(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 477 286 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
18.10.2017 Bulletin 2017/42

(21) Application number: **12151260.2**

(22) Date of filing: **16.01.2012**

(51) Int Cl.:
H01T 13/20 *(2006.01)* ***H01T 13/16*** *(2006.01)*
H01T 13/39 *(2006.01)*

(54) **Spark plug**

Zündkerze

Bougie d'allumage

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

(30) Priority: **17.01.2011 JP 2011006987**

(43) Date of publication of application:
18.07.2012 Bulletin 2012/29

(73) Proprietor: **NGK SPARK PLUG CO., LTD.**
Nagoya-shi, Aichi 467-8525 (JP)

(72) Inventors:
- **Ban, Kenji**
  Nagoya-shi, Aichi 4678525 (JP)
- **Kato, Tomoaki**
  Nagoya-shi, Aichi 4678525 (JP)
- **Kataoka, Yoshikazu**
  Nagoya-shi, Aichi 4678525 (JP)

(74) Representative: **Zimmermann & Partner Patentanwälte mbB**
Postfach 330 920
80069 München (DE)

(56) References cited:
JP-A- 2009 151 984 **JP-A- 2009 200 002**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 477 286 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[Technical Field]

[0001] The present invention relates to a spark plug used in an internal combustion engine, or the like.

[Background Art]

[0002] A spark plug used in a combustion device such as an internal combustion engine includes, for example, a center electrode extending in a direction of the axis, an insulating body provided on the outer periphery of the center electrode, a hollow cylindrical metal shell provided on the outer periphery of the insulating body, and a bar-like ground electrode of which one end portion is joined to the leading end portion of the metal shell. The ground electrode is disposed with an approximately intermediate portion thereof bent back in such a way that the leading end portion thereof is opposed to the leading end portion of the center electrode, thereby forming a spark discharge gap between the leading end portion of the center electrode and the other end portion of the ground electrode. Also, a technology is known whereby a noble metal tip is provided in a region of the other end portion of the ground electrode which forms the spark discharge gap, thus achieving an improvement in wear resistance and ignitability.

[0003] Meanwhile, the ground electrode is disposed protruding toward the central side of a combustion chamber. For this reason, there is a danger that the ground electrode is overheated, and that preignition (premature ignition) occurs due to the high temperature ground electrode, or erosion or breakage occurs in the ground electrode.

[0004] Therefore, in order to achieve an improvement in thermal resistance of the ground electrode while maintaining ignitability, a technique (a so-called transverse discharge type of spark plug) is proposed whereby the ground electrode is made comparatively short, and the leading end face of the ground electrode (a noble metal tip) is opposed to the side surface of the leading end portion of the center electrode, thus generating a spark discharge in a direction approximately perpendicular to the axis (for example, refer to Patent Document 1 or the like). According to the technique, as it is possible to reduce the amount of heat received by the ground electrode, and it becomes easier to transfer the heat in the ground electrode to the metal shell side, it is possible to improve thermal resistance. Also, as it is possible to cause a flame kernel to grow smoothly toward the central side of the combustion chamber without the growth being inhibited by the ground electrode, it is possible to sufficiently maintain ignitability.

[Related Art Documents]

[Patent Documents]

[0005] [Patent Document 1] JP-A-2009-151984
JP 2009 200002 A describes a spark plug. JP 2009 151984 describes a spark plug.

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0006] However, in recent years, an engine with a supercharger, a high compression engine, and the like, have been proposed in order to realize low fuel consumption, low emission, and high power. For this reason, there is a danger that a voltage (a discharge voltage) necessary for generating a spark discharge increases more than before, or the ground electrode becomes higher in temperature, and there is concern that wear of the ground electrode or noble metal tip induced by a spark discharge progresses quickly.

[0007] Herein, in order to improve the wear resistance of the ground electrode and the like, it is conceivable to increase an area in which the ground electrode (noble metal tip) and center electrode are opposed to each other, but in this case, there is a danger that a flame kernel growth is inhibited by the ground electrode (noble metal tip) or center electrode, or variation occurs in a discharge position, causing deterioration in ignitability.

[0008] The invention, having been contrived bearing in mind the heretofore described circumstances, has an object of providing a spark plug having a ground electrode or noble metal tip opposed to the side surface of the leading end portion of a center electrode, wherein it is possible to realize performance superior in both ignitability and wear resistance.

[Means for Solving the Problems]

[0009] Hereafter, an itemized description will be given of each configuration suitable for achieving the object. Working effects specific to the corresponding configurations are quoted as necessary.

[0010] Configuration 1. A spark plug of this configuration includes:

an insulating body having an axial hole passing therethrough in a direction of an axis;
a center electrode inserted in the axial hole;
a metal shell provided on an outer periphery of the insulating body;
a ground electrode fixed to a leading end portion of the metal shell; and
a ground electrode side tip, formed from a metal containing a noble metal, of which at least one end portion is joined to a leading end portion of the ground electrode,
the center electrode having at its leading end portion a center electrode side tip formed from a metal containing a noble metal,
another end face of the ground electrode side tip being opposed to a side surface of the center electrode side tip, and a gap being formed between the other end face of the ground electrode side tip and the side surface of the center electrode side tip, wherein
when an area of a region, on a projection plane onto which the ground electrode side tip and a leading end face of the center electrode side tip are projected on a virtual plane perpendicular to the axis, bounded by a first tangent line drawn from one end of a side corresponding to the other end face of the ground electrode side tip to a projection region corresponding to the leading end face of the center electrode side tip, a second tangent line drawn from the other end of the side corresponding to the other end face of the ground electrode side tip to the projection region corresponding to the leading end face of the center electrode side tip, a projection line corresponding to the other end face of the ground electrode side tip, and a projection line corresponding to the outer periphery of the leading end face of the center electrode side tip, is taken to be SA1 (mm^2),
an area of a region in which a projection region of the center electrode side tip and a projection region of the other end face of the ground electrode side tip overlap when the center electrode side tip and the other end face of the ground electrode side tip are projected onto a virtual plane parallel to the other end face of the ground electrode side tip, is taken to be SA2 (mm^2), and
the size of the gap is taken to be G (mm),
$0.12 \leq SA1 \times SA2/G(mm^3) \leq 0.49$ is satisfied,
when a distance along the axis between a point, on the other end face of the ground electrode side tip, positioned closest to a rear end side in the direction of the axis, and a point, on a surface of the center electrode side tip opposed to the other end face of the ground electrode side tip, positioned closest to the leading end side along the axis, is taken to be A (mm), and
a length along the axis of the other end face of the ground electrode side tip is taken to be B (mm),
$0.05 \leq A \leq B+0.2$ and $0.3 \leq B \leq 0.7$ are satisfied, and
when the area of the other end face of the ground electrode side tip is taken to be SX (mm^2),
$0.3 \leq SX \leq 0.6$ and $0.4 \leq G \leq 1.0$ are satisfied.

[0011] On the projection plane, when tangent lines are drawn from the one end and other end of the side corresponding to the other end face of the ground electrode side tip to the projection region corresponding to the leading end face of the center electrode side tip, it is possible to draw two tangent lines from each end, but the "first tangent line" and "second tangent line" mean two tangent lines which do not intersect with each other between the side corresponding to the other end face of the ground electrode side tip and the projection region corresponding to the leading end face of the center electrode side tip.

[0012] According to the configuration 1, a configuration is adopted such that the relative positions of the ground electrode side tip and center electrode side tip satisfy $0.12 \leq SA1 \times SA2/G$. Consequently, it is possible to suppress an increase in discharge voltage, and it is possible to more reliably prevent a spark discharge being generated between only small portions of the ground electrode side tip and center electrode side tip, and the ground electrode side tip and the like wearing out locally. As a result of this, it is possible to effectively improve wear resistance.

[0013] Furthermore, according to the configuration 1, a configuration is adopted such that $SA1 \times SA2/G \leq 0.49$ is satisfied. Consequently, it is possible to more reliably prevent a flame kernel growth inhibition due to the existence of the ground electrode side tip or center electrode side tip, and it is possible to prevent a situation in which a discharge position varies in the extreme. As a result of this, it is possible to realize superior ignitability while sufficiently maintaining the wear resistance improvement effect.

[0014] In addition, according to the configuration 1, a configuration is adopted such that the distance B is set to 0.3mm or more, and the ground electrode side tip has a sufficient thickness. Consequently, it is possible to suppress an overheating in the ground electrode side tip, and it is possible to secure a sufficient wear volume in the ground electrode side tip.

[0015] Also, a configuration is adopted such that the distance A is set to 0.05mm or more, and the area in which the center electrode side tip and ground electrode side tip are opposed to each other is not reduced to an extreme. Because of this, it is possible to more reliably prevent a situation in which spark discharges with an edge portion of each of the

center electrode side tip and ground electrode side tip as a base point are concentrically generated, and the edge portions wear out unevenly.

[0016] As above, the working effect achieved by setting the distance B to 0.3mm or more and the working effect achieved by setting the distance A to 0.05mm or more act synergetically, and it is thus possible to achieve a further improvement in wear resistance.

[0017] Furthermore, according to the configuration 1, a configuration is adopted such that the distance B is set to 0.7mm or less, and the thickness of the ground electrode side tip is not excessively increased. Consequently, it is possible to more reliably prevent a situation in which a flame kernel growth is inhibited, or heat is removed from a flame kernel, by the ground electrode side tip.

[0018] In addition, a configuration is adopted such that the distance A is set to "B+0.2mm" or less, and the amount by which the center electrode side tip protrudes toward the leading end side in the direction of the axis thereof with respect to the other end face of the ground electrode side tip is not excessively increased. Consequently, it is possible to cause a flame kernel to grow toward the central side of a combustion chamber without the growth being inhibited by the center electrode side tip.

[0019] Also, while it is common that the center electrode side tip is joined to a base material of the center electrode via a welded junction formed by a laser welding or the like, it is possible, by setting the distance A to "B+0.2mm" or less, to space the other end face of the ground electrode side tip from the welded junction. Because of this, it is possible to more reliably prevent a spark discharge being generated between the ground electrode side tip and welded junction (that is, at a position away from the center of the combustion chamber).

[0020] As above, the working effect achieved by setting the distance B to 0.7mm or less and the working effect achieved by setting the distance A to "B+0.2mm" or less act synergetically, and it is thus possible to still further improve ignitability.

[0021] Moreover, according to the configuration 1, as the spark discharge gap size G is set to 1.0mm or less, it is possible to more reliably suppress an increase in discharge voltage, and furthermore, as the area SX is set to 0.3mm^2 or more, it is possible to secure a still larger wear volume of the ground electrode side tip. Because of this, it is possible to achieve a further improvement in wear resistance.

[0022] Also, according to the configuration 1, as the spark discharge gap size G is set to 0.4mm or more, and the area SX is set to 0.6mm^2 or less, it is possible to more effectively suppress a flame kernel growth inhibition due to the ground electrode side tip or the like. As a result of this, it is possible to further improve ignitability.

[0023] Configuration 2. A spark plug of this configuration includes:

an insulating body having an axial hole passing therethrough in a direction of an axis;
a center electrode inserted in the axial hole;
a metal shell provided on an outer periphery of the insulating body; and
a ground electrode of which one end portion is fixed to a leading end portion of the metal shell,
another end face of the ground electrode being opposed to a side surface of the leading end portion of the center electrode, and
a gap being formed between the other end face of the ground electrode and the side surface of the leading end portion of the center electrode, wherein
when an area of a region, on a projection plane onto which the ground electrode and a leading end face of the center electrode are projected on a virtual plane perpendicular to the axis, bounded by a third tangent line drawn from one end of a side corresponding to the other end face of the ground electrode to a projection region corresponding to the leading end face of the center electrode, a fourth tangent line drawn from the other end of the side corresponding to the other end face of the ground electrode to the projection region corresponding to the leading end face of the center electrode, a projection line corresponding to the other end face of the ground electrode, and a projection line corresponding to the outer periphery of the leading end face of the center electrode, is taken to be SB 1 (mm^2),
an area of a region in which a projection region of the center electrode and a projection region of the other end face of the ground electrode overlap when the center electrode and the other end face of the ground electrode are projected onto a virtual plane parallel to the other end face of the ground electrode, is taken to be SB2 (mm^2), and
the size of the gap is taken to be G (mm),
$0.21 \leq SB1 \times SB2/G(mm^3) \leq 0.49$ is satisfied.

[0024] The "third tangent line" and "fourth tangent line" mean two tangent lines which do not intersect with each other between the side corresponding to the other end face of the ground electrode and the projection region corresponding to the leading end face of the center electrode.

[0025] According to the configuration 2, with a spark plug wherein the other end face of the ground electrode is opposed to the side surface of the leading end portion of the center electrode, it is possible to realize performance superior in both wear resistance and ignitability.

[0026] In the configuration 2, also, it may be arranged that the center electrode side tip is provided at the leading end

portion of the center electrode, or it may be arranged that the center electrode side tip is not provided at the leading end portion of the center electrode.

[0027] Configuration 3. In this configuration, the spark plug according to the configuration 1 or 2 is characterized in that when a cross-sectional area of the ground electrode is taken to be SY (mm^2), and the width of the ground electrode is taken to be W (mm), on any cross section, of a portion from the longitudinal center to the one end of the ground electrode, in a direction perpendicular to a central axis of the ground electrode,
$2.3 \leq SY \leq 3.5$ and $1.8 \leq W \leq 2.2$ are satisfied.

[0028] According to the configuration 3, as the cross-sectional area SY on one end side (the side on which the ground electrode is fixed to the metal shell) of the ground electrode is set to $2.3mm^2$ or more, it is possible to efficiently transfer heat from the other end portion to the one end side (metal shell side) of the ground electrode. Also, even when the cross-sectional area is set to $2.3mm^2$ or more, the thickness of the ground electrode is excessively increased when the width of the ground electrode is reduced to an extreme, meaning that the ground electrode takes a form in which it protrudes toward the central side of the combustion chamber, and there is concern that the ground electrode is overheated, but as the width W is set to 1.8mm or more, it is possible to dispel the concern. That is, by setting the width W to 1.8mm or more while setting the cross-sectional area SY to $2.3mm^2$ or less, it is possible to achieve a further improvement in thermal resistance with a transverse discharge type of spark plug commonly superior in thermal resistance.

[0029] Furthermore, according to the configuration 3, as the cross-sectional area SY is set to $3.5mm^2$ or less, it is possible to more reliably prevent heat being removed from a flame kernel by the ground electrode, and as the width W is set to 2.2mm or less, it is possible to effectively suppress a flame kernel growth inhibition due to the ground electrode. As a result of this, it is possible to achieve a still further improvement in ignitability.

[0030] Configuration 4. In this configuration 4, the spark plug according to any one of the configurations 1 to 3 is characterized in that
the ground electrode includes an outer layer and an inner layer, provided inside the outer layer, which is formed from a metal with better thermal conductivity than the outer layer, and
when a cross-sectional area of the inner layer is taken to be SI (mm^2), and the cross-sectional area of the ground electrode is taken to be SZ (mm^2), on a cross section on which the cross-sectional area of the inner layer is largest in a direction perpendicular to the central axis of the ground electrode,
$0.2 \geq SI/SZ \geq 0.5$ is satisfied.

[0031] According to the configuration 4, a configuration is adopted such that the inner layer superior in thermal conductivity is provided inside the ground electrode, and $0.2 \leq SI/SZ$ is satisfied (that is, the inner layer has a sufficient volume with respect to the ground electrode). Consequently, it is possible to dramatically enhance the thermal conductivity of the ground electrode, and it is possible to very effectively improve thermal resistance.

[0032] Meanwhile, when the proportion occupied by the inner layer on the cross section of the ground electrode is excessively increased, the outer layer eventually becomes smaller in thickness, and there is a danger that the outer layer is damaged accompanying a thermal expansion of the inner layer. In this regard, according to the configuration 4, as $SI/SZ \leq 0.5$ is set, it is possible to secure a sufficient thickness of the outer layer, and it is thus possible to sufficiently maintain the strength of the outer layer. As a result of this, it is possible to more reliably prevent damage to the outer layer induced by a thermal expansion of the inner layer.

[0033] Configuration 5. In this configuration, the spark plug according to any one of the configurations 1 to 4 is characterized in that
both side surfaces of the ground electrode adjacent to an opposite surface of the ground electrode opposed to the center electrode form a curved shape convex outward, and
when the curvature radii of the external lines of the two side surfaces are taken to be R (mm) on a cross section perpendicular to the central axis of the ground electrode,
$R \leq 1.5$ is satisfied.

[0034] When the curvature radii are not constant, each "curvature radius R" refers to the curvature radius of a virtual circle, on a cross section perpendicular to the central axis of the ground electrode, passing through three points, one end point and the other end point of the external line of each corresponding side surface, and the midpoint between the two points.

[0035] According to the configuration 5, as both side surfaces of the ground electrode are formed into a convexly curved surface, it becomes easier for a fuel gas to infiltrate into the gap, and it is thus possible to further improve ignitability.

[Brief Description of the Drawings]

[0036]

[Fig. 1] Fig. 1 is a partially sectioned front view showing a configuration of a spark plug.
[Fig. 2] Fig. 2 is a partially sectioned enlarged front view showing a configuration of a leading end portion of the

spark plug.

[Fig. 3] Fig. 3 is a partially enlarged sectional view showing a cross-sectional shape of a ground electrode, and the like.

[Fig. 4] Fig. 4 is a partially enlarged side view showing a configuration of a leading end portion of the ground electrode.

[Fig. 5] Fig. 5 is a projection view wherein a center electrode and the like are projected onto a virtual plane perpendicular to an axis.

[Fig. 6] Fig. 6 is a projection view wherein the center electrode and the like are projected onto a virtual plane parallel to another end face of a ground electrode side tip.

[Fig. 7] Fig. 7 is a partially sectioned enlarged front view showing a configuration of a leading end portion of a spark plug in a second embodiment.

[Fig. 8] Fig. 8 is a projection view wherein the center electrode and the like are projected onto a virtual plane perpendicular to the axis in the second embodiment.

[Fig. 9] Fig. 9 is a projection view wherein the center electrode and the like are projected onto a virtual plane parallel to another end face of a ground electrode in the second embodiment.

[Fig. 10] Fig. 10 is a partially sectioned enlarged front view showing a configuration of a sample in a comparison example.

[Fig. 11] Fig. 11 is a graph showing results of a desktop spark endurance test on samples wherein distances A and B are variously changed.

[Fig. 12] Fig. 12 is a graph showing results of an ignitability evaluation test on samples wherein the distances A and B are variously changed.

[Fig. 13] Fig. 13 is a graph showing results of the desktop spark endurance test on samples wherein an area SX and spark discharge gap size G are variously changed.

[Fig. 14] Fig. 14 is a graph showing results of the ignitability evaluation test on samples wherein the area SX and spark discharge gap size G are variously changed.

[Fig. 15] Fig. 15 is a graph showing results of the ignitability evaluation test on samples wherein an area SY and a width W of the ground electrode are variously changed.

[Fig. 16] Fig. 16 is a graph showing thermal value improvement values of samples wherein SI/SZ is variously changed.

[Fig. 17] Fig. 17 is a graph showing critical air/fuel ratio fluctuation ranges of samples wherein the cross-sectional shape of the ground electrode is variously changed.

[Fig. 18] Fig. 18 is a partially sectioned enlarged front view showing a configuration of a spark plug in another embodiment.

[Fig. 19] Fig. 19 is a partially enlarged plan view showing a configuration of a ground electrode in another embodiment.

[Fig. 20] Fig. 20 is a partially enlarged plan view showing a configuration of a ground electrode in another embodiment.

[Modes for Carrying Out the Invention]

[0037] Hereafter, a description will be given of embodiments, while referring to the drawings.

[0038] [First Embodiment] Fig. 1 is a partially sectioned front view showing a spark plug 1. In Fig. 1, a description will be given with a direction of an axis CL1 of the spark plug 1 as an up-down direction in the drawing, the lower side as the leading end side of the spark plug 1, and the upper side as the rear end side.

[0039] The spark plug 1 is configured of a hollow cylindrical insulator 2 acting as an insulating body, a hollow cylindrical metal shell 3 which holds the insulator 2, and the like.

[0040] The insulator 2, being formed by sintering alumina or the like, as is well known, includes in the external portion thereof a rear end side barrel portion 10 formed on the rear end side, a large diameter portion 11 formed closer to the leading end side than the rear end side barrel portion 10 so as to protrude outward in a radial direction, a middle barrel portion 12 formed closer to the leading end side than the large diameter portion 11 so as to be smaller in diameter than the large diameter portion 11, and an insulator nose length portion 13 formed closer to the leading end side than the middle barrel portion 12 so as to be smaller in diameter than the middle barrel portion 12. In addition, the large diameter portion 11, the middle barrel portion 12, and the larger proportion of the insulator nose length portion 13, of the insulator 2 are housed inside the metal shell 3. Then, a tapered shoulder 14 is formed at the junction of the middle barrel portion 12 and insulator nose length portion 13, and the insulator 2 is retained on the metal shell 3 by the shoulder 14.

[0041] Furthermore, an axial hole 4 extending along the axis CL1 is formed in the insulator 2 so as to pass through the insulator 2, and a center electrode 5 is inserted and fixed on the leading end side of the axial hole 4. The center electrode 5 has a bar-like (cylindrical) shape as a whole, and a leading end portion thereof protrudes from the leading end of the insulator 2. In addition, the center electrode 5 includes an inner layer 5A formed from copper or a copper alloy and an outer layer 5B formed from an Ni alloy with nickel (Ni) as a primary component. Furthermore, a cylindrical center electrode side tip 31, joined to the outer layer 5B via a welded junction 34 formed by a laser welding or the like, which is formed from a metal containing a noble metal (for example, platinum or iridium) is provided at the leading end portion of the center electrode 5.

[0042] Also, a terminal electrode 6 is inserted and fixed on the rear end side of the axial hole 4 in a condition in which it protrudes from the rear end of the insulator 2.

[0043] Furthermore, a cylindrical resistor 7 is disposed between the center electrode 5 and terminal electrode 6 in the axial hole 4. Both end portions of the resistor 7 are electrically connected to the center electrode 5 and terminal electrode 6 via electrically conductive glass seal layers 8 and 9 respectively.

[0044] In addition, the metal shell 3 is formed in a hollow cylindrical shape from a metal such as a low carbon steel, and a thread portion (a male thread portion) 15 for mounting the spark plug 1 on a combustion device such as an internal combustion engine or a fuel cell reformer is formed on the outer peripheral surface of the metal shell 3. Also, a seat 16 is formed on the rear end side of the thread portion 15 so as to protrude toward the outer peripheral side, and a ring-like gasket 18 is fitted over a thread neck 17 at the rear end of the thread portion 15. Furthermore, a tool engagement portion 19 of hexagonal cross section for engaging a tool such as a wrench when mounting the metal shell 3 in the combustion device is provided on the rear end side of the metal shell 3. Also, a caulked portion 20 bent inward in the radial direction is provided on the rear end side of the metal shell 3.

[0045] In addition, a tapered shoulder 21 for retaining the insulator 2 is provided on the inner peripheral surface of the metal shell 3. Then, the insulator 2 is inserted from the rear end side toward the leading end side of the metal shell 3, and fixed to the metal shell 3 by caulking a rear end side opening portion of the metal shell 3 inward in the radial direction, that is, forming the caulked portion 20, in a condition in which the shoulder 14 of the insulator 2 is retained by the shoulder 21 of the metal shell 3. An annular plate packing 22 is interposed between the shoulders 14 and 21 of both the insulator 2 and the metal shell 3. Because of this, the interior of a combustion chamber is maintained airtight, thus preventing a fuel gas infiltrating into a space between the insulator nose length portion 13 of the insulator 2 and metal shell 3 inner peripheral surface exposed to the interior of the combustion chamber from leaking to the exterior.

[0046] Furthermore, in order to make a caulking seal more complete, annular ring members 23 and 24 are interposed between the metal shell 3 and the insulator 2 on the rear end side of the metal shell 3, and a space between the ring members 23 and 24 is filled with talc 25 powder. That is, the metal shell 3 holds the insulator 2 across the plate packing 22, ring members 23 and 24, and talc 25.

[0047] Also, as shown in Fig. 2, one end portion of a ground electrode 27 having a bar-like shape is joined to a leading end portion 26 of the metal shell 3. The ground electrode 27, being bent back in an approximately intermediate portion, includes an outer layer 27Z formed from an Ni alloy with Ni as a primary component and an inner layer 27I, provided inside the outer layer 27Z, which is formed from a metal (for example, copper, a copper alloy, or pure Ni) with higher thermal conductivity than the outer layer 27Z. In the embodiment, a configuration is adopted such that the distance between the leading end of the inner layer 27I and the other end of the ground electrode 27 is sufficiently small (for example, 2mm or less).

[0048] In addition, in the embodiment, both side surfaces 27S1 and 27S2 adjacent to an opposite surface 27T opposed to the center electrode side tip 31 (positioned on the center electrode 5 side) have a curved shape convex outward, on any cross section in a direction perpendicular to a central axis CL2 of the ground electrode 27, as shown in Fig. 3. Then, when the curvature radii of the external lines of both side surfaces 27S 1 and 27S2 are taken to be R1 (mm) and R2 (mm) respectively on a cross section perpendicular to the central axis CL2 of the ground electrode 27, a configuration is adopted such that $R1 \leq 1.5$ and $R2 \leq 1.5$ are satisfied. When the curvature radii are not constant, each "curvature radius R1 and R2" refers to the curvature radius of a virtual circle passing through three points, one end point and the other end point of the external line of each corresponding side surface 27S1 and 27S2, and the midpoint between the two points.

[0049] Furthermore, the ground electrode 27 is configured in such a way as to have an approximately constant width and cross-sectional area in its longitudinal direction, and when the cross-sectional area of the ground electrode 27 is taken to be SY (mm^2), and the width of the ground electrode 27 is taken to be W (mm), on any cross section in a direction perpendicular to the central axis CL2 of the ground electrode 27, a configuration is adopted such that $2.3 \leq SY \leq 3.5$ and $1.8 \leq W \leq 2.2$ are satisfied. In the embodiment, a configuration is adopted such that the cross-sectional area SY and the like satisfy the heretofore mentioned expressions on any cross section in a direction perpendicular to the central axis CL2, but it is sufficient that a configuration is adopted such that the cross-sectional area SY and the like satisfy the heretofore mentioned expressions on any cross section, in a direction perpendicular to the central axis CL2, of a portion from the longitudinal center of the ground electrode 27 to the one end of the ground electrode 27.

[0050] Moreover, when the cross-sectional area of the inner layer 27I is taken to be SI (mm^2), and the cross-sectional area of the ground electrode 27 is taken to be SZ (mm^2), on a cross section on which the cross-sectional area of the inner layer 27I is largest in a direction perpendicular to the central axis CL2 of the ground electrode 27, SI and SZ are set so as to satisfy $0.2 \leq SI/SZ \leq 0.5$. In the embodiment, in at least half a range in which the inner layer 27I is buried, in the longitudinal direction of the ground electrode 27, the cross-sectional area of the inner layer 27I in a direction perpendicular to the central axis CL2 of the ground electrode 27 is set to 0.2 times or more the cross-sectional area of the ground electrode 27.

[0051] Returning to Fig. 2, a ground electrode side tip 32 formed from a metal containing a noble metal (for example, platinum or iridium) is joined to the leading end side of the opposite surface 27T of the ground electrode 27 in such a

way as to protrude from another end face 27F of the ground electrode 27. The ground electrode side tip 32 has a rectangular cross-sectional shape (refer to Fig. 4), and one end portion thereof is joined to the ground electrode 27 in a condition in which one portion of the one end portion is buried into the ground electrode 27. In addition, another end face 32F of the ground electrode side tip 32 is opposed to the side surface of the leading end portion of the center electrode side tip 31. Then, a spark discharge gap 33 acting as a gap is formed between the side surface of the center electrode side tip 31 and the other end face 32F of the ground electrode side tip 32, and an arrangement is such that, in the spark discharge gap 33, a spark discharge is carried out in a direction approximately parallel to a direction perpendicular to the axis CL1.

[0052] Also, in the embodiment, when a distance along the axis CL1 between a point, on the other end face 32F of the ground electrode side tip 32, positioned closest to the rear end side in the direction of the axis CL1 and a point, on a surface of the center electrode side tip 31 opposed to the other end face 32F of the ground electrode side tip 32, positioned closest to the leading end side along the axis CL1, is taken to be A (mm), and a length of the other end face 32F of the ground electrode side tip 32 along the axis CL1 is taken to be B (mm), a configuration is adopted such that $0.05 \leq A \leq B+0.2$ and $0.3 \leq B \leq 0.7$ are satisfied.

[0053] Furthermore, when the size of the spark discharge gap 33 (the shortest distance between the two tips 31 and 32) is taken to be G (mm), the distance between the center electrode side tip 31 and ground electrode side tip 32 is set so as to satisfy $0.4 \leq G \leq 1.0$. In addition, when the area of the other end face 32F of the ground electrode side tip 32 is taken to be SX (mm^2), each of the width and thickness of the ground electrode side tip 32 is set so as to satisfy $0.3 \leq SX \leq 0.6$ (for example, the ground electrode side tip 32 is such that the width thereof is set to 0.75mm or more and 0.85 or less, and the thickness thereof is set to 0.4mm or more and 0.7 or less).

[0054] In addition, in the embodiment, a configuration is adopted such that an area SA1 (mm^2; in Fig. 5, the region patterned with scattered points) to be described hereafter, shown in Fig. 5, when the ground electrode side tip 32 and the leading end face of the center electrode side tip 31 are projected, along the axis CL1, onto a virtual plane perpendicular to the axis CL1, an area SA2 (mm^2; in Fig. 6, the region patterned with scattered points) to be described hereafter, shown in Fig. 6, when the center electrode side tip 31 and the other end face 32F of the ground electrode side tip 32 are projected, in a direction perpendicular to the axis CL1, onto a virtual plane parallel to the other end face 32F of the ground electrode side tip 32, and a size G (mm) of the spark discharge gap 33, satisfy $0.12 \leq SA1 \times SA2/G(mm^3) \leq 0.49$.

[0055] The area SA1 refers to the area of a region AR1 bounded by a first tangent line TL1 drawn from one end of a side corresponding to the other end face 32F of the ground electrode side tip 32 to a projection region corresponding to the leading end face of the center electrode side tip 31, a second tangent line TL2 drawn from the other end of the side corresponding to the other end face 32F of the ground electrode side tip 32 to the projection region corresponding to the leading end face of the center electrode side tip 31, a projection line (the side) corresponding to the other end face 32F of the ground electrode side tip 32, and a projection line corresponding to the outer periphery of the leading end face of the center electrode side tip 31, as shown in Fig. 5.

[0056] Also, the area SA2 refers to the area of a region AR2 in which a projection region of the center electrode side tip 31 and a projection region of the ground electrode side tip 32 overlap, as shown in Fig. 6.

[0057] As heretofore described in detail, according to the embodiment, a configuration is adopted such that the relative positions of the ground electrode side tip 32 and center electrode side tip 31 satisfy $0.12 \leq SA1 \times SA2/G$. Consequently, it is possible to suppress an increase in discharge voltage, and it is possible to more reliably prevent a spark discharge being generated between only small portions of the ground electrode side tip 32 and center electrode side tip 31, and the ground electrode side tip 32 and the like wearing out locally. As a result of this, it is possible to effectively improve wear resistance.

[0058] Furthermore, as a configuration is adopted such that $SA1 \times SA2/G \leq 0.49$ is satisfied, it is possible to more reliably prevent a flame kernel growth inhibition due to the existence of the ground electrode side tip 32 or center electrode side tip 31, and it is possible to suppress a situation in which a discharge position varies in the extreme. As a result of this, it is possible to realize superior ignitability while sufficiently maintaining the wear resistance improvement effect.

[0059] In addition, as the distance B is set to 0.3mm or more, it is possible to achieve a suppression of overheating in the ground electrode side tip 32, or the like, and as the distance A is set to 0.05mm or more, it is possible to more reliably prevent uneven wear in an edge portion of the center electrode side tip 31 or ground electrode side tip 32. As a result of this, it is possible to achieve a further improvement in wear resistance.

[0060] Moreover, as the distance B is set to 0.7mm or less, it is possible to effectively suppress heat being removed from a flame kernel by the ground electrode side tip 32, or the like, and as the distance A is set to "B+0.2mm" or less, it is possible to cause a flame kernel to grow smoothly toward the central side of the combustion chamber. Because of this, it is possible to further improve ignitability.

[0061] Also, as the size G of the spark discharge gap 33 is set to 0.1mm or less, it is possible to more reliably suppress an increase in discharge voltage, and furthermore, as the area SX is set to $0.3mm^2$ or more, it is possible to secure a still larger wear volume of the ground electrode side tip 32. Because of this, it is possible to achieve a further improvement in wear resistance.

[0062] In addition, as the size G of the spark discharge gap 33 is set to 0.4mm or more, and the area SX is set to 0.6mm^2 or less, it is possible to more effectively suppress a flame kernel growth inhibition due to the ground electrode side tip 32 or the like, and it is possible to further improve ignitability.

[0063] Also, by setting the width W to 1.8mm or more while setting the cross-sectional area SY to 2.3mm^2 or more, it is possible to further suppress an overheating in the ground electrode 27 while sufficiently enhancing the thermal conductivity of the ground electrode 27. As a result of this, it is possible to further improve thermal resistance.

[0064] Furthermore, as the cross-sectional area SY is set to 3.5mm^2 or less, it is possible to more reliably prevent heat being removed from a flame kernel by the ground electrode 27, and as the width W is set to 2.2mm or less, it is possible to effectively suppress a flame kernel growth inhibition due to the ground electrode 27. Because of this, it is possible to achieve a further improvement in ignitability.

[0065] In addition, a configuration is adopted such that the inner layer 27I superior in thermal conductivity is provided inside the ground electrode 27, and $0.2 \leq SI/SZ$ is satisfied. Consequently, it is possible to dramatically enhance the thermal conductivity of the ground electrode 27, and it is possible to very effectively improve thermal resistance.

[0066] Also, as $SI/SZ \leq 0.5$ is set, it is possible to secure a sufficient thickness of the outer layer 27Z, and it is possible to more reliably prevent damage to the outer layer 27Z induced by a thermal expansion of the inner layer 27I.

[0067] Moreover, as both side surfaces 27S1 and 27S2 of the ground electrode 27 are formed into a convexly curved surface, it becomes easier for a fuel gas becomes infiltrate into the spark discharge gap 33, and it is thus possible to further improve ignitability.

[Second Embodiment]

[0068] Next, a second embodiment will be described centered on differences from the first embodiment. In the first embodiment, the ground electrode side tip 32 is joined to the leading end portion of the ground electrode 27, and the other end face 32F of the ground electrode side tip 32 is opposed to the side surface of the center electrode side tip 31. As opposed to this, in the second embodiment, a configuration is adopted such that the ground electrode side tip 32 is not provided, and another end face 37F of a ground electrode 37 is opposed to the side surface of the leading end portion of the center electrode 5 (the side surface of the center electrode side tip 31), as shown in Fig. 7. Then, a spark discharge gap 43 is formed between the other end face 37F of the ground electrode 37 and the side surface of the leading end portion of the center electrode 5 (the side surface of the center electrode side tip 31).

[0069] In addition, in the second embodiment, a configuration is adopted such that an area SB1 (mm^2; in Fig. 8, the region patterned with scattered points) to be described hereafter, shown in Fig. 8, when the ground electrode 37 and the leading end face of the center electrode 5 (center electrode side tip 31) are projected, along the axis CL1, onto a virtual plane perpendicular to the axis CL1, an area SB2 (mm^2; in Fig. 9, the region patterned with scattered points) to be described hereafter, shown in Fig. 9, when the center electrode 5 (center electrode side tip 31) and the other end face 37F of the ground electrode 37 are projected, in a direction perpendicular to the axis CL1, onto a virtual plane parallel to the other end face 37F of the ground electrode 37, and a size G (mm) of the spark discharge gap 43, satisfy $0.21 \leq SB1 \times SB2/G(mm^3) \leq 0.49$.

[0070] The area SB1 refers to the area of a region AR3 bounded by a third tangent line TL3 drawn from one end of a side corresponding to the other end face 37F of the ground electrode 37 to a projection region corresponding to the leading end face of the center electrode 5 (center electrode side tip 31), a fourth tangent line TL4 drawn from the other end of the side corresponding to the other end face 37F of the ground electrode 37 to the projection region corresponding to the leading end face of the center electrode 5 (center electrode side tip 31), a projection line (the side) corresponding to the other end face 37F of the ground electrode 37, and a projection line corresponding to the outer periphery of the leading end face of the center electrode 5 (center electrode side tip 31), as shown in Fig. 8.

[0071] Also, the area SB2 refers to the area of a region AR4 in which a projection region of the center electrode 5 (center electrode side tip 31) and a projection region of the other end face 37F of the ground electrode 37 overlap, as shown in Fig. 9.

[0072] As above, according to the second embodiment, working effects the same as those of the first embodiment are achieved.

[0073] In particular, in the second embodiment, it is possible, by satisfying $0.21 \leq SB1 \times SB2/G$, to realize superior wear resistance even when the ground electrode 37 inferior in wear resistance compared with the ground electrode side tip 32 is opposed to the center electrode 5 (center electrode side tip 31).

[0074] Next, in order to confirm the working effects achieved by the heretofore described embodiments, spark plug samples wherein the ground electrode side tip is provided on the ground electrode, and the value of the expression $SA1 \times SA2/G$ (mm^3) is variously changed, are fabricated, and a desktop spark endurance test and flame kernel growth evaluation test are carried out on each sample. Then, test results of the individual samples are compared with test results when the tests are carried out on spark plug samples (samples in a comparison example; refer to Fig. 10) wherein a ground electrode side tip (0.8mm in length) formed from an iridium alloy is provided on the opposite surface of the other

end portion of the ground electrode, and the other end face of the ground electrode side tip is opposed to the leading end face of a center electrode side tip (0.5mm in length). Herein, it is taken that samples are given a "o" evaluation when they have performance superior to that of the samples in the comparison example, and that samples are given a "×" evaluation when they have performance equivalent or inferior to that of the samples in the comparison example.

[0075] The outline of the desktop spark endurance test is as follows. That is, after mounting samples in a predetermined chamber, the pressure in the chamber is set to 1.6MPa, and each sample is discharged over 300 hours with the frequency of an applied voltage set to 100Hz (that is, at the rate of 6000 times per minute). Then, a spark plug gap size is measured after an elapse of 300 hours, and an increment (a gap increment) with respect to a spark discharge gap size (an initial gap size G) before the test (in an initial condition) is measured. It can be said that the smaller the gap increment, the more superior in terms of wear resistance.

[0076] Furthermore, the outline of the flame kernel growth evaluation test is as follows. That is, after mounting samples in a predetermined chamber, a predetermined voltage is applied to each sample, generating a spark discharge. Then, after an elapse of a predetermined time after the spark discharge, as well as a schlieren image in the center of the spark discharge gap and in the vicinity thereof being obtained, the obtained schlieren image is binarized using a predetermined threshold, and the area of a high-density portion (that is, the area of a postgrowth flame kernel) is measured. It can be said that the larger the area, the more superior in terms of ignitability.

[0077] Results of the two tests are shown in Table 1. The outside diameter of the leading end face of the center electrode side tip, the width of the ground electrode side tip, the distance A, the length B, and the initial gap size G, in each sample are shown in Table 1 as reference. Also, each sample is such that the ground electrode is formed into a rectangular cross-sectional shape.

[Table 1]

Outside diameter (mm) of leading end face of center electrode side tip	Width (mm) of ground electrode side tip	Length B (mm)	Distance A (mm)	Initial gap size G (mm)	SA1×SA2/G	Wear resistance	Ignitability
0.4	0.4	0.3	0.1	0.4	0.02	×	○
0.4	1.2	0.3	0.1	1.0	0.04	×	○
0.8	0.4	0.7	0.1	0.4	0.05	×	○
0.8	0.4	0.7	0.1	1.0	0.05	×	○
0.8	0.8	0.5	0.1	1.0	0.07	×	○
0.8	1.2	0.7	0.1	1.0	0.07	×	○
0.4	0.4	0.3	0.7	1.0	0.12	○	○
0.4	0.4	0.7	0.7	1.0	0.12	○	○
0.4	0.4	0.3	0.7	0.4	0.13	○	○
0.4	0.4	0.7	0.7	0.4	0.13	○	○
0.4	0.8	0.5	0.7	1.0	0.18	○	○
0.4	0.8	0.5	0.7	0.4	0.21	○	○
0.4	1.2	0.3	0.7	1.0	0.25	○	○
0.4	1.2	0.7	0.7	1.0	0.25	○	○
0.4	1.2	0.3	0.7	0.4	0.31	○	○
0.4	1.2	0.7	0.7	0.4	0.31	○	○
0.6	0.8	0.5	0.7	1.0	0.32	○	○
0.8	0.4	0.3	0.7	1.0	0.33	○	○
0.8	0.4	0.7	0.7	0.4	0.34	○	○
0.6	0.8	0.5	0.7	0.4	0.37	○	○
0.7	0.8	0.5	0.7	1.0	0.40	○	○

(continued)

Outside diameter (mm) of leading end face of center electrode side tip	Width (mm) of ground electrode side tip	Length B (mm)	Distance A (mm)	Initial gap size G (mm)	SA1×SA2/G	Wear resistance	Ignitability
0.7	0.8	0.5	0.7	0.4	0.45	○	○
0.8	0.8	0.5	0.7	1.0	0.49	○	○
0.8	0.8	0.5	0.7	0.4	0.55	○	×
0.8	1.2	0.3	0.7	1.0	0.64	○	×
0.8	1.2	0.7	0.7	1.0	0.64	○	×
0.8	1.2	0.3	0.7	0.4	0.78	○	×
0.8	1.2	0.7	0.7	0.4	0.78	○	×

[0078] As shown in Table 1, it is revealed that the samples with SA1×SA2/G set to larger than 0.49 are inferior in ignitability. It is conceivable that this is because a flame kernel growth is inhibited by the ground electrode side tip (ground electrode) or center electrode side tip, or variation occurs in the discharge position.

[0079] Also, it is found that the samples are inferior in wear resistance when SA1×SA2/G is set to smaller than 0.12. It is conceivable that this is because the ground electrode side tip or center electrode side tip wears out locally, or the discharge voltage increases.

[0080] As opposed to this, it is confirmed that the samples satisfying $0.12 \leq SA1 \times SA2/G \leq 0.49$ have performance superior in both ignitability and wear resistance.

[0081] Next, plural spark plug samples wherein, when the leading end side is taken to be a plus side, and the rear end side is taken to be a minus side, in the direction of the axis, with a point on the other end face of the ground electrode side tip positioned closest to the rear end side as a reference, the distance A (mm) along the axis from the reference to the leading end face of the center electrode side tip and the length B (mm) of the other end face of the ground electrode side tip along the axis are variously changed, are fabricated, and an ignitablity evaluation test and the desktop spark endurance test are carried out on each sample.

[0082] The outline of the ignitability evaluation test is as follows. That is, after mounting each sample on a four cylinder engine (N/A) of 1.6L displacement, an ignition timing is set to 60° BTDC, and the engine is operated at a rotation speed of 1600rpm. Then, while air/fuel ratios are being gradually increased (a fuel is being made thinner), an engine torque variation rate is measured for each air/fuel ratio, and an air/fuel ratio when the engine torque variation rate exceeds 5% is specified as a critical air/fuel ratio. This means that the higher the critical air/fuel ratio, the more superior in ignitability.

[0083] Results of the desktop spark endurance test are shown in Fig. 11, and results of the ignitability evaluation test are shown in Fig. 12. In Figs. 11 and 12, test results of the samples with the distance B set to 0.1mm are indicated by circles, test results of the samples with the distance B set to 0.3mm are indicated by triangles, test results of the samples with the distance B set to 0.5mm are indicated by squares, and test results of the samples with the distance B set to 0.7mm are indicated by diamonds. Also, in Fig. 12, test results of the samples with the distance B set to 0.9mm are indicated by cross marks. As well as the desktop spark endurance test, an_existing equipment endurance test [a test wherein, after mounting each sample on a four cylinder engine (DOHC I/C T/C) of 0.66L displacement, the engine is operated at full throttle (=6000rpm) over 500 hours, and a gap increment is measured after an elapse of 500 hours] is carried out on each sample, but approximately the same results are obtained in both tests. For this reason, only the results of the desktop spark endurance test are shown in Fig. 11. Also, in Fig. 11, the distance A being minus means that the other end face of the ground electrode side tip is positioned closer to the leading end side in the direction of the axis than the leading end face of the center electrode side tip. Furthermore, each sample is such that $0.12 \leq SA1 \times SA2/G(mm^3) \leq 0.49$, $0.3 \leq SX(mm) \leq 0.6$, and $0.4 \leq G(mm) \leq 1.0$ are satisfied, and the ground electrode is formed into a rectangular cross-sectional shape.

[0084] As shown in Fig. 11, it is revealed that the samples with the distance B set to less than 0.3mm are slightly inferior in wear resistance as the spark discharge gap is liable to increase. It is conceivable that this is because wear of the ground electrode side tip progresses quickly because the ground electrode side tip is overheated, or a sufficient wear volume cannot be secured. Also, it is confirmed that the samples with the distance A set to less than 0.05mm are also slightly inferior in wear resistance. It is conceivable that this is because spark discharges with the edge portion of each of the center electrode side tip and ground electrode side tip as a base point are concentrically generated.

[0085] Furthermore, as shown in Fig. 12, it is found that the samples with the distance B set to greater than 0.7mm,

and the samples with the distance A set to greater than "B+0.2mm", are slightly inferior in ignitability. It is conceivable that this is because a flame kernel growth becomes liable to be inhibited by the ground electrode side tip or center electrode side tip, or the like.

[0086] As opposed to this, it is revealed that the samples with the distance A set to 0.05mm or more and the distance B set to 0.3mm or more have superior wear resistance as the gap increment is less than 0.10mm. Furthermore, it is found that the samples with the distance A set to "B+0.2mm" or less and the distance B set to 0.7mm or less are superior in ignitability as the critical air/fuel ratio exceeds 20.

[0087] Next, spark plug samples wherein the area SX(mm^2) of the other end face of the ground electrode side tip and the spark discharge gap size G are variously changed are fabricated, and the desktop spark endurance test and ignitability evaluation test are carried out on each sample. Results of the desktop spark endurance test are shown in Fig. 13, and results of the ignitability evaluation test are shown in Fig. 14. In Figs. 13 and 14, test results of the samples with the area SX set to 0.1mm^2 are indicated by circles, test results of the samples with the area SX set to 0.3mm^2 are indicated by triangles, test results of the samples with the area SX set to 0.6mm^2 are indicated by squares, and test results of the samples with the area SX set to 0.9mm^2 are indicated by diamonds. Also, in the desktop spark endurance test, each sample is such that the distance A is set to 0.05mm, and the distance B is set to 0.3mm, while in the ignitability evaluation test, each sample is such that the distance A is set to 0.9mm, and the distance B is set to 0.7mm. Furthermore, in both tests, each sample is configured in such a way as to satisfy $0.12 \leq SA1 \times SA2/G(mm^3) \leq 0.49$, and is such that the ground electrode is formed into a rectangular cross-sectional shape.

[0088] As shown in Fig. 13, it is confirmed that the samples with the spark discharge gap size G set to over 1.0mm and the samples with the area SX set to less than 0.3mm^2 are slightly inferior in wear resistance as the gap increment becomes comparatively large. It is conceivable that this is because the discharge voltage increases, or no sufficient wear volume of the ground electrode side tip is secured.

[0089] Also, as shown in Fig. 14, it is found that the samples with the spark discharge gap size G set to less then 0.4mm and the samples with the area SX set to larger than 0.6mm^2 are slightly inferior in ignitability. It is conceivable that this is because a flame kernel growth becomes liable to be inhibited by the ground electrode side tip or the like.

[0090] As opposed to this, it is revealed that the samples with the spark discharge gap size G set to 0.4mm or more and 1.0mm or less, and the area SX set to 0.3mm^2 or more and 0.6mm^2 or less, have more superior wear resistance and ignitability.

[0091] According to the above test results, it can be said that, in order to realize performance superior in both ignitability and wear resistance with a spark plug which, including the ground electrode side tip, has the spark discharge gap between the ground electrode side tip and center electrode, it is preferable to satisfy $0.12 \leq SA1 \times SA2/G \leq 0.49$, $0.05 \leq A(mm) \leq B+0.2$, $0.3 \leq B(mm) \leq 0.7$, $0.3 \leq SX \leq (mm2) \leq 0.6$, and $0.4 \leq G(mm) \leq 1.0$.

[0092] Next, spark plug samples wherein a configuration is adopted such that the ground electrode side tip is not provided, and the other end face of the ground electrode is opposed to the side surface of the leading end portion of the center electrode, and the value of the expression SB1×SB2/G is variously changed, are fabricated, and the desktop spark endurance test and flame kernel growth evaluation test are carried out on each sample. Results of both tests are shown in Table 2. The outside diameter of the leading end face of the center electrode side tip, the width of the ground electrode leading end, the distance A, and the initial gap size G, in each sample are shown in Table 2 as reference.

[Table 2]

Outside diameter (mm) of leading end face of center electrode side tip	Width (mm) of leading end of ground electrode	Distance A (mm)	Initial gap size G (mm)	SB1×SB2/G	Wear resistance	Ignitability
0.4	0.4	0.1	0.4	0.02	×	○
0.4	1.2	0.1	1.0	0.04	×	○
0.8	0.4	0.1	1.0	0.05	×	○
0.8	0.4	0.1	0.4	0.05	×	○
0.8	0.8	0.1	1.0	0.07	×	○
0.8	1.2	0.1	1.0	0.07	×	○
0.4	0.4	0.7	1.0	0.12	×	○
0.4	0.4	0.7	0.4	0.13	×	○
0.4	0.8	0.7	1.0	0.18	×	○
0.4	0.8	0.7	0.4	0.21	○	○

(continued)

Outside diameter (mm) of leading end face of center electrode side tip	Width (mm) of leading end of ground electrode	Distance A (mm)	Initial gap size G (mm)	SB1×SB2/G	Wear resistance	Ignitability
0.4	1.2	0.7	1.0	0.25	○	○
0.4	1.2	0.7	0.4	0.31	○	○
0.6	0.8	0.7	1.0	0.32	○	○
0.8	0.4	0.7	1.0	0.33	○	○
0.8	0.4	0.7	0.4	0.34	○	○
0.6	0.8	0.7	0.4	0.37	○	○
0.7	0.8	0.7	1.0	0.40	○	○
0.7	0.8	0.7	0.4	0.45	○	○
0.8	0.8	0.7	1.0	0.49	○	○
0.8	0.8	0.7	0.4	0.55	○	×
0.8	1.2	0.7	1.0	0.64	○	×
0.8	1.2	0.7	0.4	0.78	○	×

[0093] As shown in Table 2, it is revealed that the samples with SB1×SB2/G set to larger than 0.49 are inferior in ignitability. It is conceivable that this is because a flame kernel growth is inhibited by the ground electrode or center electrode, or variation occurs in the discharge position.

[0094] Also, it is found that the samples are inferior in wear resistance when SB1×SB2/G is set to smaller than 0.21. It is conceivable that this is because the ground electrode or center electrode wears out locally, or the discharge voltage increases.

[0095] As opposed to this, it is confirmed that the samples satisfying $0.21 \leq SB1 \times SB2/G \leq 0.49$ have performance superior in both ignitability and wear resistance.

[0096] According to the heretofore described test results, it can be said that it is preferable to satisfy $0.21 \leq SB1 \times SB2/G \leq 0.49$ in order to realize performance superior in both ignitability and wear resistance with a spark plug which does not include the ground electrode side tip, and has the spark discharge gap between the ground electrode and center electrode.

[0097] Next, a thermal resistance evaluation test and the ignitability evaluation test wherein the ignition timing is changed from 60° BTDC to 70° BTDC (that is, stricter conditions are set) are carried out on spark plug samples wherein the cross-sectional area SY (mm^2) of the ground electrode and the width W (mm) of the ground electrode are variously changed.

[0098] The outline of the thermal resistance test is as follows. That is, after mounting samples on an engine of SC17.6 (SAE J2203) of which the compression ratio is set to 5.6 and the ignition timing is set to 30° BTDC, a certain amount of supercharging is carried out while the engine is being operated at 2700rpm using a benzene-based fuel, and a fuel injection amount at which the temperature in the combustion chamber is highest is specified. Then, it is confirmed whether or not preignition occurs when the engine is operated at the specified fuel injection amount.

[0099] Results of the thermal resistance evaluation test are shown in Tables 3 and 4, and results of the ignitability evaluation test are shown in Fig. 15. Test results of samples wherein the cross-sectional area SY is changed after setting the width W to 1.8mm are shown in Table 3, and test results of samples wherein the width W is changed after setting the cross-sectional area SY to $2.3mm^2$ are shown in Table 4. Also, in Fig. 15, test results of the samples with the cross-sectional area SY set to $2.1mm^2$ are indicated by circles, test results of the samples with the cross-sectional area SY set to $2.3mm^2$ are indicated by triangles, test results of the samples with the cross-sectional area SY set to $2.9mm^2$ are indicated by squares, test results of the samples with the cross-sectional area SY set to $3.5mm^2$ are indicated by diamonds, and test results of the samples with the cross-sectional area SY set to $4.0mm^2$ are indicated by cross marks. Each sample is configured in such a way as to satisfy $0.12 \leq SA1 \times SA2/G \leq 0.49$, and is such that the ground electrode is formed into a rectangular cross-sectional shape.

[Table 3]

Cross-sectional area SY (mm^2)	Presence or absence of preignition
2.1	Present
2.3	Absent
2.6	Absent
2.9	Absent
3.2	Absent
3.5	Absent
4.0	Absent

[Table 4]

Width W (mm)	Presence or absence of preignition
1.5	Present
1.8	Absent
2.2	Absent
2.5	Absent

[0100] As shown in Table 3, it is confirmed that preignition occurs in the samples with the cross-sectional area SY set to less than $2.3mm^2$. It is conceivable that this is because, as the ground electrode is comparatively thin, the efficiency of thermal conduction from the other end portion to the one end portion of the ground electrode decreases, and the ground electrode is overheated. Also, as shown in Table 4, it is found that the samples with the width W set to less than 1.8mm are inferior in thermal resistance even when the cross-sectional area is set to $2.3mm^2$. It is conceivable that this is because the thickness of the ground electrode increases eventually by reducing the width, as a result of which the ground electrode takes a form in which it protrudes toward the combustion chamber center side which is higher in temperature, and the amount of heat received by the ground electrode increases.

[0101] In addition, as shown in Fig. 15, it is revealed that the samples with the cross-sectional area SY set to over $3.5mm^2$ and the samples with the width W set to over 2.2mm are slightly inferior in ignitability. It is conceivable that this is because heat becomes liable to be removed from a flame kernel by the ground electrode, or the flame kernel growth becomes liable to be inhibited by the ground electrode.

[0102] As opposed to this, it is found that the samples with the cross-sectional area SY set to $2.3mm^2$ or more and $3.5mm^2$ or less, and the width W set to 1.8mm or more and 2.2mm or less, are more superior in both ignitability and thermal resistance.

[0103] According to the heretofore described test results, it can be said that it is preferable to satisfy $2.3 \leq SY(mm^2) \leq 3.5$ and $1.8 \leq W(mm) \leq 2.2$ in order to further improve both ignitability and thermal resistance.

[0104] Next, spark plug samples wherein SI/SZ is variously changed by increasing and reducing the cross-sectional area SI(mm^2) of the inner layer of the ground electrode and the cross-sectional area SZ (mm^2) of the ground electrode, on a cross section on which the cross-sectional area of the inner layer is largest in a direction perpendicular to the central axis of the ground electrode, are fabricated, and a desktop burner test and thermal resistance improvement value measurement test are carried out on each sample.

[0105] The outline of the desktop burner test is as follows. That is, each sample, after being heated by a burner for one minute in such a way that the temperature of the ground electrode reaches 1050°C in an ambient air atmosphere, is slowly cooled for one minute, and with this treatment as one cycle, 3000 cycles are implemented. Then, by observing the ground electrode after 3000 cycles are finished, the presence or absence of a crack in the outer layer induced by an expansion of the inner layer is confirmed. Results of the test are shown in Table 5.

[0106] Also, the outline of the thermal resistance improvement value measurement test is as follows. That is, thermal values of spark plug samples wherein, after setting the cross-sectional area SY of the ground electrode to $2.3mm^2$, $2.6mm^2$, or $2.9mm^2$, the ground electrode is formed from an Ni alloy, without the inner layer being provided therein, are measured one for each of the cross-sectional areas SY. Then, each of thermal values of spark plug samples wherein, after setting the cross-sectional area SY of the ground electrode to $2.3mm^2$, $2.6mm^2$, or $2.9mm^2$, SI/SZ is variously changed, is measured, and improvement values of the thermal values with respect to thermal values of compared

samples with the same cross-sectional area SY are measured. Results of the test are shown in Fig. 16. In Fig. 16, test results of the samples with the cross-sectional area SY set to 2.3mm^2 are indicated by circles, test results of the samples with the cross-sectional area SY set to 2.6mm^2 are indicated by triangles, and test results of the samples with the cross-sectional area SY set to 2.9mm^2 are indicated by squares.

[0107] Also, thermal values are measured in the following way. That is, after mounting samples on an engine of SC17.6 (SAE J2203) of which the compression ratio is set to 5.6, and the ignition timing is set to 30° BTDC, a certain amount of supercharging is carried out while the engine is being operated at a rotation speed of 2700rpm using a benzene-based fuel, and a fuel injection amount is adjusted to one at which the temperature of the combustion chamber is highest at the supercharging amount. An increase of the supercharging amount and the adjustment of the fuel injection amount are repeatedly carried out, and a supercharging pressure immediately before preignition (premature ignition) occurs is specified. Subsequently, as well as an engine output when the engine is stably operated for three minutes by carrying out a fine adjustment of the specified supercharging pressure and the adjustment of the fuel injection amount being measured, a mean effective pressure (PSI) is calculated, and the mean effective pressure is specified as the thermal value of each sample.

[Table 5]

SI/SZ	Presence or absence of crack in outer layer
0.1	Absent
0.2	Absent
0.3	Absent
0.4	Absent
0.5	Absent
0.6	Present

[0108] As shown in Table 5 and Fig. 16, it is revealed that the samples with SI/SZ set to 0.2 or more and 0.5 or less are such that no crack occurs in the outer layer, and it is possible to dramatically improve thermal resistance. It is conceivable that this is because, by setting SI/SZ to 0.5 or less, the outer layer has a thickness enough to withstand a thermal expansion of the inner layer, and by setting SI/SZ to 0.2 or more, a sufficient volume of the inner layer superior in thermal conductivity is secured, and the thermal conductivity of the ground electrode is improved.

[0109] According to the heretofore described test results, it can be said that it is preferable, from the standpoint of achieving a further improvement in thermal resistance while achieving a prevention of damage to the ground electrode (outer layer), to configure in such a way as to satisfy $0.2 \leq SI/SZ \leq 0.5$.

[0110] Next, spark plug samples wherein the ground electrode is formed into a rectangular cross-sectional shape, and spark plug samples wherein the side surface of the ground electrode is formed into a curved shape convex outward, and a curvature radius R of the side surface is set to 1.2mm, 1.5mm, or 1.8mm, are fabricated. Then, after mounting each sample on an engine in such a way that the position of one ground electrode relative to the engine (fuel nozzle) differs from that of another, the ignitability evaluation test (the ignition timing is changed from 60° BTDC to 70° BTDC) is carried out, and a critical air/fuel ratio in each relative position is measured. A range in which the critical air/fuel ratio fluctuates accompanying a change of the relative position in each sample is shown in Fig. 17.

[0111] As shown in Fig. 17, it is revealed that the samples with the curvature radius R to 1.5mm or less are such that it is possible to stably realize superior ignitability as the critical air/fuel ratio fluctuation range becomes very much narrower, and the critical air/fuel ratio becomes larger overall. It is conceivable that this is because a fuel gas becomes likely to make its way into the spark discharge gap in a form such as to flow down the ground electrode.

[0112] According to the heretofore described test results, it can be said that, in order to further improve ignitability, it is preferable to form the side surface of the ground electrode into a curved shape convex outward, and to set the curvature radius R of the side surface to 1.5mm or less.

[0113] The invention, not being limited to the contents described in the heretofore described embodiments, may be implemented in, for example, the following ways. It goes without saying that other applications and modification examples which are not illustrated below are also possible as a matter of course.

(a) In the first embodiment, the ground electrode side tip 32 is joined to the opposite surface 27T of the ground electrode 27, but a ground electrode side tip 42 may be joined to the other end face 27F of the ground side electrode 27, as shown in Fig. 18.

(b) In the second embodiment, the center electrode side tip 31 is provided at the leading end portion of the center

electrode 5, but the center electrode 5 may be configured without providing the center electrode side tip 31.

(c) In the heretofore described embodiments, the ground electrode 27 is configured in such a way as to have an approximately constant width in its longitudinal direction, but a configuration may be adopted such that a tapered portion 48 (49) is provided in the leading end portion of the ground electrode 27 (37), and the ground electrode 27 (37) is gradually reduced in width toward the other end side thereof. In this case, a flame kernel growth inhibition due to the ground electrode 27 (37) is further suppressed, and it is thus possible to further improve ignitability.

(d) In the heretofore described embodiments, a description is given wherein the ground electrode 27 forms a two-layer structure, but the ground electrode 27 may be configured from a single metal (for example, an Ni alloy), or may be configured in such a way as to form a multi-layer structure with three layers or more. When the multi-layer structure is formed, it is desirable that a layer inside the outer layer 27Z includes a metal with better thermal conductivity than the outer layer 27Z. For example, an interlayer configured from a copper alloy or pure copper may be provided inside the outer layer 27Z, and an innermost layer configured from pure nickel provided inside the interlayer. Also, when the ground electrode 27 forms a three or more layer structure, plural layers including a metal with better thermal conductivity than the outer layer 27Z correspond to the inner layer 27I. For example, when adopting a configuration wherein the interlayer and innermost layer are provided, the interlayer and innermost layer correspond to the inner layer 27I.

(e) In the heretofore described embodiments, an embodiment is given of a case in which the ground electrode 27 is joined to the leading end portion 26 of the metal shell 3, but the invention can also be applied to a case in which a ground electrode is formed in such a way as to cut out one portion of a metal shell (or one portion of a leading end metal welded to the metal shell in advance) (for example, JP-A-2006-236906).

(f) In the heretofore described embodiments, the tool engagement portion 19 is formed into a hexagonal cross-sectional shape, but the shape of the tool engagement portion 19 is not limited to this kind of shape. The tool engagement portion 19 may be formed in, for example, a Bi-HEX (variant dodecagonal) shape [ISO22977:2005(E)].

[Description of Reference Numerals and Signs]

[0114]

1 Spark plug
2 Insulator (insulating body)
3 Metal shell
4 Axial hole
5 Center electrode
27 Ground electrode
27F Another end face (of ground electrode)
27I Inner layer
27T Opposite surface (of ground electrode)
27S1, 27S2 Side surface (of ground electrode)
27Z Outer layer
31 Center electrode side tip
32 Ground electrode side tip
32F Another end face (of ground electrode side tip)
33 Spark discharge gap (gap)
CL1 Axis
CL2 Central axis (of ground electrode)
TL1 First tangent line
TL2 Second tangent line
TL3 Third tangent line
TL4 Fourth tangent line

Claims

1. A spark plug (1) comprising: an insulating body (2) having an axial hole (4) passing therethrough in a direction of an axis (CL1); a center electrode (5) inserted in the axial hole (4); a metal shell (3) provided on an outer periphery of the insulating body (2); a ground electrode (27) fixed to a leading end portion of the metal shell (3); and a ground electrode side tip (32), formed from a metal containing a noble metal, of which at least one end portion is joined to a leading end portion of the ground electrode (27), the center electrode (5) having at its leading end portion a center

electrode side tip (31) formed from a metal containing a noble metal, another end face (32F) of the ground electrode side tip (32) being opposed to a side surface of the center electrode side tip (31), and a gap (33) being formed between the other end face (32F) of the ground electrode side tip (32) and the side surface of the center electrode side tip (31),

characterized in that

when an area of a region, on a projection plane onto which the ground electrode side tip (32) and a leading end face of the center electrode side tip (31) are projected on a virtual plane perpendicular to the axis (CL1), bounded by a first tangent line (TL1) drawn from one end of a side corresponding to the other end face (32F) of the ground electrode side tip (32) to a projection region corresponding to the leading end face of the center electrode side tip (31), a second tangent line (TL2) drawn from the other end of the side corresponding to the other end face (32F) of the ground electrode side tip (32) to the projection region corresponding to the leading end face of the center electrode side tip (31), a projection line corresponding to the other end face (32F) of the ground electrode side tip (32), and a projection line corresponding to the outer periphery of the leading end face of the center electrode side tip (31), is taken to be SA1 (mm^2),

an area of a region in which a projection region of the center electrode side tip (31) and a projection region of the other end face (32F) of the ground electrode side tip (32) overlap when the center electrode side tip (31) and the other end face (32F) of the ground electrode side tip (32) are projected onto a virtual plane parallel to the other end face (32F) of the ground electrode side tip (32), is taken to be SA2 (mm^2), and

the size of the gap (33) is taken to be G (mm),

$0.12 \leq SA1 \times SA2/G(mm^3) \leq 0.49$ is satisfied,

when a distance along the axis (CL1) between a point, on the other end face (32F) of the ground electrode side tip (32), positioned closest to a rear end side in the direction of the axis (CL1), and a point, on a surface of the center electrode side tip (31) opposed to the other end face (32F) of the ground electrode side tip (32), positioned closest to the leading end side along the axis (CL1), is taken to be A (mm), and

a length along the axis (CL1) of the other end face (32F) of the ground electrode side tip (32) is taken to be B (mm), $0.05 \leq A \leq B+0.2$ and $0.3 \leq B \leq 0.7$ are satisfied, and

when the area of the other end face (32F) of the ground electrode side tip (32) is taken to be SX (mm^2), $0.3 \leq SX \leq 0.6$ and $0.4 \leq G \leq 1.0$ are satisfied.

2. The spark plug (1) according to claim 1, **characterized in that**
when a cross-sectional area of the ground electrode (27) is taken to be SY (mm^2), and the width of the ground electrode (27) is taken to be W (mm), on any cross section, of a portion from the longitudinal center to the one end of the ground electrode (27), in a direction perpendicular to a central axis (CL2) of the ground electrode (27), $2.3 \leq SY \leq 3.5$ and $1.8 \leq W \leq 2.2$ are satisfied.

3. The spark plug (1) according to any one of claims 1 to 2, **characterized in that**
the ground electrode (27) includes an outer layer (27Z) and an inner layer (27I), provided inside the outer layer (27Z), which is formed from a metal with better thermal conductivity than the outer layer (27Z), and
when a cross-sectional area of the inner layer (27I) is taken to be SI (mm^2), and the cross-sectional area of the ground electrode (27) is taken to be SZ (mm^2), on a cross section on which the cross-sectional area of the inner layer (27I) is largest in a direction perpendicular to the central axis (CL2) of the ground electrode (27), $0.2 \leq SI/SZ \leq 0.5$ is satisfied.

4. The spark plug (1) according to any one of claims 1 to 3, **characterized in that**
both side surfaces (27S1 and 27S2) of the ground electrode (27) adjacent to an opposite surface (27T) of the ground electrode (27) opposed to the center electrode (5) form a curved shape convex outward, and
when the curvature radii of the external lines of the two side surfaces (27S1 and 27S2) are taken to be R (mm) on a cross section perpendicular to the central axis (CL2) of the ground electrode (27), $R \leq 1.5$ is satisfied.

Patentansprüche

1. Zündkerze (1) aufweisend: einen isolierenden Körper (2) mit einer axialen Bohrung (4), die durch ihn in eine Richtung einer Achse (CL1) durchgeht; eine Mittelelektrode (5), die in die axiale Bohrung (4) eingefügt ist; ein Metallgehäuse (3), das auf einem Außenumfang des isolierenden Körpers (2) bereitgestellt ist; eine Masseelektrode (27), die an einem vorderen Endabschnitt des Metallgehäuses (3) befestigt ist, und eine Masseelektroden-Seitenspitze (32), die aus einem Metall gebildet ist, das ein Edelmetall enthält, von der mindestens ein Endabschnitt mit einem vorderen

Endabschnitt der Masseelektrode (27) verbunden ist, hat, wobei die Mittelelektrode (5) an ihrem vorderen Endabschnitt eine Mittelelektroden-Seitenspitze (31) hat, die aus einem Metall, das ein Edelmetall enthält, gebildet ist, wobei eine andere Endseite (32F) der Masseelektroden-Seitenspitze (32) einer Seitenfläche der Mittelelektroden-Seitenspitze (31) entgegengesetzt ist, und einen Spalt (33), der zwischen der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) und der Seitenfläche der Mittelelektroden-Seitenspitze (31) gebildet ist,
dadurch gekennzeichnet, dass
wenn eine Fläche eines Bereichs auf einer Projektionsebene, auf die die Masseelektroden-Seitenspitze (32) und eine vordere Endseite der Mittelelektroden-Seitenspitze (31) auf einer virtuellen Ebene senkrecht zu der Achse (CL1) projiziert werden, die durch eine erste tangierende Linie (TL1), die von einem Ende einer Seite gezeichnet wird, die der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) entspricht, zu einem Projektionsbereich, der der vorderen Endseite der Mittelelektronen-Seitenspitze (31) entspricht, gezogen wird, eine zweite tangierende Linie (TL2) von dem anderen Ende der Seite, die der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) entspricht, zu dem Projektionsbereich, der der vorderen Endseite der Mittelelektroden-Seitenspitze (31) entspricht, gezogen wird, eine Projektionslinie, die der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) entspricht, und eine Projektionslinie, die dem Außenumfang der vorderen Endseite der Mittelelektroden-Seitenspitze (31) entspricht, begrenzt wird, als SA1 (mm^2) genommen wird,
eine Fläche eines Bereichs, in dem ein Projektionsbereich der Mittelelektroden-Seitenspitze (31) und ein Projektionsbereich der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) überlappen, wenn die Mittelelektroden-Seitenspitze (31) und die andere Endseite (32F) der Masseelektroden-Seitenspitze (32) auf eine virtuelle Ebene parallel zu der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) projiziert werden, als SA2 (mm^2) genommen wird, und
die Größe des Spalts (33) als G (mm) genommen wird,
$0{,}12 \leq SA1 \times SA2 / G\ (mm^3) \leq 0{,}49$ erfüllt ist,
wenn eine Entfernung entlang der Achse (CL1) zwischen einem Punkt auf der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) positioniert, am nächsten an einer hinteren Endseite in die Richtung der Achse (CL1), und einem Punkt auf einer Fläche der Mittelelektroden-Seitenspitze (31), die der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) entgegengesetzt ist, positioniert am nächsten an der vorderen Endseite entlang der Achse (CL1), als A (mm) genommen wird, und
eine Länge entlang der Achse (CL1) der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) als B (mm) genommen wird,
$0{,}05 \leq A \leq B + 0{,}2$ und $0{,}3 \leq B \leq 0{,}7$ erfüllt sind, und
wenn die Fläche der anderen Endseite (32F) der Masseelektroden-Seitenspitze (32) als SX (mm^2) genommen wird,
$0{,}3 \leq SX \leq 0{,}6$ und $0{,}4 \leq G \leq 1{,}0$ erfüllt sind.

2. Zündkerze (1) nach Anspruch 1, **dadurch gekennzeichnet, dass**
wenn eine Querschnittfläche der Masseelektrode (27) als SY (mm^2) betragend genommen wird, und die Breite der Masseelektrode (27) als W (mm) betragend genommen wird, auf einem Querschnitt eines Abschnitts von der Längsmitte zu dem einen Ende der Masseelektrode (27) in eine Richtung senkrecht zu einer zentralen Achse (CL2) der Masseelektrode (27),
$2{,}3 \leq SY \leq 3{,}5$ und $1{,}8 \leq W \leq 2{,}2$ erfüllt sind.

3. Zündkerze (1) nach einem der Ansprüche 1 bis 2, **dadurch gekennzeichnet, dass**
die Masseelektrode (27) eine Außenschicht (27Z) und eine Innenschicht (27I), die innerhalb der Außenschicht (27Z) bereitgestellt ist, aufweist, die aus einem Metall mit besserer Wärmeleitfähigkeit als die Außenschicht (27Z) gebildet ist, und
wenn eine Querschnittfläche der inneren Schicht (271) als SI (mm^2) genommen wird, und die Querschnittfläche der Masseelektrode (27) als SZ (mm^2) genommen wird, auf einem Querschnitt, auf dem die Querschnittfläche der inneren Schicht (271) in einer Richtung senkrecht zu der zentralen Achse (CL2) der Masseelektrode (27) am breitesten ist,
$0{,}2 \leq SI / SZ \leq 0{,}5$ erfüllt ist.

4. Zündkerze (1) nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass**
beide Seitenflächen (27S1 und 27S2) der Masseelektrode (27) benachbart zu einer entgegengesetzten Fläche (27T) der Masseelektrode (27) entgegengesetzt zu der Mittelelektrode (5) eine gewölbte Form nach außen konvex bilden, und
wenn die Krümmungsradien der externen Linien der zwei Seitenflächen (27S1 und 27S2) als R (mm) angenommen werden, auf einem Querschnitt senkrecht zu der zentralen Achse (CL2) der Masseelektrode (27),
$R \leq 1{,}5$ erfüllt ist.

Revendications

1. Bougie (1) comprenant : un corps isolant (2) comportant un trou axial (4) passant à travers celui-ci dans une direction d'un axe (CL1) ; une électrode centrale (5) insérée dans le trou axial (4) ; une enveloppe métallique (3) prévue sur une périphérie extérieure du corps isolant (2) ; une électrode de masse (27) fixée à une partie d'extrémité avant de l'enveloppe métallique (3) ; et une extrémité côté électrode de masse (32), formée à partir d'un métal contenant un métal noble, dont au moins une partie d'extrémité est jointe à une partie d'extrémité avant de l'électrode de masse (27), l'électrode centrale (5) comportant, au niveau de sa partie d'extrémité avant, une extrémité côté électrode centrale (31) formée à partir d'un métal contenant un métal noble, une autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) étant face à une surface latérale de l'extrémité côté électrode centrale (31), et un espace (33) étant formé entre l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) et la surface latérale de l'extrémité côté électrode centrale (31),
caractérisée en ce que
lorsqu'une aire d'une région, dans un plan de projection dans lequel l'extrémité côté électrode de masse (32) et une face d'extrémité avant de l'extrémité côté électrode centrale (31) sont projetées dans un plan virtuel perpendiculaire à l'axe (CL1), délimité par une première tangente (TL1) tracée à partir d'une extrémité d'un côté correspondant à l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) jusqu'à une région de projection correspondant à la face d'extrémité avant de l'extrémité côté électrode centrale (31), une deuxième tangente (TL2) tracée à partir de l'autre extrémité du côté correspondant à l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) jusqu'à la région de projection correspondant à la face d'extrémité avant de l'extrémité côté électrode centrale (31), une droite de projection correspondant à l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32), et une droite de projection correspondant à la périphérie extérieure de la face d'extrémité avant de l'extrémité côté électrode centrale (31), est désignée par SA1 (mm^2),
lorsqu'une aire d'une région, dans laquelle une région de projection de l'extrémité côté électrode centrale (31) et une région de projection de l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) se superposent lorsque l'extrémité côté électrode centrale (31) et l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) sont projetées dans un plan virtuel parallèle à l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32), est désignée par SA2 (mm^2), et
lorsque la taille de l'espace (33) est désignée par G (mm),
$0,12 \leq SA1 \times SA2/G\ (mm^3) \leq 0,49$ est satisfait,
lorsqu'une distance le long de l'axe (CL1) entre un point, sur l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32), positionné le plus près d'un côté d'extrémité arrière dans la direction de l'axe (CL1), et un point, sur une surface de l'extrémité côté électrode centrale (31) face à l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32), positionné le plus près du côté d'extrémité avant le long de l'axe (CL1), est désignée par A (mm), et
lorsqu'une longueur le long de l'axe (CL1) de l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) est désignée par B (mm),
$0,05 \leq A \leq B + 0,2$ et $0,3 \leq B \leq 0,7$ sont satisfaits, et
lorsque l'aire de l'autre face d'extrémité (32F) de l'extrémité côté électrode de masse (32) est désignée par SX (mm^2),
$0,3 \leq SX \leq 0,6$ et $0,4 \leq G \leq 1,0$ sont satisfaits.

2. Bougie (1) selon la revendication 1, **caractérisée en ce que** lorsqu'une section transversale de l'électrode de masse (27) est désignée par SY (mm^2), et lorsque la largeur de l'électrode de masse (27) est désignée par W (mm), sur n'importe quelle section transversale, d'une partie du centre longitudinal à ladite extrémité de l'électrode de masse (27), dans une direction perpendiculaire à un axe central (CL2) de l'électrode de masse (27),
$2,3 \leq SY \leq 3,5$ et $1,8 \leq W \leq 2,2$ sont satisfaits.

3. Bougie (1) selon l'une quelconque des revendications 1 et 2, **caractérisée en ce que**
l'électrode de masse (27) comprend une couche extérieure (27Z) et une couche intérieure (271), prévue à l'intérieur de la couche extérieure (27Z), qui est formée à partir d'un métal avec une meilleure conductivité thermique que la couche extérieure (27Z), et
lorsqu'une section transversale de la couche intérieure (271) est désignée par SI (mm^2), et lorsque la section transversale de l'électrode de masse (27) est désignée par SZ (mm^2), sur une section transversale sur laquelle la section transversale de la couche intérieure (271) est la plus grande dans une direction perpendiculaire à l'axe central (CL2) de l'électrode de masse (27),
$0,2 \leq SI/SZ \leq 0,5$ est satisfait.

4. Bougie (1) selon l'une quelconque des revendications 1 à 3, **caractérisée en ce que**

les deux surfaces latérales (27S1 et 27S2) de l'électrode de masse (27) adjacentes à une surface (27T) opposée de l'électrode de masse (27) face à l'électrode centrale (5) réalisent une forme incurvée convexe vers l'extérieur, et lorsque les rayons de courbure des lignes externes des deux surfaces latérales (27S1 et 27S2) sont désignés par R (mm) sur une section transversale perpendiculaire à l'axe central (CL2) de l'électrode de masse (27),
$R \leq 1,5$ est satisfait.

FIG.1

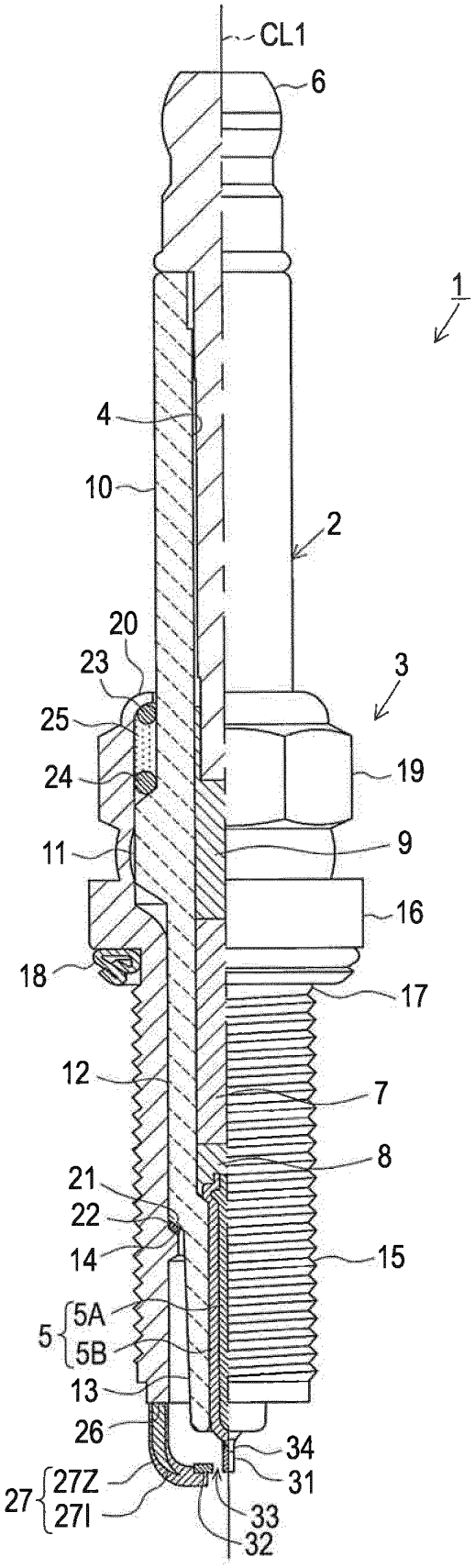

CL1
6
1
4
10
2
20
23
3
25
19
24
11
9
16
18
17
12
7
8
21
22
14
15
5
5A
5B
13
26
34
31
27
27Z
27I
33
32

FIG.2

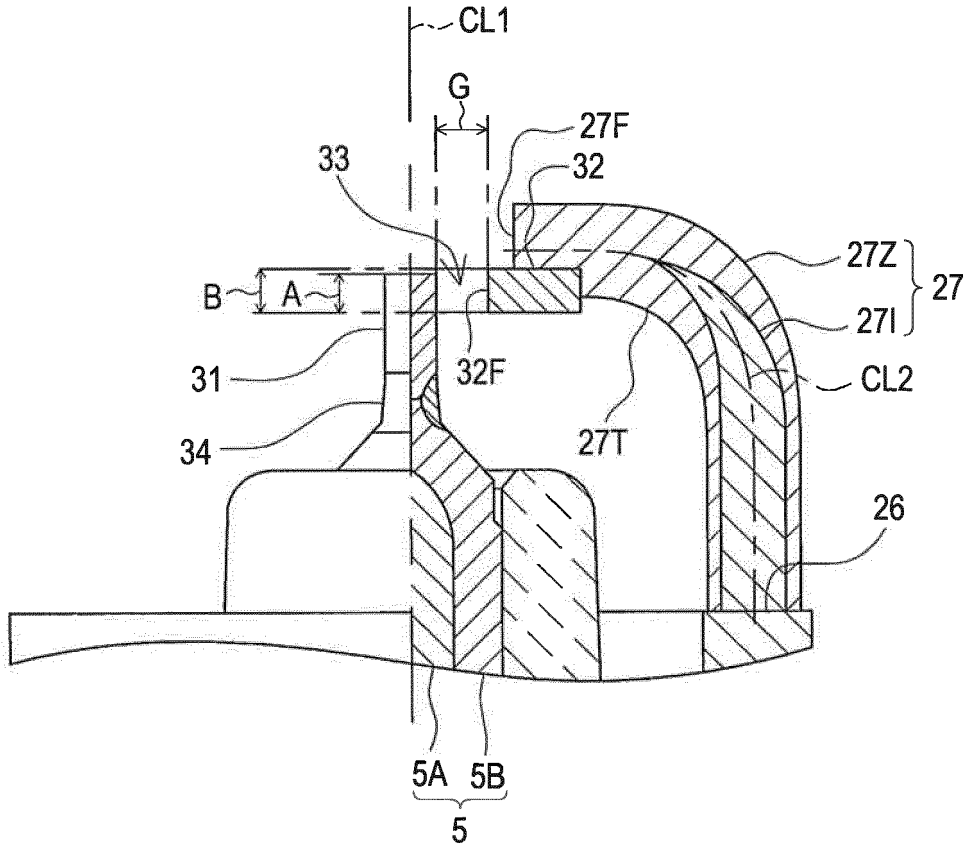


FIG.3

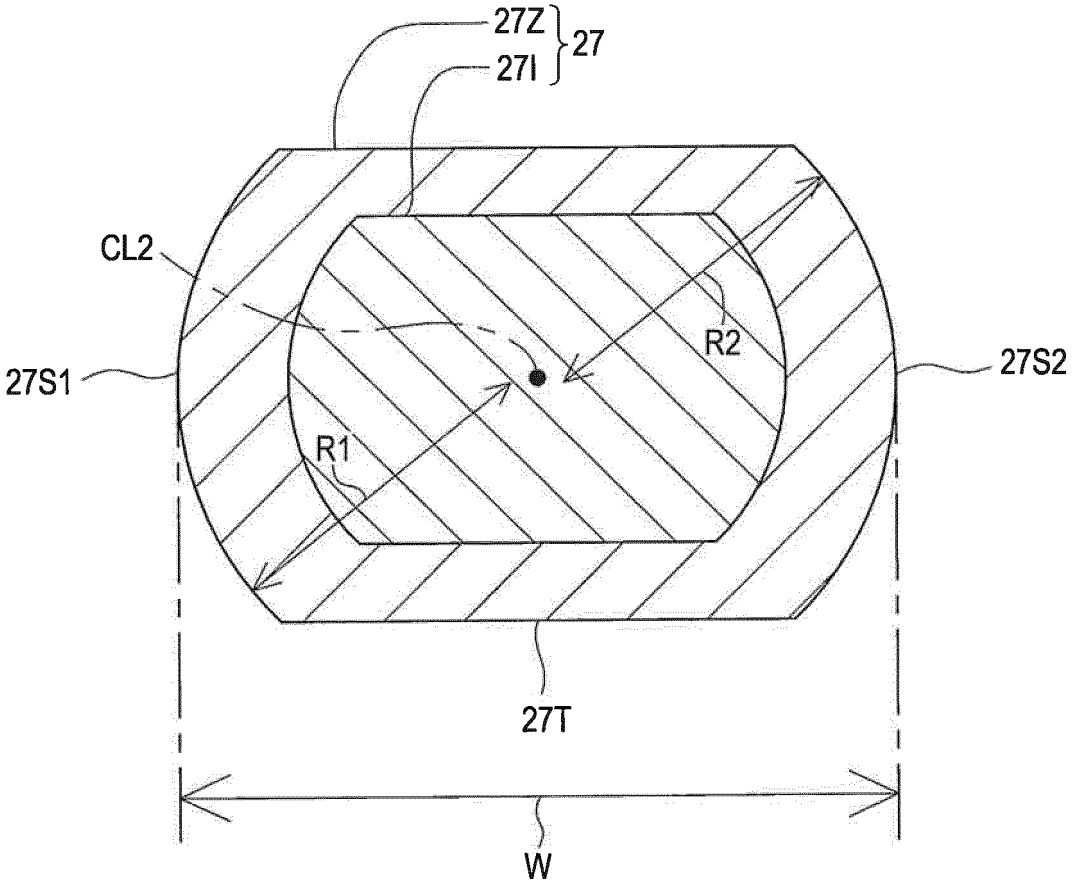


FIG.4

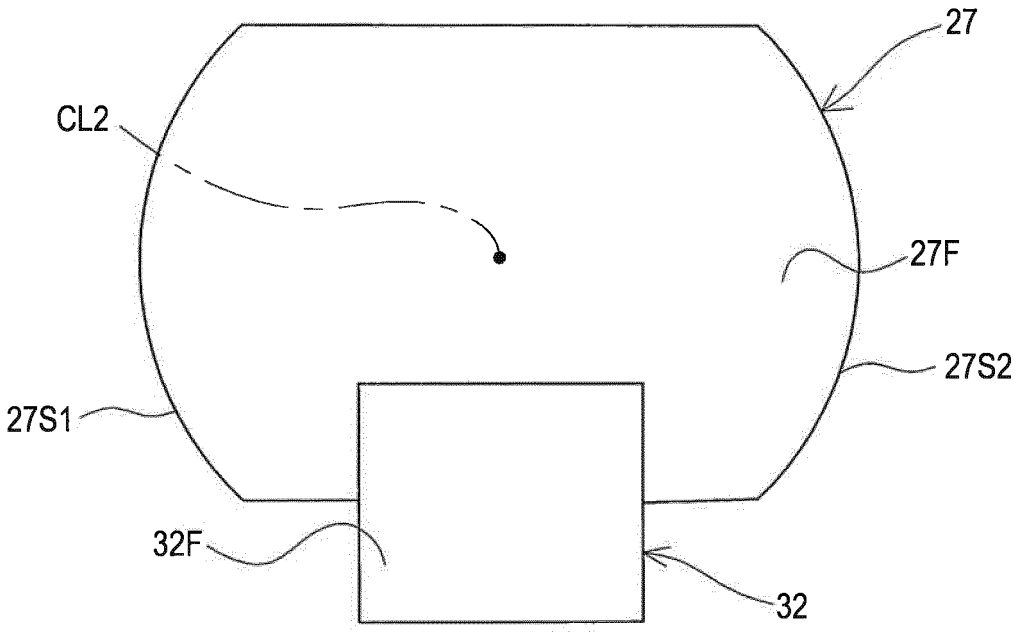


FIG.5

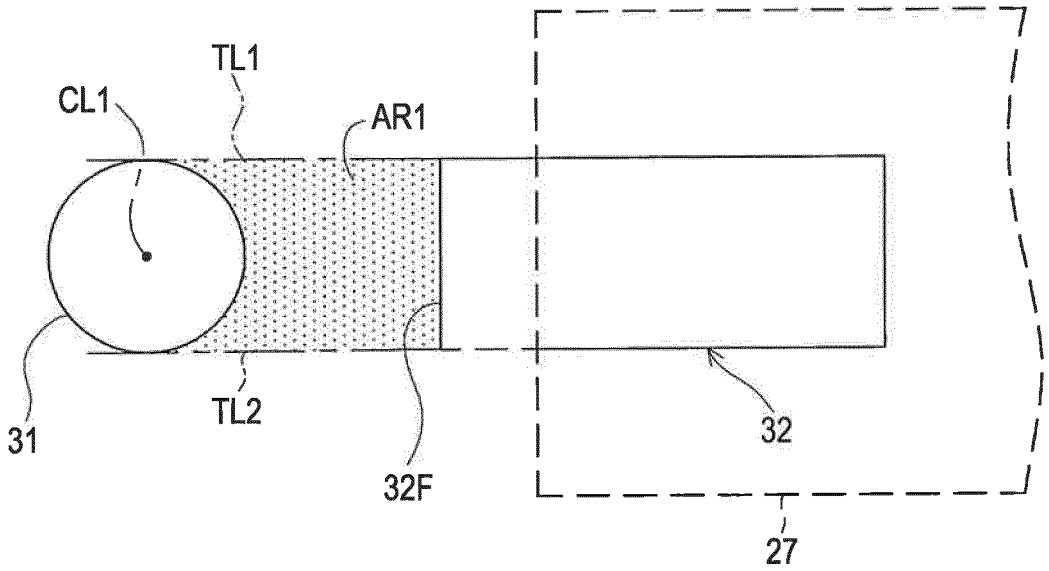


FIG.6

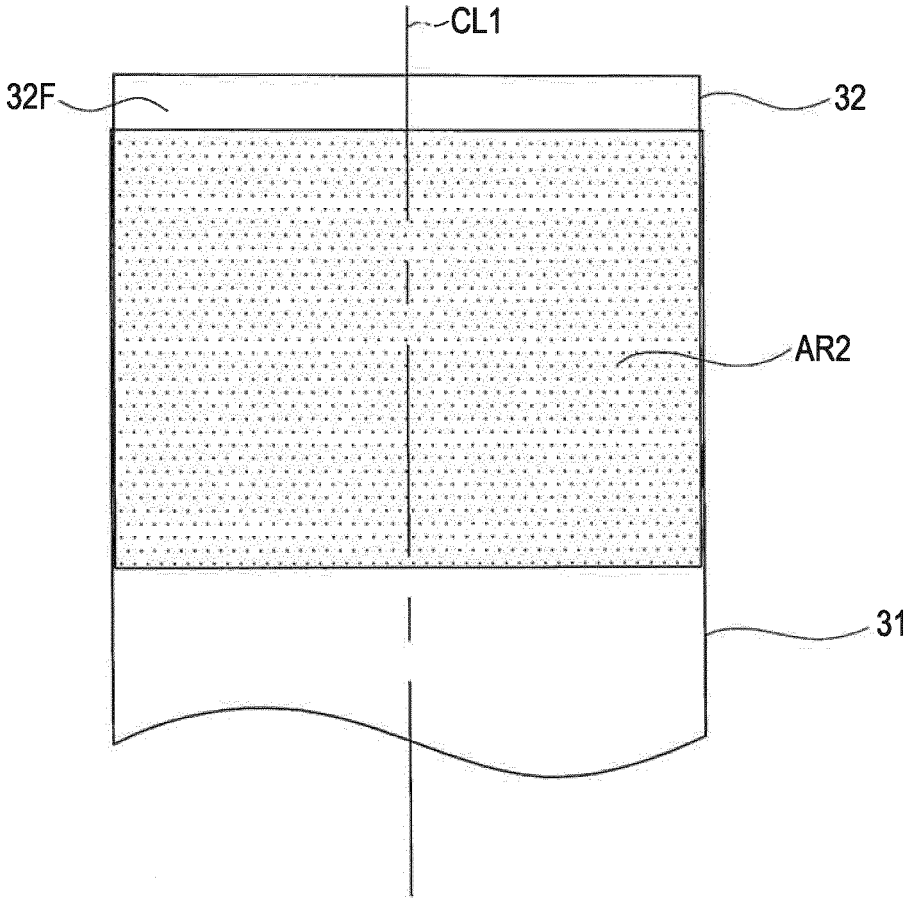


FIG.7

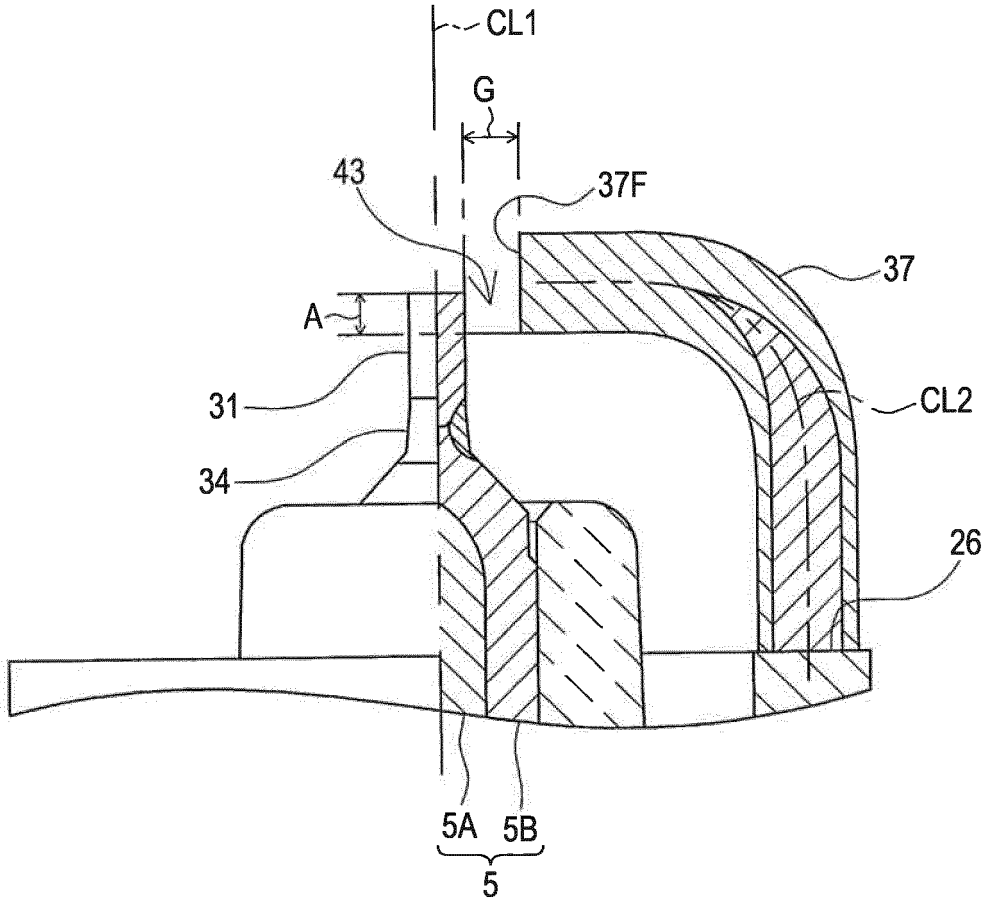


FIG.8

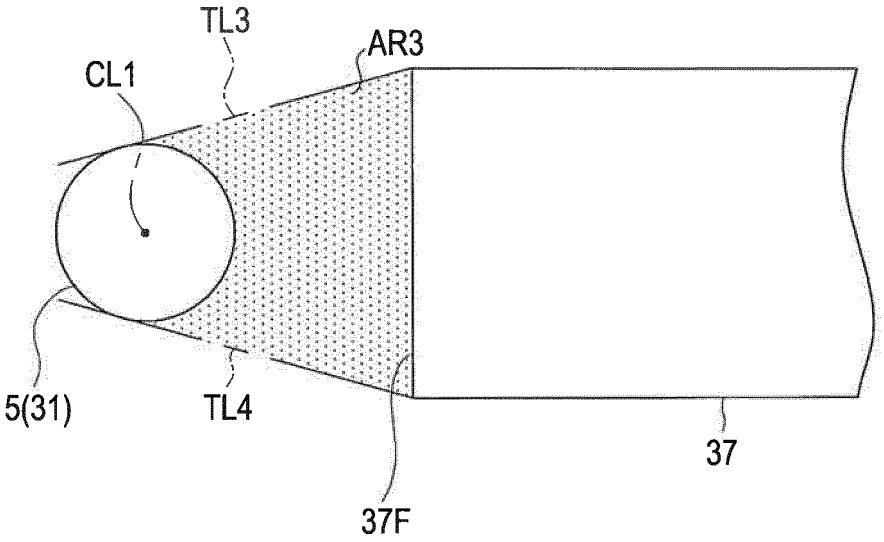


FIG.9

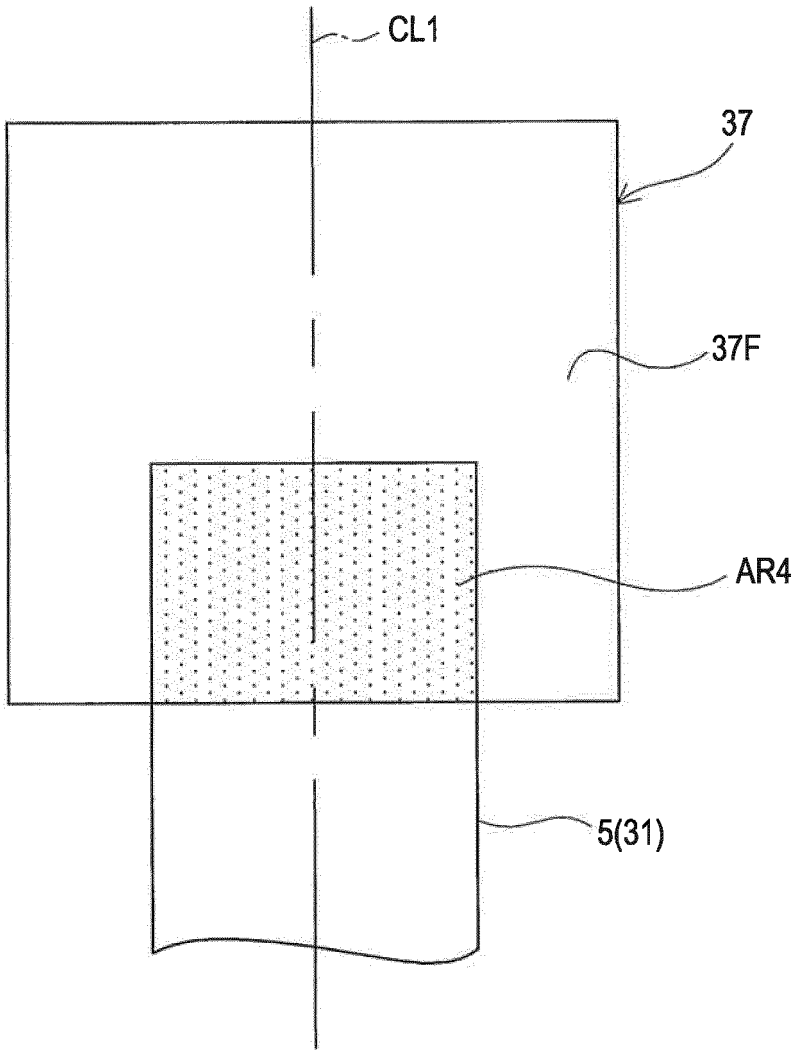


FIG.10

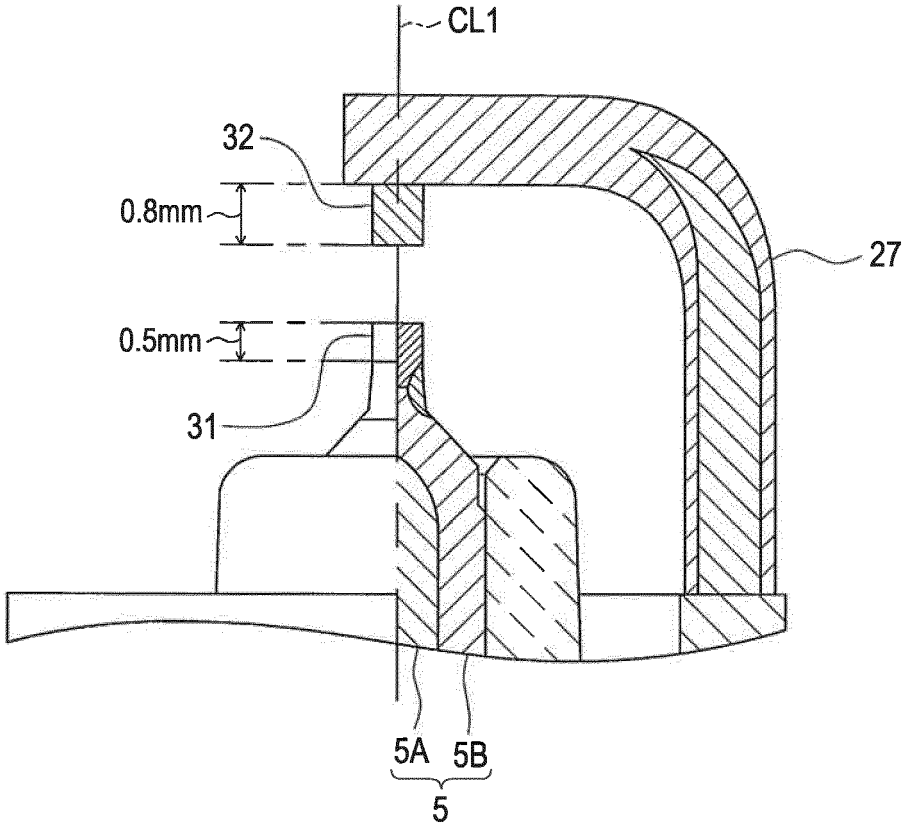


FIG.11

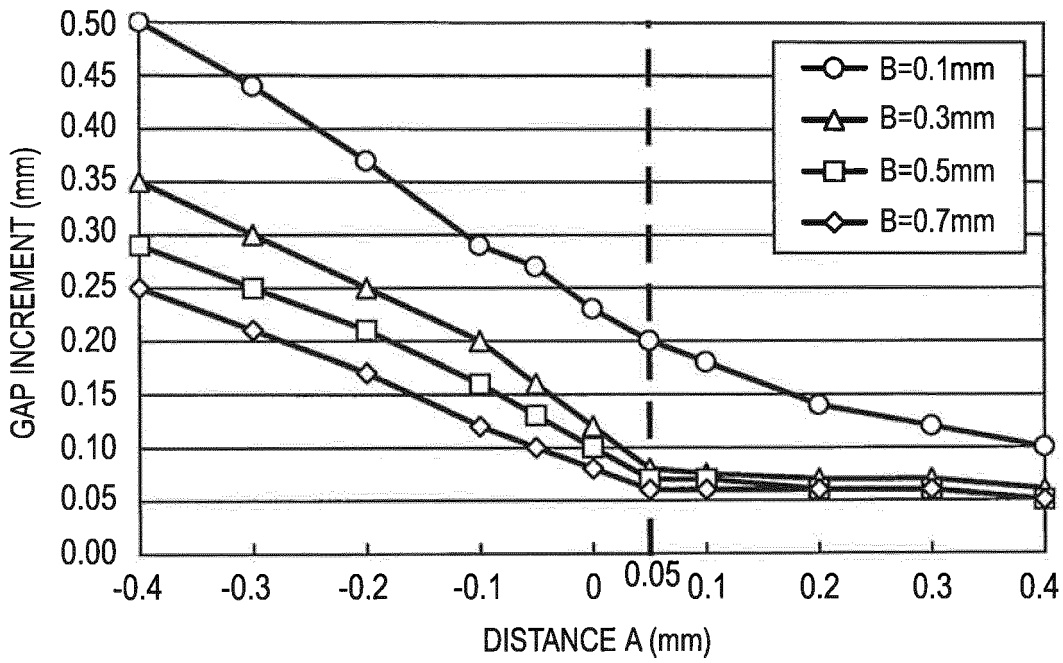

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
GAP INCREMENT (mm)
-0.4
-0.3
-0.2
-0.1
0
0.05
0.1
0.2
0.3
0.4
DISTANCE A (mm)
B=0.1mm
B=0.3mm
B=0.5mm
B=0.7mm

FIG.12

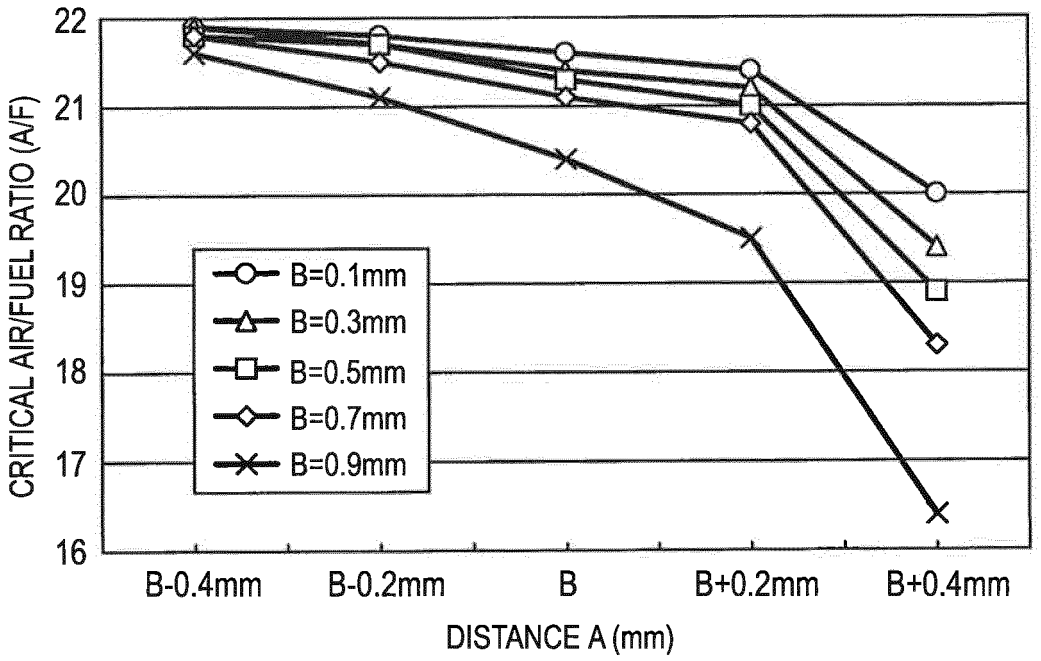

22
21
20
19
18
17
16
CRITICAL AIR/FUEL RATIO (A/F)
B=0.1mm
B=0.3mm
B=0.5mm
B=0.7mm
B=0.9mm
B-0.4mm
B-0.2mm
B
B+0.2mm
B+0.4mm
DISTANCE A (mm)

FIG.13

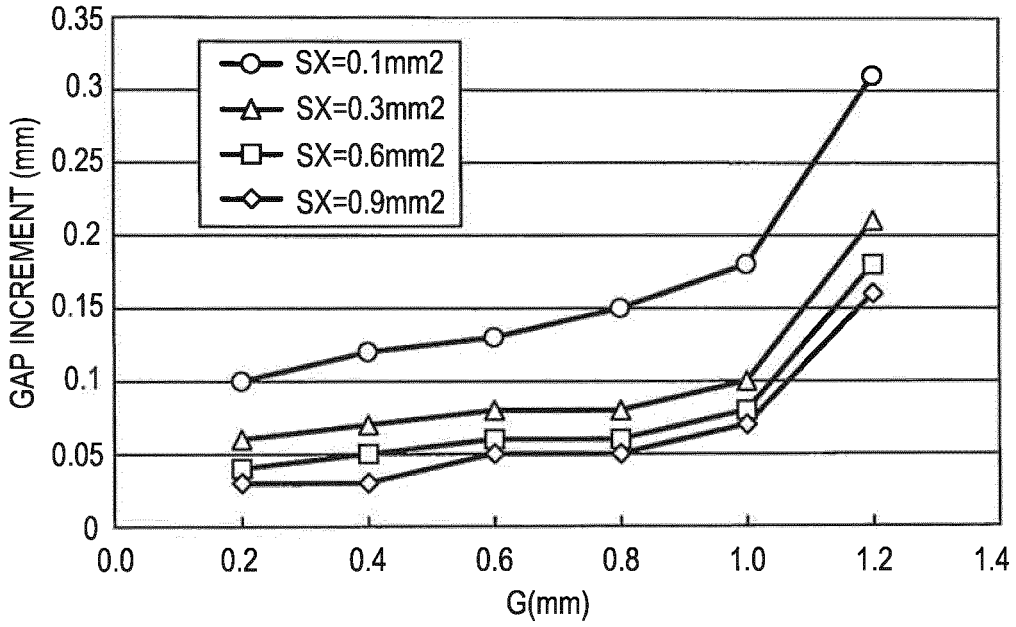

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
GAP INCREMENT (mm)
SX=0.1mm2
SX=0.3mm2
SX=0.6mm2
SX=0.9mm2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
G(mm)

FIG.14

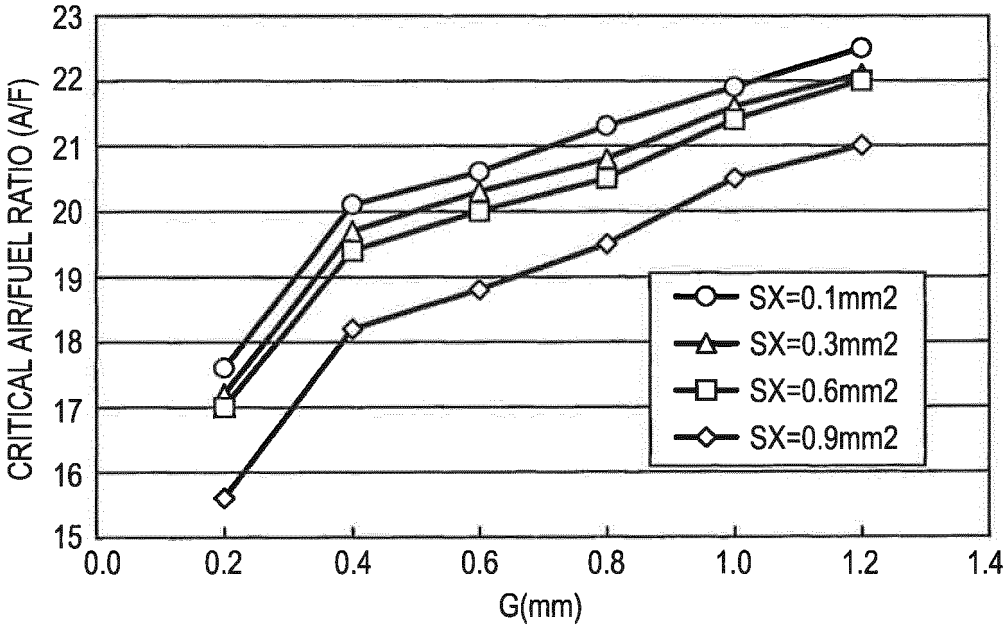

CRITICAL AIR/FUEL RATIO (A/F)
23
22
21
20
19
18
17
16
15
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
G(mm)
SX=0.1mm2
SX=0.3mm2
SX=0.6mm2
SX=0.9mm2

FIG.15

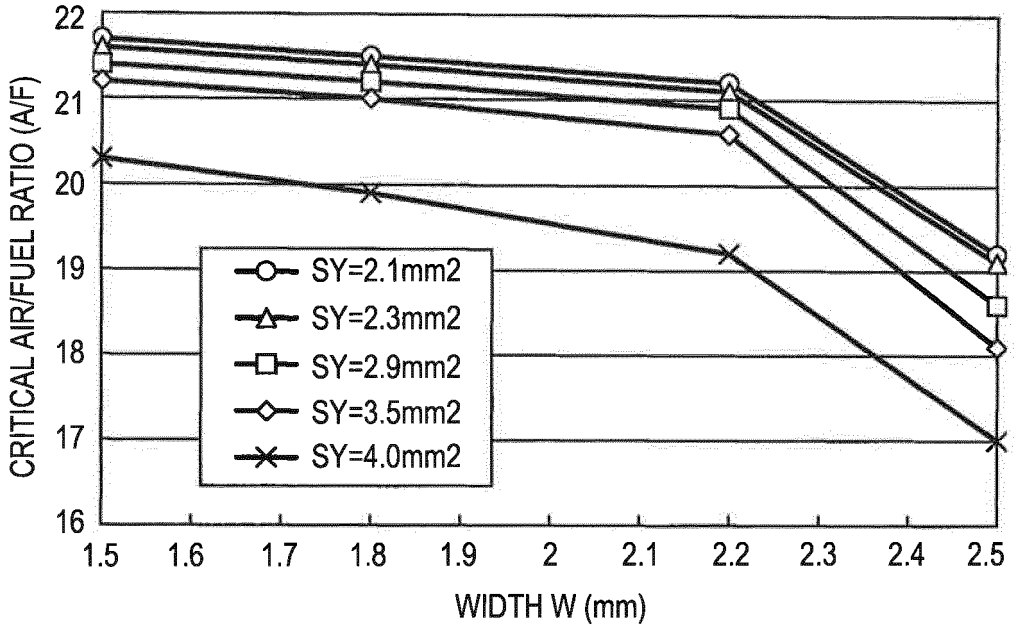

CRITICAL AIR/FUEL RATIO (A/F)
22
21
20
19
18
17
16
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
WIDTH W (mm)
SY=2.1mm2
SY=2.3mm2
SY=2.9mm2
SY=3.5mm2
SY=4.0mm2

FIG.16

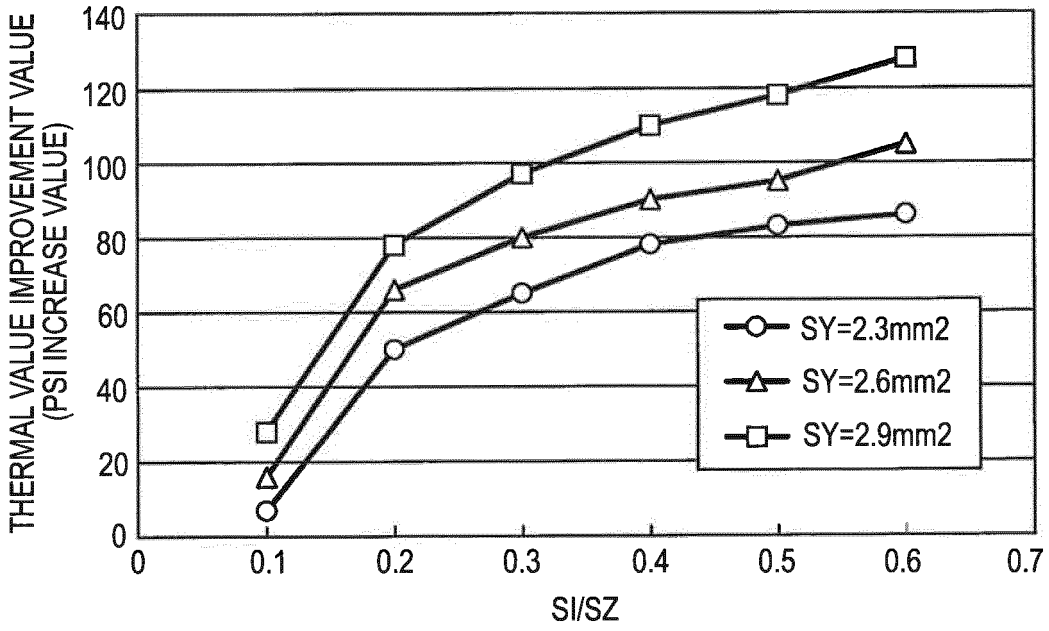

THERMAL VALUE IMPROVEMENT VALUE
(PSI INCREASE VALUE)
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
SI/SZ
SY=2.3mm2
SY=2.6mm2
SY=2.9mm2

FIG.17

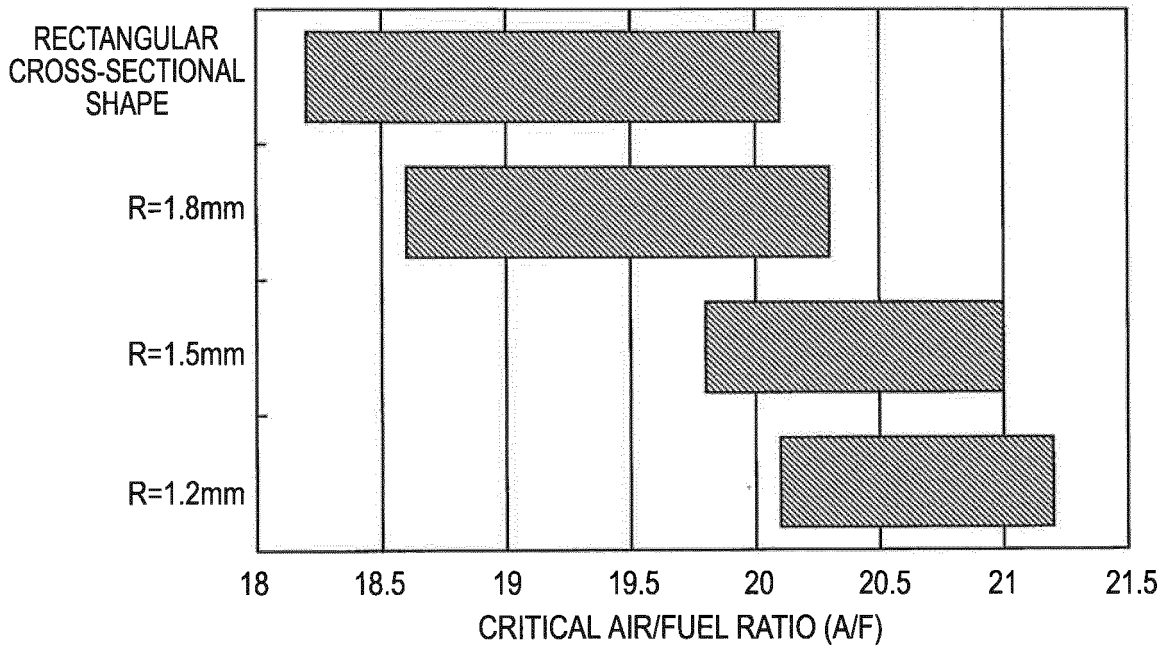

RECTANGULAR CROSS-SECTIONAL SHAPE
R=1.8mm
R=1.5mm
R=1.2mm
18
18.5
19
19.5
20
20.5
21
21.5
CRITICAL AIR/FUEL RATIO (A/F)

FIG.18

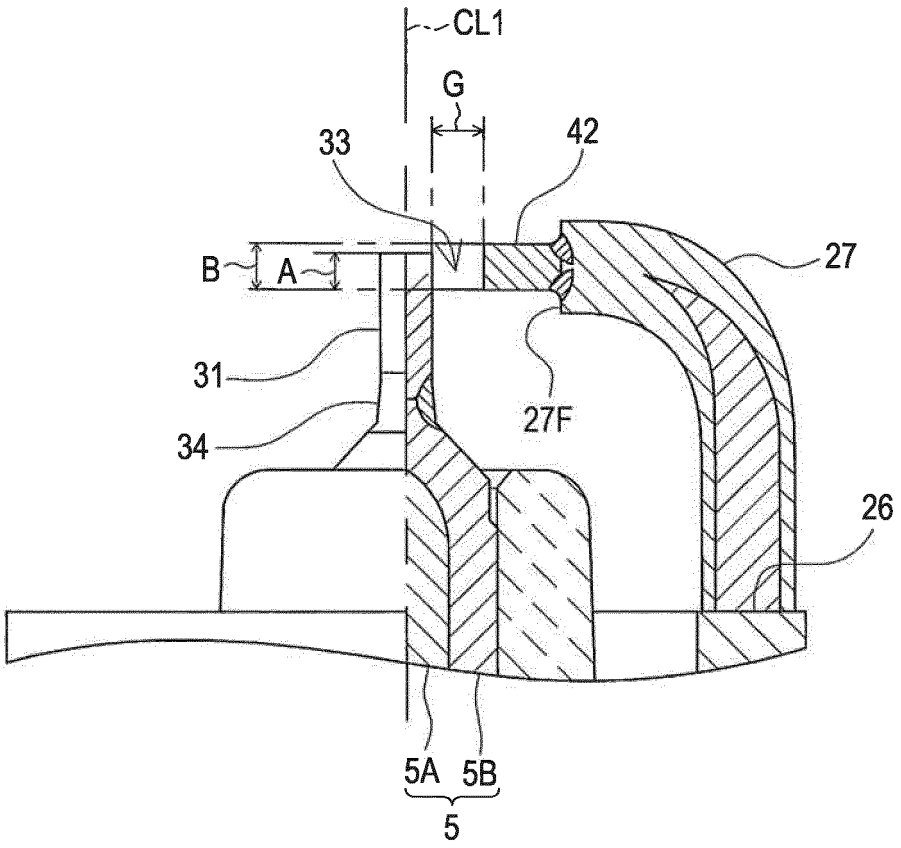


FIG.19

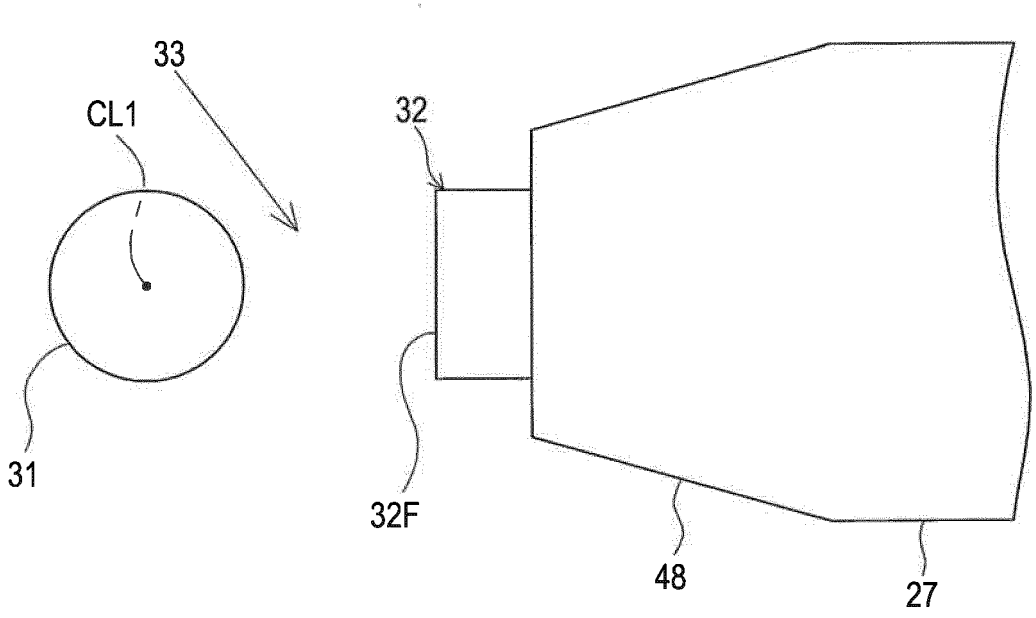
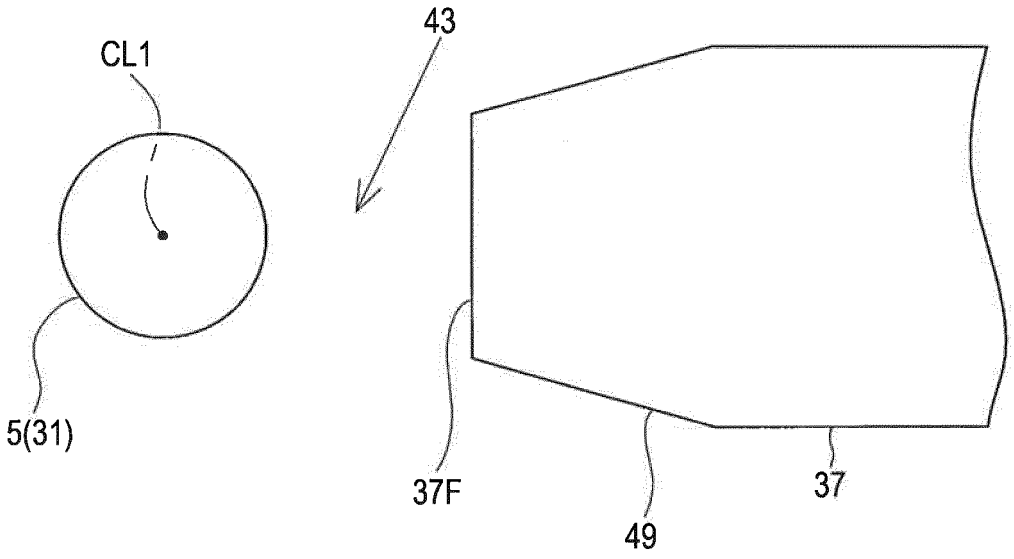


FIG.20



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2009151984 A **[0005]**
- JP 2009200002 A **[0005]**
- JP 2006236906 A **[0113]**