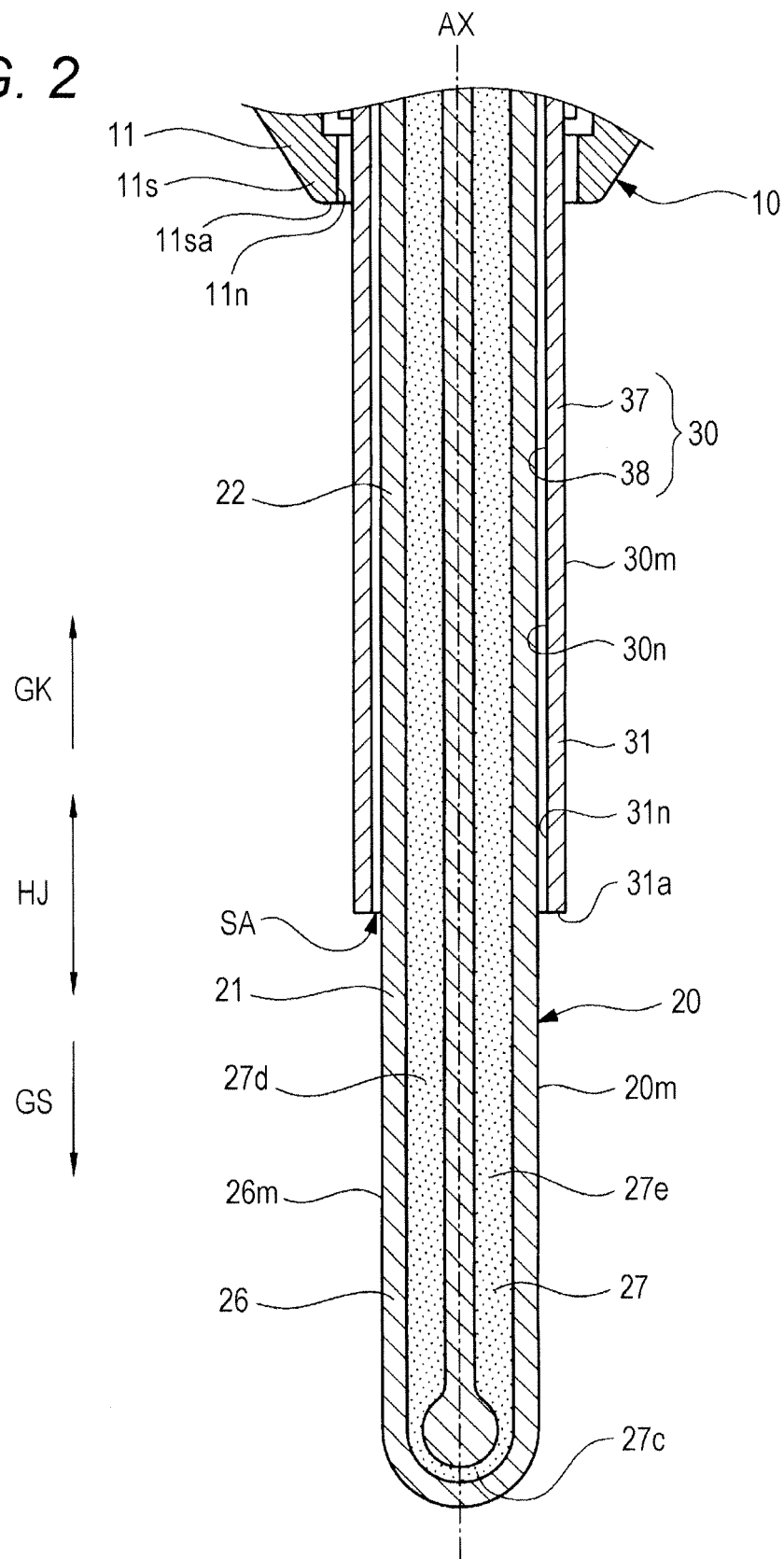


FIG. 3

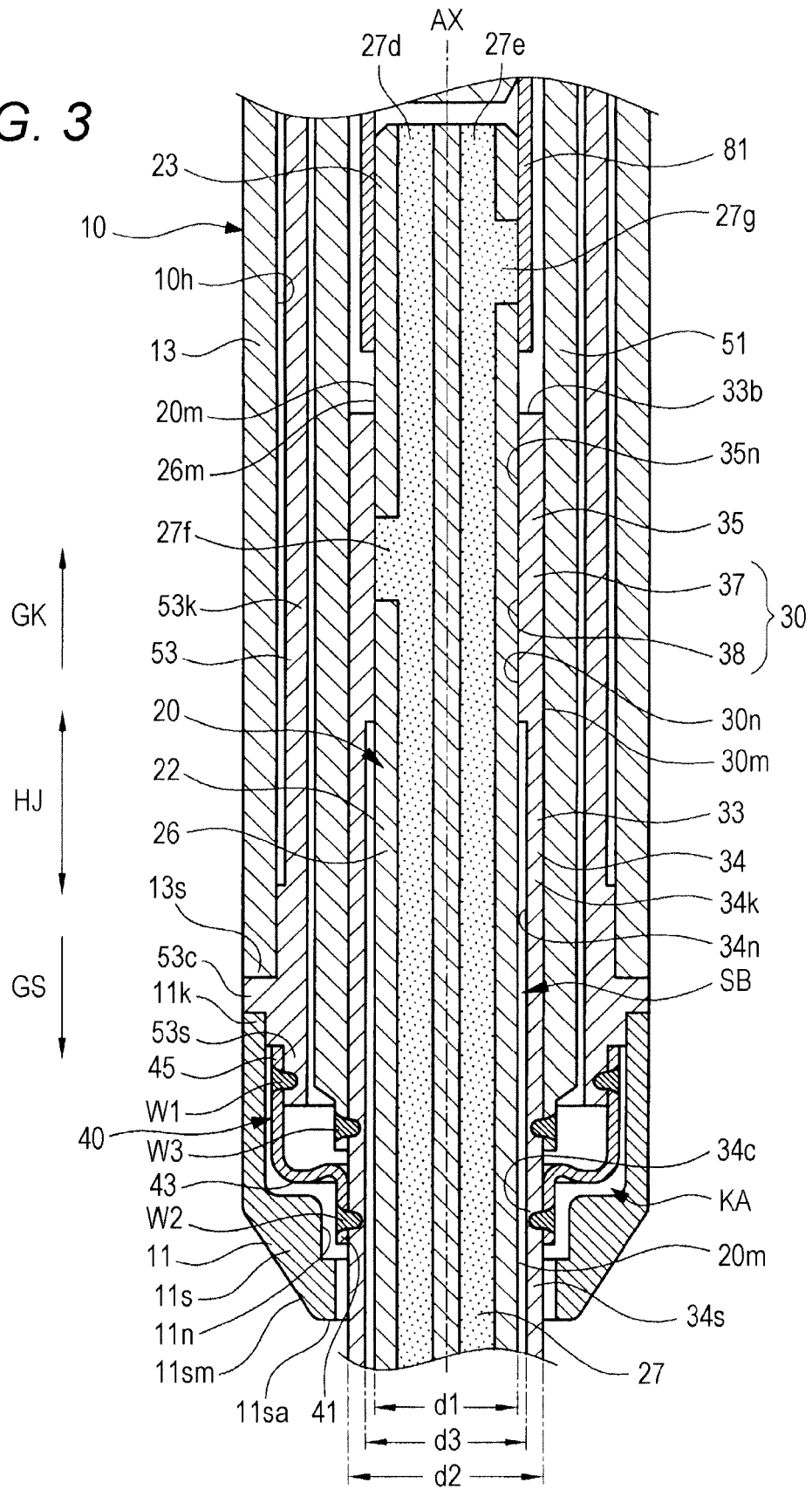


FIG. 4

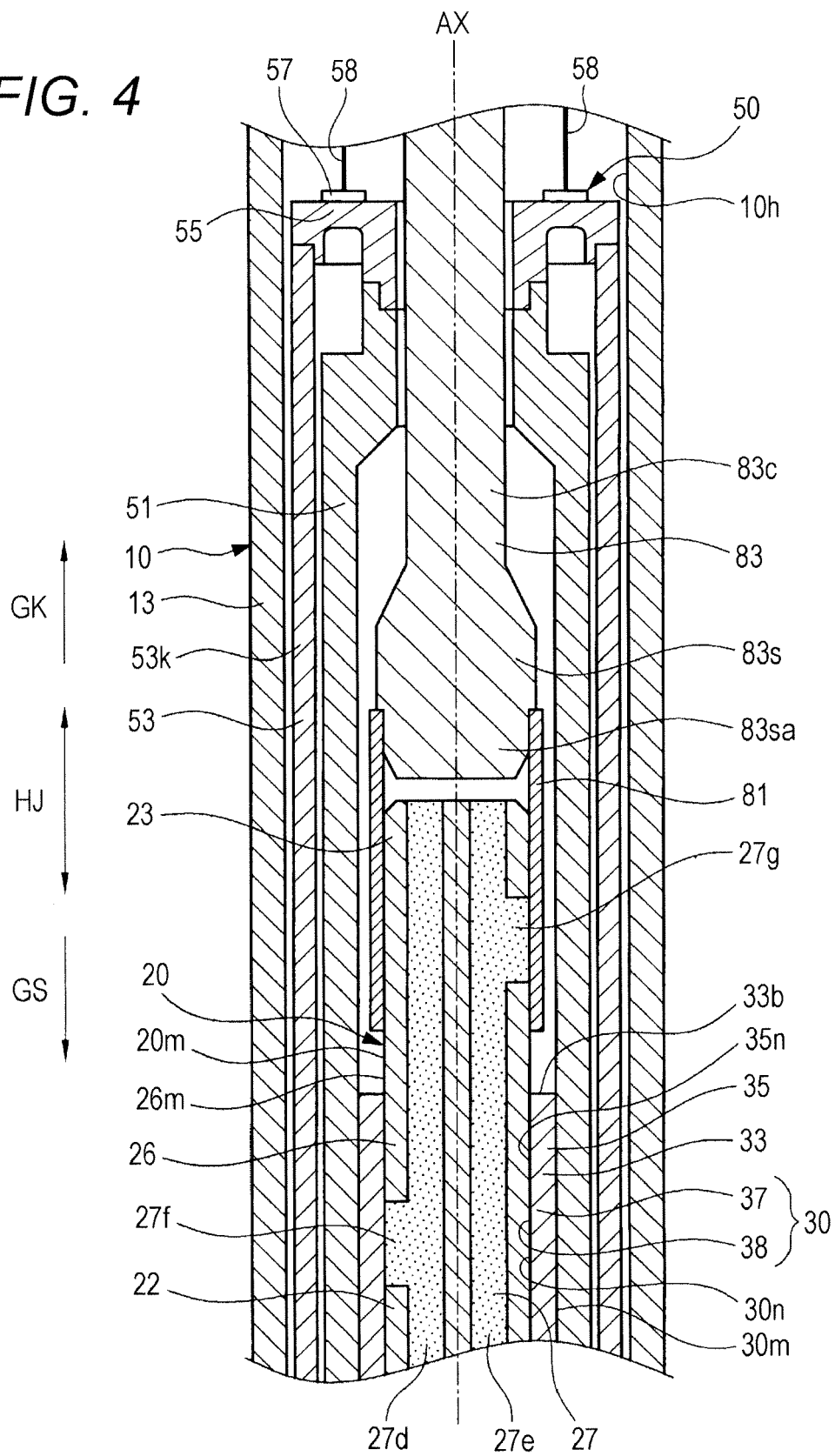
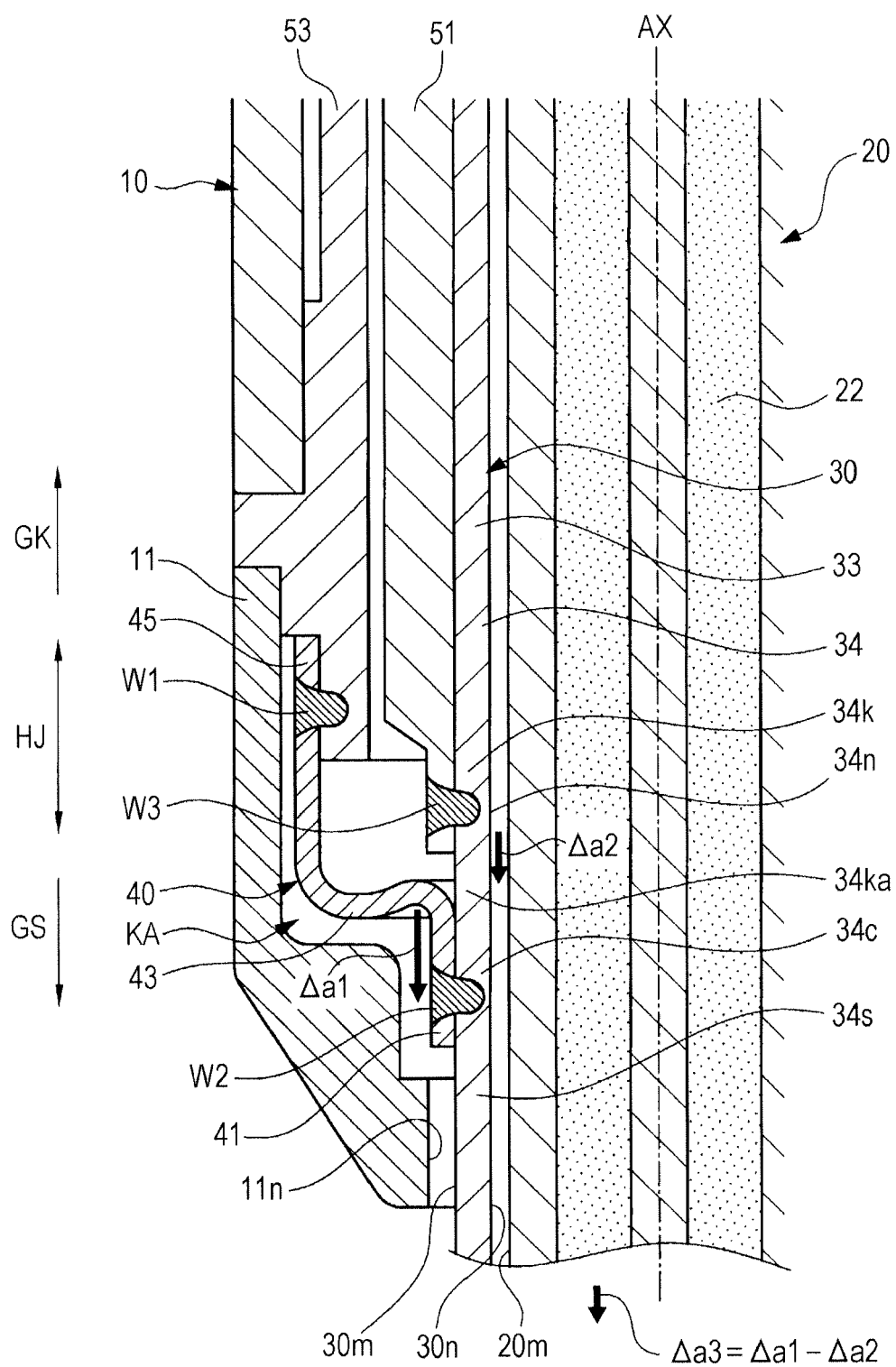


FIG. 5





EUROPEAN SEARCH REPORT

 Application Number
 EP 15 15 4163

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 May 2015	Examiner Hauck, Gunther
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27-05-2015

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