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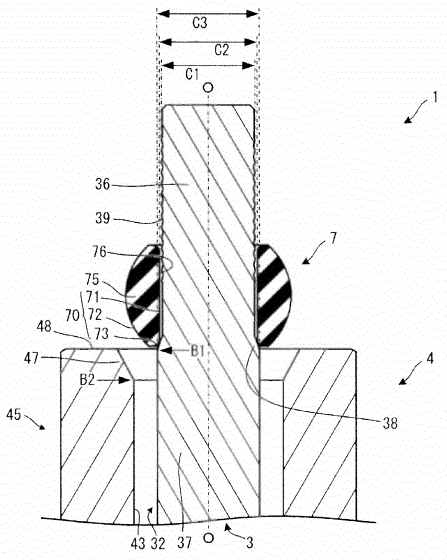
(54) GLOW PLUG

(57) A contact member (7) is configured such that a contour (70) of a cross section (75) includes a second contour segment (71) in the form of a straight line, a first contour segment (72) in the form of a curve swelling radially, and third contour segments (73) in the form of curves connecting the second contour segment (71) and the first contour segment (72). When the contact member (7) is pressed, for disposition, into a space between a connection base portion 37 of a center shaft (3) and the inner circumferential surface of an axial bore (43) of a metallic shell (4), the straight second contour segment (71) functions as a core, whereby the contact member (7) is free from inward drag or bending. Since the first contour segment (72) is curved, deformation of reducing radial thickness is smoothly performed; thus, a deformed portion having high internal stress does not arise locally. Since the inside diameter of the contact member (7) is expanded by a shoulder portion (38) of the center shaft (3), and, then, the outside diameter of the contact member (7) is narrowed by a taper portion (47) of the metallic shell (4), the contact member (7) is free from twist and wrinkling.

FIG. 4



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Description

TECHNICAL FIELD

[0001] The present invention relates to a glow plug used for assisting in start-up of a diesel engine.

BACKGROUND ART

[0002] A glow plug used for assisting in start-up of a diesel engine is such that a heater which has a heat-generating resistor at its forward end portion is held directly or indirectly at a forward end portion of a tubular metallic shell having an axial bore. A rodlike center shaft is inserted into the axial bore of the metallic shell and disposed in a condition electrically insulated from the metallic shell. One end portion of the center shaft is connected to a rear end portion of the heater, and the other end portion projects from the rear end of the metallic shell. Two electrodes led from the heater are electrically connected to the metallic shell and the center shaft, respectively.

[0003] In the thus-configured glow plug, in order to ensure gastightness through the axial bore of the metallic shell, an O-ring is disposed between the center shaft and the inner circumferential surface (wall surface) of the axial bore at the rear end side of the axial bore. Furthermore, an insulation member for ensuring electrical insulation between the metallic shell and the center shaft is disposed, on the rear end side of the O-ring, between the center shaft and the inner circumferential surface of the axial bore. A taper surface is provided in a region of the inner circumferential surface of the axial bore and/or a region of the center shaft where the O-ring is disposed. The end surface of the insulation member presses the O-ring toward the taper surface, thereby ensuring close contact of the O-ring with three contact surfaces of the inner circumferential surface of the axial bore, the center shaft, and the insulation member (refer to, for example Patent Document 1).

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0004]

Patent Document 1: Japanese Patent Application Laid-Open *(kokai)* No. 2007-292444

SUMMARY OF THE INVENTION

[0005] However, in the configuration in which the three contact surfaces of the inner circumferential surface, the center shaft, and the insulation member surround the O-ring, difficulty is encountered in providing a space for accepting deformation of a compressed O-ring. Thus, the positions of disposition of the contact surfaces must be determined accurately in relation to the O-ring. For example, in the case where the insulation member is strongly pressed into a space between the center shaft and the inner circumferential surface of the axial bore, the disposed O-ring assumes a small size. Accordingly, the O-ring is deformed in such a manner as to enter a narrow gap between the contact surfaces; thus, internal stress in a deformed portion of the O-ring increases, potentially resulting in breakage of the O-ring. By contrast, in the case where the insulation member is loosely pressed into the space, the disposed O-ring assumes a large size. Accordingly, the O-ring fails to maintain sufficient close contact with the contact surfaces; thus, a clearance is formed therebetween, potentially resulting in a failure to ensure gastightness.

[0006] Also, conventional glow plugs employ O-rings having a circular or elliptic cross section. In the process of assembling a glow plug, when the O-ring is to be disposed in a narrow gap between the center shaft and the inner circumferential surface of the axial bore, there has been involved the risk of twist of the O-ring along the circumferential direction. Also, the O-ring has a circular cross section, or the O-ring having an elliptic cross section assumes a substantially circular cross section when disposed in a space surrounded by the three contact surfaces. Thus, since a portion of the O-ring which intervenes between the center shaft and the inner circumferential surface of the axial bore assumes a short axial length, when external vibration is imposed on the center shaft, the effect of restraining oscillation of the center shaft is unlikely to be exhibited. Joint use of an axially long tube-like vibration insulating rubber or the like encounters difficulty in disposition between the center shaft and the inner circumferential surface of the axial bore and increases cost.

[0007] The present invention has been conceived to solve the above problems, and an object of the invention is to provide a glow plug having a contact member which enhances close contact with the center shaft and with the inner circumferential surface of the axial bore of the metallic shell, ensures vibration insulation for the center shaft, and facilitates attachment thereof.

[0008] According to an embodiment of the present invention, there is provided a glow plug comprising a heater having, in a forward end portion, a heat-generating resistor which generates heat through energization; a metallic shell assuming the form of a tube having an axial bore extending along a first axis which is the axis of the metallic shell, and holding the heater directly or indirectly at a forward end portion; a center shaft assuming a rodlike form, disposed in the axial bore of the metallic shell with a gap formed between the same and an inner circumferential surface of the axial bore, having one end portion connected to a rear end portion of the heater, and having the other end portion projecting from a rear end of the metallic shell; and a contact member formed from an electrically insulative elastic member, assuming an annular form, inserted into the axial bore at a rear end por-

tion of the axial bore, and disposed in such a manner as to be in contact with the inner circumferential surface of the axial bore and with the center shaft; the glow plug being characterized in that a contour of one of two cross sections resulting from cutting the contact member in a state prior to attachment to the glow plug by a plane which contains a second axis which is the axis of the contact member has a first contour segment assuming the form of a curve extending along the second axis and swelling radially outward with a radius R1 of curvature, and a second contour segment assuming the form of a straight line extending along the second axis or the form of a curve extending along the second axis and swelling radially inward with a radius R2 of curvature which satisfies a relational expression R1 < R2.

[0009] In the present embodiment, the second contour segment having the radius R2 of curvature extends along the second axis with a radius of curvature greater than that of the first contour segment having the radius R1 of curvature. Thus, when the contact member is pressed in along the second axis, the second contour segment can function as a core which supports the entire contact member and restrains the contact member from bending and being dragged inward. Therefore, the contact member is restrained from bending or wrinkling at the second contour segment.

[0010] Also, when the contact member is disposed between the center shaft and the inner circumferential surface of the axial bore, the radial thickness of the contact member perpendicular to the second axis is compressed. Since the first contour segment assumes the form of a curve swelling outward in a radial direction of the contact member, compressive deformation can be performed smoothly. Also, since, in the course of deformation, deformation can be such that material moves from a thick region to a thin region, a deformed region having high internal stress does not arise locally; thus, even when the glow plug is subjected to external vibration or the like, the contact member is unlikely to be broken. Also, the contact member is in contact with two members (two surfaces); namely, the center shaft and the inner circumferential surface of the axial bore. Therefore, in view of establishment of gastightness of the axial bore by the contact member, there is no need to form a complicated seal surface on the metallic shell and the center shaft, which are counter members of contact with the contact member, so that machining is facilitated, leading to a reduction in cost.

[0011] In the present embodiment, the contact member may be such that, as viewed on the one cross section, a length along an extending direction of the second axis is longer than a length along a direction orthogonal to the second axis. Through employment of such configuration, when the contact member is disposed between the center shaft and the inner circumferential surface of the axial bore, there can be increased an axial intervening length of the contact member intervening between the center shaft and the inner circumferential surface of the axial bore. Therefore, the center shaft can be more reliably held in the axial bore; thus, there can be more reliably restrained oscillation of the center shaft stemming from imposition of external vibration on the center shaft.

[0012] In the present embodiment, the center shaft may further comprise a rear trunk portion disposed at such a position with respect to the extending direction of the first axis of the metallic shell as to face the rear end portion of the inner circumferential surface of the axial bore, and having a diameter greater than that of the other end portion, and a shoulder portion connecting the rear trunk portion and the other end portion in a tapered manner. The metallic shell may further comprise a taper portion expanding in a tapered manner at the rear end portion of the axial bore from a position located forward of a forward end of the shoulder portion toward the rear end located rearward of the position with respect to the extending direction of the first axis. The contact member may be disposed such that the second contour segment is in contact with the center shaft and such that the first contour segment is in contact with an inner circumferential surface of the axial bore located forward of the taper portion.

[0013] For example, even in the case where the first axis of the metallic shell and the axis of the center shaft fail to coincide with each other, when the contact member is disposed between the center shaft and the inner circumferential surface of the axial bore, the taper portion can guide the contact member toward the center of the axial bore. Therefore, misalignment between the first axis and the axis of the center shaft can be corrected via the contact member. By specifying that the outside diameter of the rear trunk portion be greater than the inside diameter of the contact member, in attachment of the contact member to the glow plug, first, the contact member can be brought into contact with the axial bore in a condition that the inside diameter of the contact member is expanded by the shoulder portion. Then, in a state in which the contact member is in contact with the center shaft (i.e., in a state in which a big gap is not formed between the contact member and the center shaft), the outside diameter of the contact member is narrowed along the taper portion; thus, the contact member is free from inward dragging and, thus, free from twist along the circumferential direction and wrinkling. Therefore, the contact member can be reliably in contact with the inner circumferential surface of the axial bore and with the outer circumferential surface of the center shaft, whereby gastightness through the axial bore can be reliably established.

[0014] In the present embodiment, the contour of the contact member may further comprise a third contour segment which is connected, at one end, to the second contour segment; which extends radially outward from the one end toward the other end thereof while extending along the second axis; which is connected, at the other end, to the first contour segment; and whose point of connection to the first contour segment is an end of the

contact member with respect to the extending direction of the second axis. In attachment of the contact member to the glow plug, the contact member first comes into contact with the shoulder portion. At the time of this contact, first, the third contour segment, which extends radially outward while extending along the second axis, comes into contact with the shoulder portion. Thus, friction of the contact member against the shoulder portion is small, so that the contact member can be prevented from being caught by the shoulder portion and dragged inward.

[0015] In the present embodiment, the contour may form a mirror image with respect to a center position in the extending direction of the second axis. That is, since the contact member is symmetrical along the extending direction of the second axis, in attachment of the contact member to the glow plug, the contact member can be fitted, in either orientation with respect to the direction of the axis P, to a rear end portion of the center shaft. Thus, there can be omitted labor for checking and correcting orientation in attachment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

[FIG. 1] Longitudinal sectional view of a glow plug 1.
[FIG. 2] Sectional view on an enlarged scale of a rear end portion of the glow plug 1.
[FIG. 3] View showing, perspectively and in section, a contact member 7 in a state prior to attachment to the glow plug 1.
[FIG. 4] Sectional view on an enlarged scale of a rear end portion of the glow plug 1 in the process of attaching the contact member 7 to the glow plug 1.
[FIG. 5] Sectional view on an enlarged scale of the rear end portion of the glow plug 1 in the process of attaching the contact member 7 to the glow plug 1.
[FIG. 6] View showing, perspectively and in section, a contact member 107 in a state prior to attachment to the glow plug 1.
[FIG. 7] View showing, perspectively and in section, a contact member 207 in a state prior to attachment to the glow plug 1.
[FIG. 8] View showing, perspectively and in section, a contact member 307 in a state prior to attachment to the glow plug 1.

MODES FOR CARRYING OUT THE INVENTION

[0017] A glow plug according to an embodiment of the present invention will next be described with reference to the drawings. The entire structure of a glow plug 1 is described, by way of example, with reference to FIGS. 1 and 2. The drawings referred to herein are used for explaining technical features which the present invention can employ, and the configuration, etc., of the glow plug appearing in the drawings are given by way of illustration and not of limitation. In the following description, the axis of a metallic shell 4 is referred to as the axis O, and the axis O serves as reference in describing the positional relationship, orientations, and directions of those component members of the glow plug 1 which are attached to the metallic shell 4. With respect to the extending direction of the axis O (hereinafter, may be referred to as "the direction of the axis O"), a side on which a ceramic heater 2 is disposed (the lower side in FIG. 1) is referred to as the forward side of the glow plug 1. The axis O corresponds to the "first axis" in the present invention. An axis P, which will be described later, indicates the axis of a contact member 7 in a state prior to attachment to the glow plug 1, and, in the process of assembly and after assembly, the axis O is used as reference for description. The axis P corresponds to the "second axis" in the present invention.

[0018] The glow plug 1 shown in FIG. 1 is attached to, for example, a combustion chamber of a direct-injection-type diesel engine (not shown), and is used as a heat source for assisting in ignition at start-up of an engine. The glow plug 1 includes the metallic shell 4, a holding member 8, the ceramic heater 2, a center shaft 3, a connection terminal 5, an insulation member 6, the contact member 7, and a connection ring 85.

[0019] First, the ceramic heater 2 is described. The ceramic heater 2 assumes the form of a round bar and has a substrate 21 which is formed from an electrically insulating ceramic and whose forward end portion 22 is formed into a hemispherical shape. A heat-generating element 24 formed from an electrically conductive ceramic and having a substantially U-shaped section is embedded in the substrate 21. The heat-generating element 24 includes a heat-generating resistor 27 and leads 28 and 29. The heat-generating resistor 27 is disposed in the forward end portion 22 of the ceramic heater 2 and is curved and bent at opposite ends in a shape resembling the letter U according to the curved surface of the forward end portion 22. The leads 28 and 29 are connected to opposite ends, respectively, of the heat-generating resistor 27 and extend substantially in parallel with each other toward a rear end portion 23 of the ceramic heater 2. The cross-sectional area of the heat-generating resistor 27 is smaller than that of each of the leads 28 and 29, and, upon energization, heat is generated mainly by the heat-generating resistor 27. Electrode lead portions 25 and 26 project radially from the leads 28 and 29, respectively, at respective positions located rearward of the center of the ceramic heater 2. The electrode lead portions 25 and 26 are exposed at the outer circumferential surface of the ceramic heater 2 at positions deviated from each other in the direction of the axis O.

[0020] Next, the holding member 8 is described. The holding member 8 is a cylindrical metal member extending in the direction of the axis O and radially holds a trunk portion of the ceramic heater 2 within its tubular hole 84. The forward end portion 22 and the rear end portion 23 of the ceramic heater 2 project from the opposite ends

of the holding member 8. A trunk portion 81 of the holding member 8 has a thick-walled flange portion 82 formed on a side toward the rear end thereof. The holding member 8 has a stepped metal-shell engagement portion 83 which is located rearward of the flange portion 82 and is engaged with a forward end portion 41 of the metallic shell 4, which will be described later. Of the electrode lead portions 25 and 26 of the ceramic heater 2, the electrode lead portion 25 located on a side toward the forward end is in contact with the inner circumferential surface of the tubular hole 84 of the holding member 8, whereby the electrode lead portion 25 and the holding member 8 are electrically connected to each other.

[0021] Also, the tubular connection ring 85 of metal is press-fitted to the rear end portion 23 of the ceramic heater 2 projecting rearward from the metallic-shell engagement portion 83 of the holding member 8. The electrode lead portion 26 of the ceramic heater 2 is in contact with the inner circumferential surface of the connection ring 85, whereby the electrode lead portion 26 and the connection ring 85 are electrically connected to each other. As a result of the forward end portion 41 of the metallic shell 4, which will be described later, being joined to the metallic-shell engagement portion 83 of the holding member 8, the electrode lead portion 25 is electrically connected to the metallic shell 4. While the connection ring 85 connected to the electrode lead portion 26 is disposed within the metallic shell 4, the ceramic heater 2 and the metallic shell 4 are positioned by the holding member 8 such that the connection ring 85 and the metallic shell 4 are held mutually in an electrically insulated condition.

[0022] Next, the metallic shell 4 is described. The metallic shell 4 is a slender tubular metal member having an axial bore 43 extending therethrough in the direction of the axis O. The inner circumference of the forward end portion 41 of the metallic shell 4 is engaged with the outer circumference of the metallic-shell engagement portion 83 of the above-mentioned holding member 8, whereby the metallic shell 4 is electrically connected, via the holding member 8, to the electrode lead portion 25 of the ceramic heater 2. The overlap region of the forward end portion 41 and the metallic-shell engagement portion 83 is subjected to laser welding, whereby the metallic shell 4 and the holding member 8 are joined together. The metallic shell 4 has an intermediate trunk portion 44 formed between the forward end portion 41 and the rear end portion 45 and extending long in the direction of the axis O, and the intermediate trunk portion 44 has a mounting portion 42 formed on the outer circumferential surface of a portion located on a side toward the rear end, the mounting portion 42 having threads for mounting the glow plug 1 to an engine head of an internal combustion engine (not shown). The intermediate trunk portion 44 also has a tool engagement portion 46 located rearward of the mounting portion 42, having a hexagonal cross section, and adapted to allow a tool to be engaged therewith in mounting the glow plug 1 to the engine head. As shown in FIG. 2, the rear end portion 45 of the metallic shell 4 has a taper portion 47 formed on the inner circumferential surface of the axial bore 43 and expanding in a tapered form from the axial bore 43 to the opening of a rear end 48.

[0023] Next, the center shaft 3 is described. As shown in FIG. 1, the center shaft 3 is a rodlike metal member extending in the direction of the axis O and is inserted into the axial bore 43 of the metallic shell 4. An intermediate trunk portion 33 located between a forward end portion 31 and a rear end portion 32 of the center shaft 3 is smaller in outside diameter than the forward end portion 31 and the rear end portion 32. The forward end portion 31 has a small-diameter ring engagement portion 34 formed at its forward end so as to be engaged with the inner circumference of the connection ring 85. As a result of the ring engagement portion 34 being engaged with the connection ring 85, the ceramic heater 2 and the center shaft 3 are unitarily connected together along the axis O via the connection ring 85. Although unillustrated, the overlap region of the forward end portion 31 and the connection ring 85 is subjected to laser welding, whereby the forward end portion 31 and the connection ring 85 are joined together. Through this joining, the center shaft 3 is electrically connected to the electrode lead portion 26 of the ceramic heater 2 via the connection ring 85. As mentioned above, since the ceramic heater 2 and the metallic shell 4 are positioned by the holding member 8, the center shaft 3 and the metallic shell 4 are held mutually in an electrically insulated condition in the axial bore 43.

[0024] As shown in FIG. 2, the rear end portion 32 of the center shaft 3 has a connection end portion 36 projecting from the rear end 48 of the metallic shell 4, and a connection base portion 37 which connects the connection end portion 36 and the intermediate trunk portion 33. The connection end portion 36 has a lock portion 39 formed by knurling its outer circumferential surface. The connection end portion 36, including the lock portion 39, is smaller in outside diameter than the connection base portion 37. A shoulder portion 38 is formed between the connection end portion 36 and the connection base portion 37 for connecting, in a tapered manner, the connection end portion 36 and the connection base portion 37.

[0025] The contact member 7 and the insulation member 6 are disposed on the rear end portion 32 of the center shaft 3. The contact member 7, which will be described later, is disposed between the inner circumferential surface of the axial bore 43 of the metallic shell 4 and the connection base portion 37 of the center shaft 3, holds the center shaft 3 in the axial bore 43 to thereby restrain oscillation of the center shaft 3, and maintains gastightness of the axial bore 43.

[0026] The insulation member 6 is a tubular member formed from a heat-resistant, electrically insulative material; for example, nylon (registered trademark), for preventing short circuit which could otherwise result from contact between the metallic shell 4 and the center shaft

3 or the connection terminal 5 (which will be described later). The insulation member 6 is fitted to the center shaft 3 such that the rear end portion 32 of the center shaft 3 is inserted through the insulation member 6; is positioned such that a taper portion 63 provided on its outer circumference is in contact with the taper portion 47 of the metallic shell 4; and maintains an electrically insulating condition between the metallic shell 4 and the center shaft 3. In this condition, a rear end 65 of the insulation member 6 projects rearward from the rear end 48 of the metallic shell 4, and a flange portion 51 (which will be described later) of the connection terminal 5 is in contact with the rear end 65, whereby the connection terminal 5 and the metallic shell 4 are held mutually in an electrically insulated condition.

[0027] The connection terminal 5 is fixedly attached to the connection end portion 36 of the center shaft 3. The connection terminal 5 has a cap-like trunk portion 52 which is fitted externally to the connection end portion 36, and a pin-like protrusion 53 protruding rearward from the trunk portion 52. The trunk portion 52 has a flange portion 51 provided at its forward open end in such a manner as to radially project along the entire circumference. When the connection terminal 5 is fitted externally to the connection end portion 36 of the center shaft 3, the flange portion 51 comes into contact with the rear end 65 of the insulation member 6. Also, in a state in which the connection terminal 5 is pressed forward with respect to the direction of the axis O, the trunk portion 52 is crimped radially inward, whereby the inner circumferential surface of the trunk portion 52 is firmly locked to the lock portion 39 of the connection end portion 36. Since the lock portion 39 is knurled, the force of fixation is enhanced for the trunk portion 52 which is crimped to the lock portion 39, whereby the connection terminal 5 and the center shaft 3 are unitarily fixed and electrically connected to each other.

[0028] In mounting the glow plug 1 to the engine head (not shown), a plug cap (not shown) is fitted to the protrusion 53 of the connection terminal 5. The heat-generating element 24 (see FIG. 1) of the ceramic heater 2 generates heat through application of electricity between one end of the heat-generating resistor 27 which is grounded to the engine via the holding member 8 and the metallic shell 4, and the other end of the heat-generating resistor 27 which is connected to the plug cap via the connection terminal 5 and the center shaft 3.

[0029] Next, the contact member 7 is described. As mentioned above, the contact member 7 is a member disposed between the inner circumferential surface of the axial bore 43 of the metallic shell 4 and the connection base portion 37 of the center shaft 3, holds the center shaft 3 in the axial bore 43 to thereby restrain oscillation of the center shaft 3, and maintains gastightness of the axial bore 43. As shown in FIG. 3, the contact member 7 is formed into a cylindrical shape from a heat-resistant, electrically insulative material; for example, fluororubber, acrylic rubber, or silicone rubber. Preferably, the contact member 7 has a Knoop hardness of 60 to 80.

[0030] Specifically, the contact member 7 has such a cylindrical shape as to have a tubular hole 76 extending in the extending direction of its axis P (hereinafter, may be referred to as "the direction of the axis P"), and is formed in such a manner as to have a substantially D-shaped cross section in a state prior to attachment to the glow plug 1. More specifically, when the cylindrical contact member 7 is cut (split) into two pieces by a plane which contains the axis P, each of the pieces has two cross sections. In the present embodiment, when attention is focused on one 75 of two cross sections of the piece, a contour 70 of the cross section 75 assumes the following form.

[0031] The contour 70 has three kinds of contour segments (line segments which constitute the contour); namely, a second contour segment 71, a first contour segment 72, and third contour segments 73. The second contour segment 71 extends in the form of a straight line along the axis P. The first contour segment 72 assumes the form of a curve extending along the axis P and swelling radially outward in a direction orthogonal to the axis P. The third contour segments 73 connect the second contour segment 71 and the first contour segment 72 at their ends located on the same side with respect to the axis P, and each of the third contour segments 73 assumes the form of a curve extending toward the outside of the cross section 75 while swelling. Also, connections between the first contour segment 72 and the third contour segments 73 are upper and lower (forward and rear) ends of the contact member 7 with respect to the direction of the axis P.

[0032] Also, the first contour segment 72 is disposed radially outward of the second contour segment 71 and is longer in length along the direction of the axis P than the second contour segment 71. Therefore, each of the third contour segments 73 extends radially outward from the end of the second contour segment 71 and is connected to the end of the first contour segment 72. Furthermore, the contour 70 forms a mirror image with respect to the center position (represented by the dash-dot-dot line A-A in FIG. 3) in the direction of the axis P. That is, the contact member 7 has a symmetrical shape along the direction of the axis P.

[0033] The following provisions are made for the contact member 7 having the above-mentioned cross-sectional shape, with respect to the shapes of the second contour segment 71 and the first contour segment 72. The first contour segment 72 assumes, as mentioned above, the form of a curve swelling outward in a radial direction perpendicular to the axis P and has a radius R1 of curvature. The second contour segment 71 assumes the form of a straight line; however, assuming that the second contour segment 71 assumes the form of a curve having a radius R2 of curvature, the second contour segment 71 can be considered as a curve having infinite R2. Therefore, the present embodiment specifies that the radius R2 of curvature of the second contour segment 71

and the radius R1 of curvature of the first contour segment 72 satisfy the relational expression R1 < R2. In other words, the first contour segment 72 swelling radially outward is greater in radial swelling than the second contour segment 71 in the form of a straight line (according to the above assumption, swelling radially inward). Also, the present embodiment specifies that the cross-sectional shape of the contact member 7 is such that a length L1 along the extending direction of the axis P is longer than a length L2 along a direction orthogonal to the extending direction of the axis P (i.e., along a radial direction) (i.e., the cross-sectional shape satisfies the relational expression L1 > L2).

[0034] The contact member 7 having such a shape can be manufactured by an ordinary method for manufacturing an O-ring except that an employed die or mold differs from that employed in the ordinary method. For example, the contact member 7 can be manufactured by compression forming; specifically, upper and lower dies having shapes corresponding to the shape of the contact member 7 are pressed, from above and from underneath, against a sheet of fluororubber. The manufacturing method is not limited thereto. Injection molding can be utilized; specifically, a material, such as fluororubber, is injected into a split-type mold whose cavity has the shape of the contact member 7. Alternatively, machining can be utilized; specifically, an annular member (ring) of fluororubber or a like material is machined into the shape of the contact member 7.

[0035] The glow plug 1 having such a structure is assembled as outlined below. A material composed of an electrically conductive ceramic powder, binder, etc., is injection-molded into an element green-body which is to become the heat-generating element 24 of the ceramic heater 2. Also, an electrically insulating ceramic powder is die-pressed into substrate green-body halves which are collectively to become the substrate 21 of the ceramic heater 2. An assembly of the substrate green-body halves with the element green-body accommodated therein in a sandwiched condition is subjected to press compression. The compressed assembly is subjected to a debindering process, a firing process, such as hot pressing, and then a surface polishing process, thereby yielding the rodlike ceramic heater 2 having a hemispherical forward end. The method of manufacturing the ceramic heater 2 may be modified as appropriate. For example, The substrate green-body may be manufactured as follows: a previously formed substrate green-body half is placed in a die; the element green-body is placed on the substrate green-body half; the electrically insulating ceramic powder is charged into the die; and press compression is performed.

[0036] The ceramic heater 2 is press-fitted into the connection ring 85 formed by forming a steel material, such as stainless steel, into the shape of pipe, thereby establishing electrical connection between the connection ring 85 and the electrode lead portion 26. Similarly, the ceramic heater 2 is press-fitted into the holding member 8 formed into a predetermined shape, thereby establishing electrical connection between the holding member 8 and the electrode lead portion 25. Meanwhile, the center shaft 3 is formed as follows: a rodlike member formed by cutting an iron-based material (e.g., Fe-Cr-Mo steel) into a predetermined dimension is subjected plastic working, cutting, etc. In a state in which the ring engagement portion 34 of the center shaft 3 is engaged with the connection ring 85 fitted to the ceramic heater 2, the overlap region is subjected to laser welding, thereby uniting the center shaft 3 and the ceramic heater 2.

[0037] The tubular metallic shell 4 is formed from an iron-based material, such as S45C, and threads are formed on the mounting portion 42 by rolling. Furthermore, the taper portion 47 is formed, by cutting or the like, on the inner circumferential surface of the axial bore 43 at the rear end portion 45 of the metallic shell 4 in such a manner as to expand in a tapered form from the axial bore 43 to the opening of the rear end 48. The center shaft 3 united to the ceramic heater 2, etc., is inserted through the axial bore 43 of the metallic shell 4. The overlap region of the metallic shell 4 and the holding member 8 is subjected to laser welding, whereby the metallic shell 4 and the holding member 8 are joined together.

[0038] Next, the contact member 7 is fitted to the rear end portion 32 of the center shaft 3 projecting from the rear end 48 of the metallic shell 4. As mentioned above, since the contact member 7 has a symmetrical shape (mirror image) along the direction of the axis P, the contact member 7 can be fitted in either orientation with respect to the direction of the axis P. Also, as shown in FIG. 4, an inside diameter C1 of the tubular hole 76 of the contact member 7 is greater than an outside diameter C2 of the connection end portion 36 of the center shaft 3. Thus, when the connection end portion 36 is inserted through the contact member 7, there can be prevented damage to the tubular hole 76 (the inner circumferential surface of the contact member 7) which could otherwise result from rubbing between the inner circumferential surface of the tubular hole 76 and the lock portion 39 of the connection end portion 36.

[0039] With respect to the direction of the axis O, a forward end position B1 (corresponding to the boundary between the shoulder portion 38 and the connection base portion 37) of the shoulder portion 38 of the center shaft 3 is located rearward of a forward end position B2 (corresponding to the starting position of expansion of the taper portion 47 of the axial bore 43) of the taper portion 47 of the metallic shell 4. Therefore, after the connection end portion 36 is inserted through the contact member 7, the contact member 7 reaches the shoulder portion 38 of the center shaft 3 before coming into contact with the taper portion 47 of the metallic shell 4.

[0040] Also, the inside diameter C1 of the tubular hole 76 of the contact member 7 is smaller than the outside diameter C3 of the connection base portion 37 of the center shaft 3. Therefore, when the contact member 7 which has reached the shoulder portion 38 is further

pressed in forward along the direction of the axis O, the tubular hole 76 is expanded along the taper of the shoulder portion 38. At this time, the third contour segment 73 of the cross section 75 of the contact member 7 (see FIG. 3) is pressed against the tapered shoulder portion 38. Since the third contour segment 73 assumes the form of a curve swelling toward the outside of the cross section 75, the inside diameter of the contact member 7 can be smoothly expanded along the taper of the shoulder portion 38.

[0041] When the contact member 7 whose tubular hole 76 is expanded by the shoulder portion 38 is pressed in forward along the direction of the axis O in a state in which the inner circumferential surface of the tubular hole 76 is in contact with the outer circumferential surface of the connection base portion 37, next, the outer circumferential surface of the contact member 7 comes into contact with the taper portion 47 of the metallic shell 4. When the contact member 7 is further pressed in, as shown in FIG. 5, a portion of the contact member 7 on a side toward the outer circumferential surface is elastically deformed along the taper portion 47, and the contact member 7 is inserted forward beyond the forward end position B2 of the taper portion 47. The first contour segment 72 assumes the form of a curve swelling outward in a radial direction of the contact member 7 with the radius R1 of curvature. Therefore, as compared with the second contour segment 71 assuming the form of a straight line (assuming that the second contour segment 71 assumes the form of a curve, the radius R2 of curvature is infinite), the first contour segment 72 can be more smoothly deformed such that the radial thickness of the contact member 7 is compressed. The contact member 7 is first expanded in inside diameter by the shoulder portion 38 of the center shaft 3 and then reaches a state in which the inner circumferential surface of the tubular hole 76 is in contact with the outer circumferential surface of the connection base portion 37. While the contact member 7 is in this state (i.e., in a state in which a big gap is not formed between the contact member 7 and the center shaft 3), the outside diameter of the contact member 7 is narrowed by the taper portion 47 of the metallic shell 4; thus, the contact member 7 is free from inward dragging and, thus, free from twist along the circumferential direction and wrinkling. Meanwhile, a jig may be used, or, as shown in FIG. 5, the insulation member 6 may be utilized for pressing the contact member 7 into a space between the connection base portion 37 and the inner circumferential surface of the axial bore 43.

[0042] As mentioned above, the second contour segment 71 of the contact member 7 assumes the form of a straight line along the axis P. Thus, when the contact member 7 is pressed in along the axis O such that the pressing force acts mainly along its axis P, the second contour segment 71 can function as a core which supports the entire contact member and restrains the contact member from bending and being dragged inward. Therefore, the contact member 7 is restrained from bending or wrinkling at the second contour segment 71.

[0043] Also, when the contact member 7 is disposed between the connection base portion 37 and the inner circumferential surface of the axial bore 43, the contact member 7 is guided toward the center of the axial bore 43 by the taper portion 47 of the metallic shell 4. Thus, for example, even when misalignment arises between the axis O of the metallic shell 4 and the axis of the center shaft 3, the center shaft 3 is guided toward the center of the axial bore 43 via the contact member 7; therefore, misalignment between the axis O and the axis of the center shaft 3 can be corrected.

[0044] In this manner, since the cross section of the contact member 7 has the first contour segment 72 which swells radially outward with the radius R1 of curvature, the contact member 7 can be smoothly elastically deformed. Furthermore, since the cross section has the second contour segment 71 in the form of a straight line, the contact member 7 is reliably disposed between the connection base portion 37 and the inner circumferential surface of the axial bore 43 without involvement of bending and wrinkling. Also, the contact member 7 whose cross section before attachment has the D-shaped contour 70 is deformed such that its radial thickness is compressed to thereby impart, to the contact member 7, a flat profile along the axis P. Thus, deformation is such that material in a thickest region (located near the center with respect to the direction of the axis P) moves toward thin regions (opposite end regions with respect to the direction of the axis P). Therefore, in the contact member 7, a deformed region having high internal stress does not arise locally; thus, even when the glow plug 1 is subjected to external vibration or the like, the contact member 7 is unlikely to be broken. As viewed after attachment, the contact member 7 does not maintain the form of a mirror image along the direction of the axis P, and such deformation reliably establishes close contact of the contact member 7 with the inner circumferential surface of the axial bore 43 and with the connection base portion 37. Therefore, sufficient reaction is generated against the outer circumferential surface of the connection base portion 37 and against the inner circumferential surface of the axial bore 43. Thus, the contact member 7 can reliably hold the center shaft 3 in the axial bore 43 and thus can restrain oscillation of the center shaft 3 when the glow plug 1 receives external vibration or the like.

[0045] Also, in a space between the outer circumferential surface, encircling the axis O, of the connection base portion 37 of the center shaft 3 and the inner circumferential surface, encircling the axis O, of the axial bore 43 of the metallic shell 4, the contact member 7 has two radially separated contact surfaces for contact with the connection base portion 37 and for contact with the inner circumferential surface of the axial bore 43. For example, the position of the disposed contact member 7 may shift due to vibration generated as a result of operation of the glow plug 1. However, for the contact member 7 having the two radially separated contact surfaces for

contact with the connection base portion 37 and for connection with the inner circumferential surface of the axial bore 43, such a positional shift emerges merely as shifts of positions of contact with the two members, and the sizes of the contact surfaces can be maintained intact. Additionally, since the contact member 7 can maintain, through elastic deformation, a state of contact with the inner circumferential surface of the axial bore 43 and with the connection base portion 37, gastightness through the axial bore 43 can be reliably ensured. Also, the contact member 7 is in contact with two surfaces; namely, the inner circumferential surface of the axial bore 43 and the outer circumferential surface of the connection base portion 37. Therefore, in view of establishment of gastightness of the axial bore 43 by the contact member 7, there is no need to form a complicated seal surface on the metallic shell 4 and the center shaft 3, which are counter members of contact with the contact member 7, so that machining is facilitated, leading to a reduction in cost.

[0046] Since the contact member 7 satisfies the relational expression L1 > L2, when the contact member 7 is disposed between the center shaft 3 and the inner circumferential surface of the axial bore 43, there can be increased the intervening length, along the direction of the axis O, of the contact member 7 which intervenes between the center shaft 3 and the inner circumferential surface of the axial bore 43. Therefore, the center shaft 3 can be more reliably held in the axial bore 43; thus, there can be more reliably restrained oscillation of the center shaft 3 stemming from imposition of external vibration on the center shaft 3.

[0047] After the contact member 7 is disposed between the connection base portion 37 and the inner circumferential surface of the axial bore 43, as shown in FIG. 2, the insulation member 6 is fitted to the rear end portion 32 of the center shaft 3. In a state in which the insulation member 6 is positioned such that the taper portion 63 of the insulation member 6 is in contact with the taper portion 47 of the metallic shell 4, the insulation member 6 is fitted to the rear end portion 32 of the center shaft 3. The trunk portion 52 of the connection terminal 5 is crimped, whereby the connection terminal 5 is fixed to the connection end portion 36 of the center shaft 3, and the glow plug 1 is completed.

[0048] The present invention can be modified in various forms. In the embodiment described above, the connection member 7 is formed such that connections between the first contour section 72 and the third contour sections 73 are its upper and lower (forward and rear) ends. However, the present invention is not limited thereto. For example, the proportion of the third contour sections 73 to the contour 70 may be increased such that the third contour segments are the upper and lower ends with respect to the direction of the axis P.

[0049] Also, for example, the contact member may be formed as in the case of a contact member 107 shown in FIG. 6; specifically, a contour 170 of a cross section 175 does not have the third contour segments and has a shape resembling the letter D such that a second contour segment 171 and a first contour segment 172 are directly connected. Also, the contact member may be formed as in the case of a contact member 207 shown in FIG. 7; specifically, a contour 270 of a cross section 275 does not assume the form of a mirror image with respect to the center position in the direction of the axis P; i.e., the contour 270 is asymmetric along the direction of the axis P.

[0050] Also, for example, the contact member may be formed as in the case of a contact member 307 shown in FIG. 8; specifically, a contour 370 of a cross section 375 has a second contour segment 371 assuming the form of a curve swelling radially inward with the radius R2 of curvature. In this case, similar to the present embodiment, it suffices for the radius R1 of curvature of a first contour section 372 swelling radially outward and the radius R2 of curvature of the second contour section 371 to satisfy the relational expression R1 < R2. Through employment of this relationship, when the contact member 307 is disposed between the center shaft 3 and the inner circumferential surface of the axial bore 43, the first contour segment 372 larger in the degree of swelling than the second contour segment 371 can be smoothly elastically deformed. The second contour segment 371 smaller in the degree of swelling and closer in shape to a straight line than the first contour segment 372 can function as a core which supports the entire contact member and restrains the contact member from bending and being dragged inward.

[0051] The contact members 107, 207, and 307 shown in FIGS. 6, 7, and 8, respectively, are similar in preferred features to the contact member 7 of the present embodiment shown in FIG. 3. Specifically, preferably, the cross section is such that the length L1 along the extending direction of the axis P is longer than the length L2 along a direction orthogonal to the extending direction of the axis P (along a radial direction); i.e., the cross section has a short radial length so as to have a flat profile (L1 > L2). More preferably, the cross section is such that the radial length L2 is half the length L1 along the direction of the axis P or less ($L1/2 \geq L2$). However, depending on material and detailed configurational features, this relationship (half of the length along the axis P > the radial length ($L1/2 \geq L2$)) may not be satisfied so long as the relationship L1 > L2 is satisfied).

[0052] The glow plug 1 has the ceramic heater 2. However, the present invention is not limited thereto. The glow plug 1 may have a sheath heater configured such that a coil-like heat-generating resistor and a controlling resistor are disposed within a metallic sheath tube whose tip is hemispherically closed. Also, the glow plug may be such that the forward end portion 41 of the metallic shell 4 directly holds the ceramic heater 2 or the sheath heater without use of the holding member 8. The ceramic heater may be of a so-called surface heat-generation type in which the heat-generating element 24 is externally disposed around the substrate 21.

[0053] The connection base portion 37 of the center shaft 3 may have, at a position located toward its forward end, a stopper in the form of a flange or a protrusion for forming some level difference. Through provision of such a stopper, even when the contact member 7 is positionally shifted as a result of reception of vibration or the like, the stopper prevents movement of the contact member 7 to the intermediate trunk portion 33 of the center shaft 3. Also, the contact member 7 may be disposed between the connection base portion 37 and the inner circumferential surface of the axial bore 43 in a noncontacting manner in relation to the insulation member 6.

[0054] The contact member 7 of the present embodiment is expected primarily to ensure gastightness of the axial bore 43 and is also expected to hold the center shaft 3 to thereby restrain radial oscillation of the center shaft 3. Therefore, preferably, the contact member 7 is in close contact with the inner circumferential surface of the axial bore 43 and with the outer circumferential surface of the center shaft 3, along the full circumference around the axis O, since vibration isolation and gastightness can be ensured.

[0055] In the present embodiment, the forward end portion 31 corresponds to "one end portion," and the connection end portion 36 corresponds to "the other end portion." The connection base portion 37 corresponds to "a rear trunk portion."

Claims

1. A glow plug comprising:

a heater having, in a forward end portion, a heat-generating resistor which generates heat through energization;
a metallic shell assuming the form of a tube having an axial bore extending along a first axis which is the axis of the metallic shell, and holding the heater directly or indirectly at a forward end portion;
a center shaft assuming a rodlike form, disposed in the axial bore of the metallic shell with a gap formed between the same and an inner circumferential surface of the axial bore, having one end portion connected to a rear end portion of the heater, and having the other end portion projecting from a rear end of the metallic shell; and
a contact member formed from an electrically insulative elastic member, assuming an annular form, inserted into the axial bore at a rear end portion of the axial bore, and disposed in such a manner as to be in contact with the inner circumferential surface of the axial bore and with the center shaft;
the glow plug being **characterized in that**:

a contour of one of two cross sections resulting from cutting the contact member in a state prior to attachment to the glow plug by a plane which contains a second axis which is the axis of the contact member has
a first contour segment assuming the form of a curve extending along the second axis and swelling radially outward with a radius R1 of curvature and
a second contour segment assuming the form of a straight line extending along the second axis or the form of a curve extending along the second axis and swelling radially inward with a radius R2 of curvature which satisfies a relational expression R1 < R2.

2. A glow plug according to claim 1, wherein the contact member is such that, as viewed on the one cross section, a length along an extending direction of the second axis is longer than a length along a direction orthogonal to the second axis.

3. A glow plug according to claim 1 or 2, wherein:

the center shaft further comprises

a rear trunk portion disposed at such a position with respect to the extending direction of the first or the metallic shell as to face the rear end portion of the inner circumferential surface of the axial bore, and having a diameter greater than that of the other end portion and
a shoulder portion connecting the rear trunk portion and the other end portion in a tapered manner;

the metallic shell further comprises a taper portion expanding in a tapered manner at the rear end portion of the axial bore from a position located forward of a forward end of the shoulder portion toward the rear end located rearward of the position with respect to the extending direction of the first axis; and
the contact member is disposed such that the second contour segment is in contact with the center shaft and such that the first contour segment is in contact with an inner circumferential surface of the axial bore located forward of the taper portion.

4. A glow plug according to claim 3, wherein the contour of the contact member further comprises a third contour segment which is connected, at one end, to the second contour segment; which extends radially outward from the one end toward the other end thereof while extending along the second axis; which is connected, at the other end, to the first contour segment; and whose point of connection to the first contour

segment is an end of the contact member with respect to the extending direction of the second axis.

5. A glow plug according to claim 4, wherein the contour forms a mirror image with respect to a center position in the extending direction of the second axis.

FIG. 1

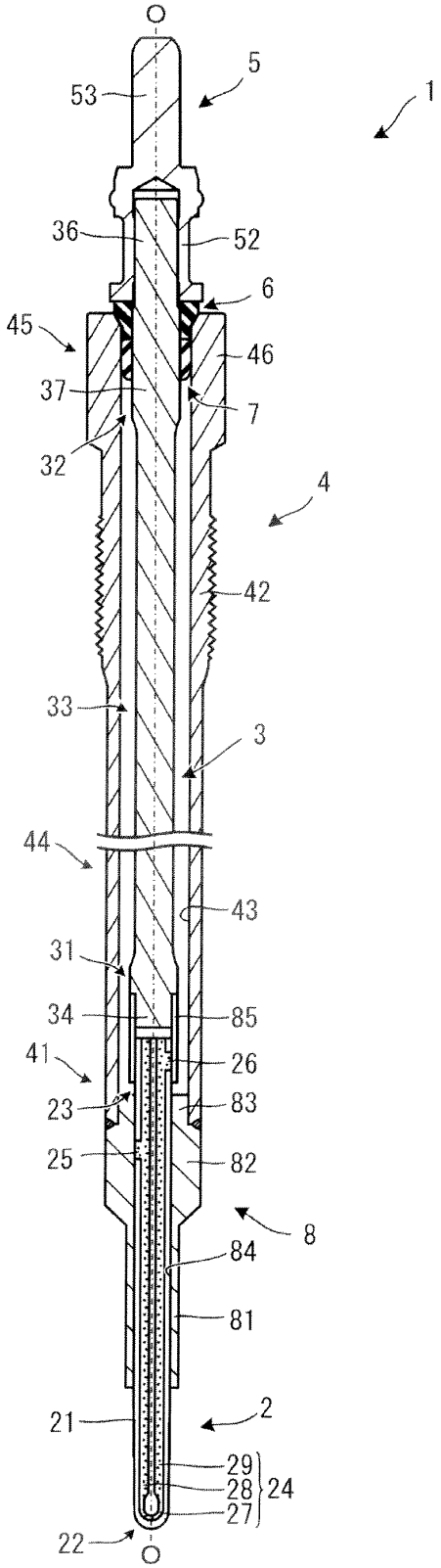
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FIG. 2

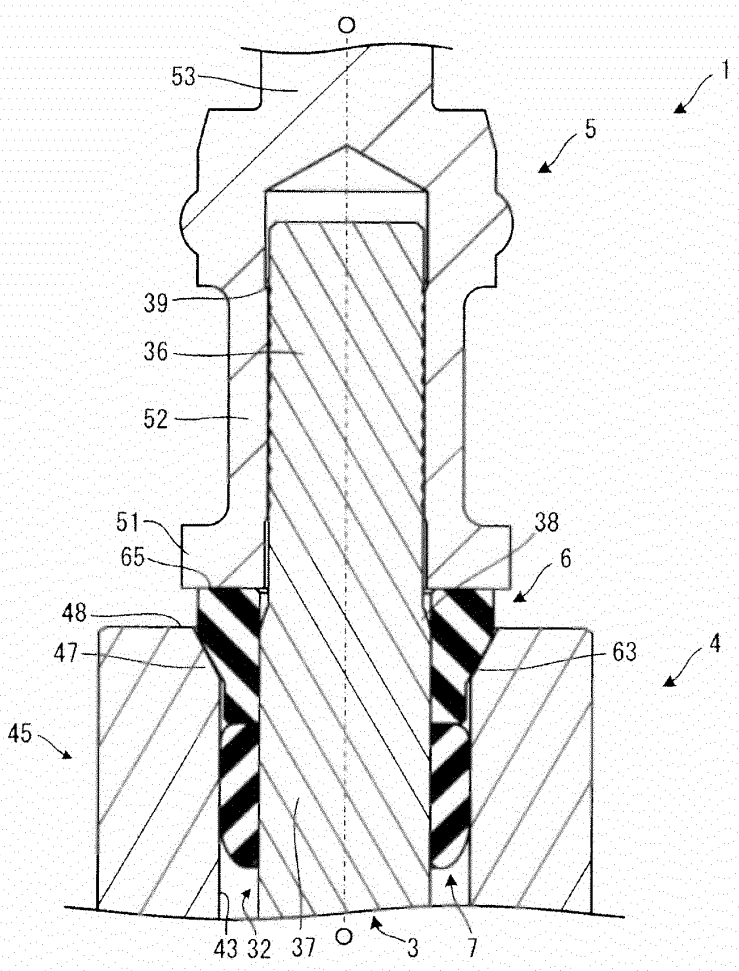
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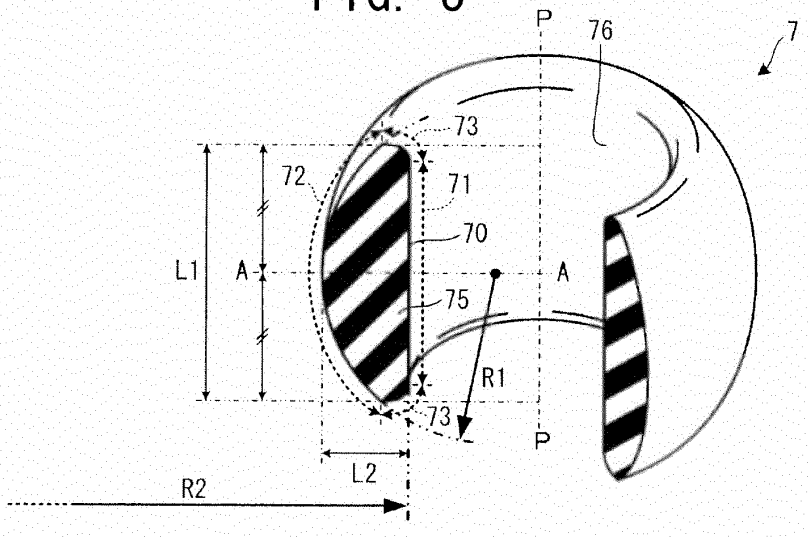
FIG. 3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R1
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L2
R2

FIG. 4

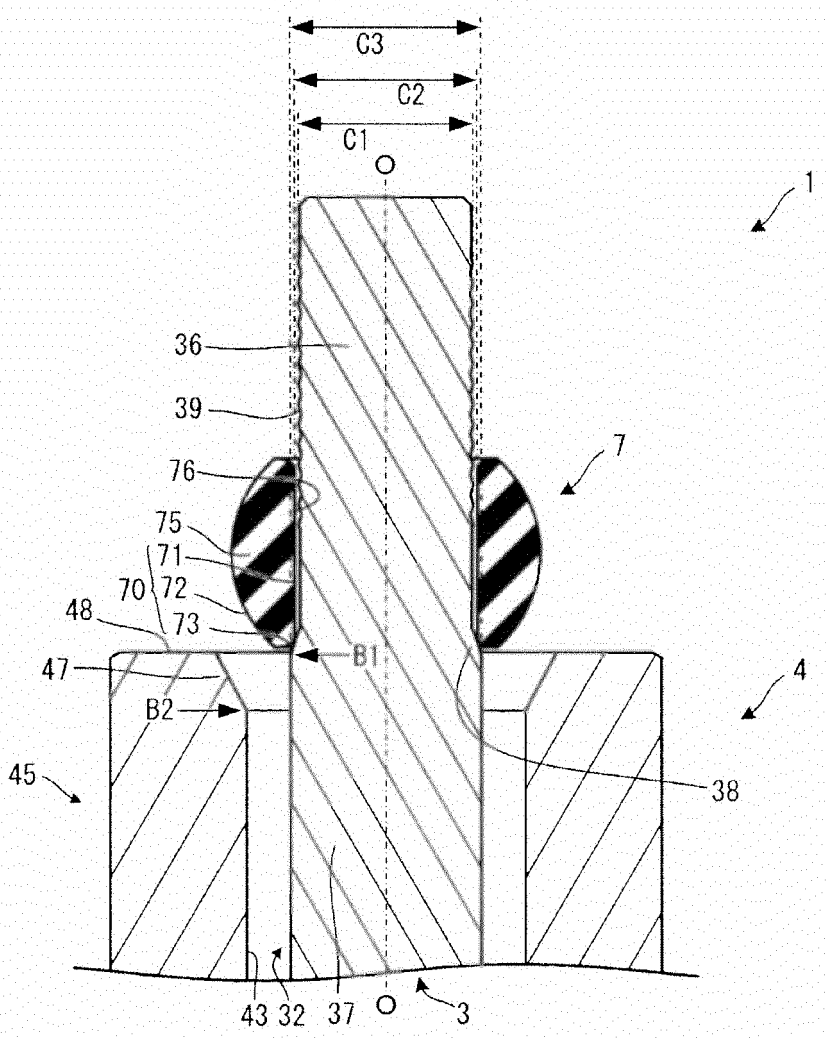
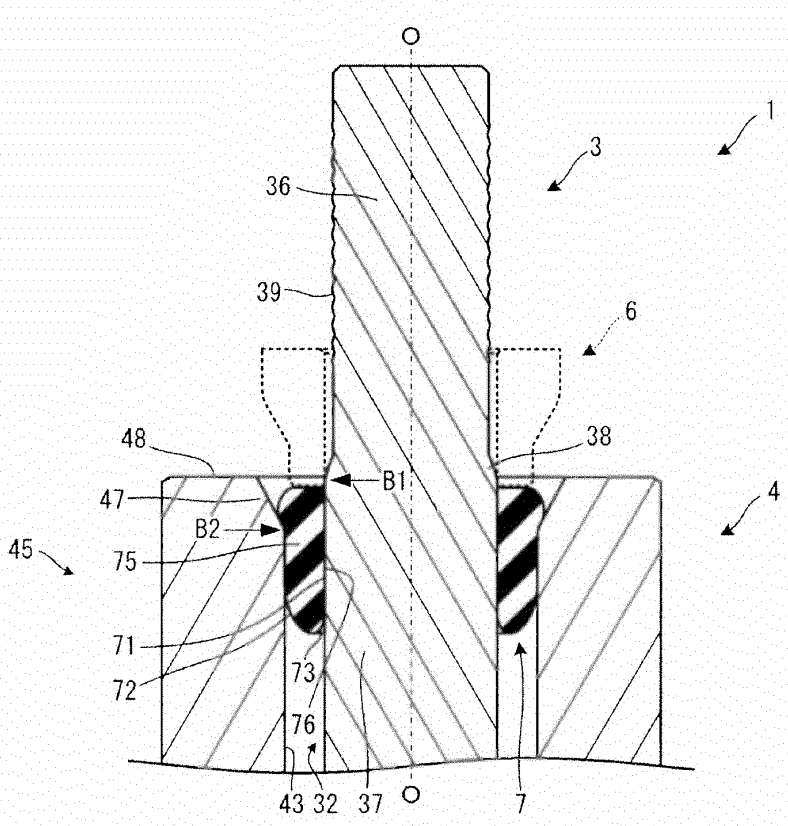


FIG. 5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O
7

FIG. 6

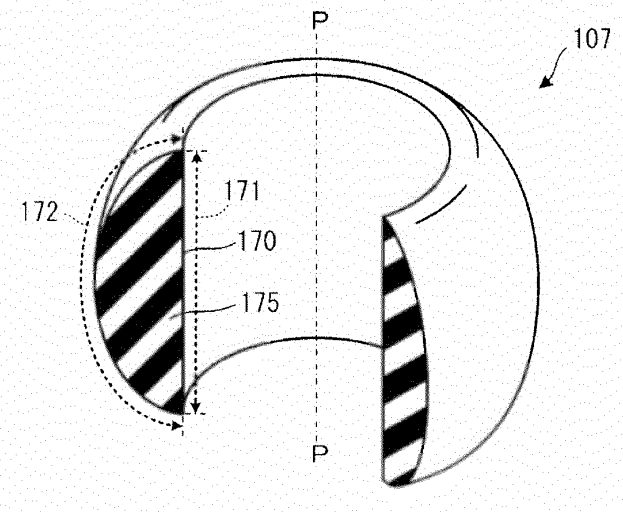
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FIG. 7

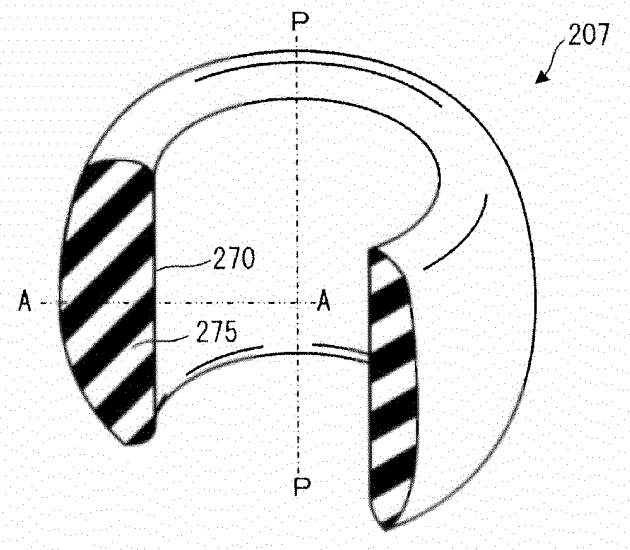
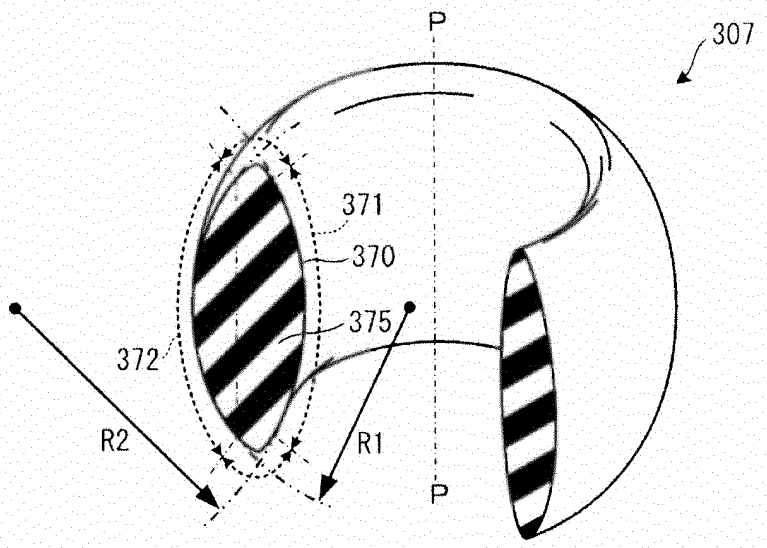


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050708

A. CLASSIFICATION OF SUBJECT MATTER
F23Q7/00(2006.01)i, *F02P19/00*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23Q7/00, F02P19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-292444 A (NGK Spark Plug Co., Ltd.), 08 November 2007 (08.11.2007), entire text; all drawings & US 2007/0241092 A1 & DE 102007015491 A1	1-5
Y	JP 2006-112478 A (NOK Corp.), 27 April 2006 (27.04.2006), page 2, lines 13 to 21; fig. 2 to 3 & EP 1647746 A1	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 February, 2012 (22.02.12)	06 March, 2012 (06.03.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050708

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 127097/1990(Laid-open No. 084863/1992) (NOK Corp.), 23 July 1992 (23.07.1992), entire text; all drawings (Family: none)	1-5

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007292444 A **[0004]**