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

(11) EP 3 214 706 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.09.2017 Bulletin 2017/36

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

(21) Application number: **17156798.5**

(22) Date of filing: **20.02.2017**

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

(30) Priority: **02.03.2016 JP 2016040507**

(71) Applicant: **NGK Spark Plug Co., Ltd.**
Nagoya-shi,
Aichi-ken 467-8525 (JP)

(72) Inventors:
- **YAMAMOTO, Masahiro**
  Nagoya-shi, Aichi-ken (JP)
- **NAKAGAWA, Keita**
  Nagoya-shi, Aichi-ken (JP)

(74) Representative: **Intès, Didier Gérard André et al**
Cabinet Beau de Loménie
158 rue de l'Université
75340 Paris Cedex 07 (FR)

(54) SPARK PLUG

(57) A spark plug includes: a center electrode (20) extending in a direction of an axis (CL); an insulator that has an axial bore and holds the center electrode (20) in the axial bore; a metal shell (50) that is disposed around the insulator in a radial direction and holds the insulator; and a ground electrode (30) that is electrically connected to the metal shell (50) and forms a gap between the ground electrode (30) and the center electrode (20).

The metal shell (50) includes a front end tube portion (55) having a through hole (551) extending therethrough from an outer circumferential surface to an inner circumferential surface thereof and through which gas drawn into the combustion chamber passes, and a front edge (TP) of the insulator can be visually confirmed when seen from a first opening (OP1) of the through hole (551) on the outer circumferential surface side toward a second opening (OP2) of the through hole (551) on the inner circumferential surface side.

EMBODIMENT

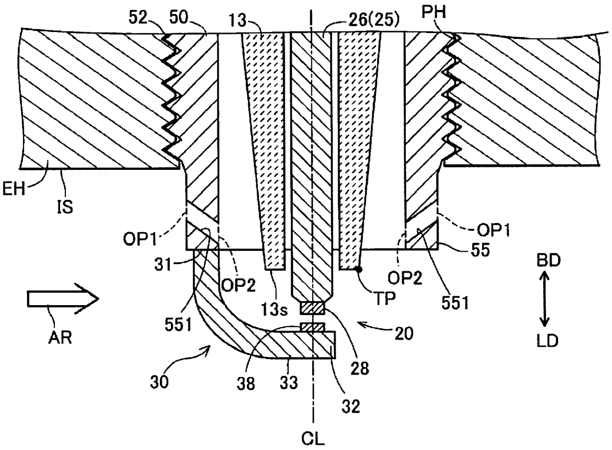

FIG. 2

EP 3 214 706 A1

Printed by Jouve, 75001 PARIS (FR)

Description

[Technical Field]

[0001] The present specification relates to a spark plug for igniting fuel gas in an internal combustion engine or the like.

[Background Art]

[0002] Patent Document 1 discloses a technique by which, when the front end of an insulator of a spark plug used in an internal combustion engine protrudes to the combustion chamber side of the internal combustion engine, a front end portion of a metal shell disposed on the outer circumference of the insulator is caused to protrude to the combustion chamber side, and a ventilation hole is provided in the front end portion. According to this technique, the provision of the ventilation hole can achieve the effect of cooling the insulator and thus can enhance the anti-pre-ignition performance.

[Prior Art Document]

[Patent Document]

[0003] [Patent Document 1] WO 2008/102842

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0004] For example, with an increase in the output of internal combustion engines in recent years, spark plugs tend to be used under a higher temperature environment in which pre-ignition is likely to occur. For this reason, spark plugs are required to have a further enhanced anti-pre-ignition performance.

[0005] The present specification discloses a technique for enhancing the anti-pre-ignition performance of a spark plug for use in an internal combustion engine.

[Means for Solving the Problems]

[0006] The technique disclosed in the present specification can be implemented as the following application examples.

[Application example 1] A spark plug including:

a center electrode extending in a direction of an axis;
an insulator that has an axial bore extending therethrough in the direction of the axis and holds the center electrode in the axial bore;
a metal shell that is disposed around the insulator in a radial direction and holds the insulator; and
a ground electrode that is electrically connected to the metal shell and forms a gap between the ground electrode and the center electrode, in which
the metal shell includes a front end tube portion that is exposed in a combustion chamber of an internal combustion engine when mounted to the internal combustion engine,
the front end tube portion has a through hole extending therethrough from an outer circumferential surface to an inner circumferential surface thereof and through which gas drawn into the combustion chamber passes, and
a front edge of the insulator can be visually confirmed when seen from a first opening of the through hole on the outer circumferential surface side toward a second opening of the through hole on the inner circumferential surface side.

With the above configuration, gas that has been drawn into the combustion chamber passes through the through hole of the front end tube portion from the outer circumferential surface side, and is blown toward the front end of the insulator. As a result, the gas drawn into the combustion chamber can be used so as to effectively cool the front end of the insulator. Accordingly, the occurrence of pre-ignition as a result of the front end of the insulator being excessively heated can be inhibited, so that it is possible to enhance the anti-pre-ignition performance of the spark plug.

[Application example 2] The spark plug according to Application example 1, in which
the first opening has an area larger than an area of the second opening.

With the above configuration, the flow rate and the flow velocity of the gas passing through the through hole can be increased.

[Application example 3] The spark plug according to Application example 1 or 2, in which
the front end tube portion has four or more of the through holes having circumferential positions different from one another.

With the above configuration, the four or more through holes allow the front end of the insulator to be effectively cooled, regardless of the circumferential position at which the spark plug is mounted to the internal combustion engine.

[Application example 4] The spark plug according to any one of Application examples 1 to 3, in which
the through hole is formed such that the insulator is not visible from the first opening when the first opening is seen along a direction perpendicular to the axis.

With the above configuration, it is possible to inhibit the pressure generated by abnormal combustion of the internal combustion engine from directly impacting the insulator through the through hole. As a result, it is possible to prevent damage to the insulator caused by abnormal combustion of the internal combustion engine.

[Application example 5] The spark plug according to any one of Application examples 1 to 3, in which the through hole is formed such that only an inner wall of the through hole is visible from the first opening when the first opening is seen from a direction perpendicular to the axis.

With the above configuration, it is possible to inhibit the pressure generated by abnormal combustion of the internal combustion engine from directly impacting the insulator through the through hole. As a result, it is possible to prevent damage to the insulator caused by abnormal combustion of the internal combustion engine.

[Application example 6] The spark plug according to any one of Application examples 1 to 5, in which a front end of the metal shell is located on a side forward of a front end of the insulator.

With the above configuration, it is possible to effectively inhibit the pressure generated by abnormal combustion of the internal combustion engine from directly impacting the insulator. As a result, it is possible to effectively prevent damage to the insulator caused by abnormal combustion of the internal combustion engine.

[Application example 7] The spark plug according to any one of Application examples 1 to 6, in which the through hole is formed at at least a circumferential position at which the ground electrode is connected to the metal shell.

[0007] Gas flowing toward the insulator from a side closer to the circumferential position at which the ground electrode is connected is likely to be obstructed by the ground electrode. The provision of the through hole at the circumferential position at which the ground electrode is connected allows the gas flowing toward the insulator from a side close to the circumferential position to be guided to the insulator, so that it is possible to enhance the anti-pre-ignition performance more effectively.

[0008] The present invention can be implemented in various forms. For example, the present invention can be implemented as a spark plug, an ignition system using the spark plug, an internal combustion engine having the spark plug mounted therein, an internal combustion engine in which the ignition system using the spark plug is mounted, or the like.

[Brief Description of the Drawings]

[0009]

[FIG. 1] Cross-sectional view of an example of a spark plug according to an embodiment.

[FIG. 2] Enlarged cross-sectional view of the vicinity of a front end of a spark plug 100.

[FIG. 3] View of the spark plug 100 as seen from a front end side toward a rear end direction BD.

[FIG. 4] Enlarged view of the vicinity of a through hole 551 shown in FIG. 2.

[FIG. 5] View illustrating a metal shell 50b according to a modification.

[FIG. 6] View illustrating a metal shell 50c according to a modification.

[FIG. 7] View illustrating a metal shell 50d according to a modification.

[Modes for Carrying Out the Invention]

A. Embodiment:

A-1. Configuration of spark plug:

[0010] FIG. 1 is a cross-sectional view of an example of a spark plug according to an embodiment. A dashed line illustrated therein indicates an axis CL of a spark plug 100. The illustrated cross section is a cross section that includes the axis CL. Hereinafter, the direction parallel to the axis CL is also referred to as "axial direction". Among the directions parallel to the axis CL, the downward direction in FIG. 1 is also referred to as a front end direction LD, and the upward direction in FIG. 1 is also referred to as a rear end direction BD. The front end direction LD is a direction extending from a metal terminal 40 described below toward electrodes 20, 30 described below. Further, a radial direction of a circle, around the axis CL, on a plane perpendicular to the axis CL is also simply referred to as "radial direction", and the circumferential direction of the circle is also simply referred to as "circumferential direction". The end in the front end direction LD is also simply referred to as a front end, and the end in the rear end direction BD is also simply referred to as a rear end.

[0011] The spark plug 100 includes an insulator 10, a center electrode 20, a ground electrode 30, a metal terminal 40, a metal shell 50, a first conductive seal layer 60, a resistor 70, a second conductive seal layer 80, a first packing 8, a talc 9, a second packing 6, and a third packing 7.

[0012] The insulator 10 is a substantially cylindrical member having an axial bore 12 that extends along the axial direction and through the insulator 10. The insulator 10 is formed by alumina being sintered (another insulating material may be used). The insulator 10 includes a leg portion 13, a reduced outer diameter portion 15, a first trunk portion 17, a flange portion 19, and a second trunk portion 18, which are arranged in this order in the rear end direction BD. The outer diameter of the reduced outer diameter portion 15 is gradually reduced in the front end direction LD. Inside the insulator 10, a reduced inner diameter portion 16 that has its inner diameter gradually reduced in the front end direction LD is formed in the vicinity of the reduced outer diameter portion 15 (in the first trunk portion 17 in the example shown in FIG. 1).

[0013] The center electrode 20 is located in the axial bore 12 of the insulator 10 on the front end side thereof. The center electrode 20 is a rod-shaped member that extends along the axial direction. The center electrode 20 includes a center electrode tip 28 and a center electrode body 26.

[0014] The center electrode body 26 includes a leg portion 25, a flange portion 24, and a head portion 23, which are arranged in this order in the rear end direction BD. The front end side portion of the leg portion 25 is exposed to the outside of the axial bore 12 on the front end side of the insulator 10. The other portions of the center electrode 20 are held in the axial bore 12. The surface, of the flange portion 24, on the front end side is supported by the reduced inner diameter portion 16 of the insulator 10.

[0015] The center electrode body 26 is formed by using, for example, nickel (Ni) or an alloy (e.g., NCF600, NCF601) containing nickel as a main component. The center electrode body 26 may include a core material that is embedded therein and formed of copper or an alloy containing copper as a main component, having higher thermal conductivity than Ni or an alloy containing Ni as a main component.

[0016] The center electrode tip 28 is joined to the front end portion of the leg portion 25 of the center electrode body 26 by, for example, laser welding. The center electrode tip 28 is formed of a material containing, as a main component, a noble metal having a high melting point. As the material of the center electrode tip 28, for example, iridium (Ir) or platinum (Pt), or an alloy containing Ir or Pt as a main component, is used.

[0017] The metal terminal 40 is located in the axial bore 12 of the insulator 10 on the rear end side thereof. The metal terminal 40 is a rod-shaped member that extends along the axial direction, and is formed by using a conductive material (e.g., a metal such as a low-carbon steel). The metal terminal 40 includes a cap mounting portion 41, a flange portion 42, and a leg portion 43, which are arranged in this order in the front end direction LD. The cap mounting portion 41 is exposed to the outside of the axial bore 12 on the rear end side of the insulator 10. The leg portion 43 is inserted in the axial bore 12 of the insulator 10.

[0018] The columnar resistor 70 is disposed between the metal terminal 40 and the center electrode 20 in the axial bore 12 of the insulator 10. The resistor 70 has a function of reducing electric wave noise generated when spark occurs. The resistor 70 is formed from, for example, a composition containing glass particles as a main component, ceramic particles other than glass, and a conductive material.

[0019] The first conductive seal layer 60 is disposed between the center electrode 20 and the resistor 70, and the second conductive seal layer 80 is disposed between the metal terminal 40 and the resistor 70. As a result, the center electrode 20 and the metal terminal 40 are electrically connected via the resistor 70 and the conductive seal layers 60 and 80. Each of the conductive seal layers 60 and 80 is formed from, for example, a composition containing glass particles of a B_2O_3-SiO_2-based material or the like and metal particles (Cu, Fe, etc.).

[0020] The metal shell 50 is a substantially cylindrical member having an insertion hole 59 that extends along the axis CL and through the metal shell 50. The metal shell 50 is formed by using a low-carbon steel material (another conductive material (e.g., metal material) may be used). The insulator 10 is inserted in the insertion hole 59 of the metal shell 50. The metal shell 50 holds the insulator 10 so as to be disposed around the insulator 10 in the radial direction. On the front end side of the metal shell 50, an end portion, of the insulator 10, on the front end side (a portion, of the leg portion 13, on the front end side in the present embodiment) is exposed to the outside of the insertion hole 59. On the rear end side of the metal shell 50, an end portion, of the insulator 10, on the rear end side (a portion, of the second trunk portion 18, on the rear end side in the present embodiment) is exposed to the outside of the insertion hole 59.

[0021] The metal shell 50 includes a front end tube portion 55, a screw portion 52, a seat portion 54, a deformable portion 58, a tool engagement portion 51, and a crimp portion 53, which are arranged in this order in the rear end direction BD. An annular gasket 5 formed by a metal plate being bent is fitted between the seat portion 54 and the screw portion 52.

[0022] The seat portion 54 is a flange-shaped portion. The screw portion 52 is a substantially cylindrical portion having a screw for being screwed to a mounting hole of an internal combustion engine (e.g., a gasoline engine) formed on the outer circumferential surface thereof. The front end tube portion 55 is a substantially cylindrical portion that is disposed on the front end side of the screw portion 52, and has no screw formed on the outer circumferential surface thereof. The length, in the axial direction, of the front end tube portion 55 is preferably 1.5 mm or more, for example. The front end tube portion 55 has a plurality of through holes 551 extending therethrough from the outer circumferential surface to the inner circumferential surface thereof. The details of the configuration of the front end tube portion 55 will be described later.

[0023] The metal shell 50 has a reduced inner diameter portion 56 disposed on the side forward of the deformable portion 58. The inner diameter of the reduced inner diameter portion 56 is gradually reduced from the rear end side in the front end direction LD. The first packing 8 is sandwiched between the reduced inner diameter portion 56 of the metal shell 50 and the reduced outer diameter portion 15 of the insulator 10. The first packing 8 is an O-ring made of iron (another material (e.g., metal material such as copper) may be used).

[0024] The tool engagement portion 51 has a shape that allows a spark plug wrench to engage therewith (e.g., hexagonal columnar shape). On the rear end side of the tool engagement portion 51, the crimp portion 53 is formed. The crimp portion 53 is disposed on the side rearward of the flange portion 19 of the insulator 10, and forms the end, of the metal shell 50, on the rear end side. The crimp portion 53 is bent inward in the radial direction.

[0025] On the rear end side of the metal shell 50, an annular space SP is formed between the inner circumferential surface of the metal shell 50 and the outer circumferential surface of the insulator 10. In the present embodiment, the space SP is a space surrounded by the crimp portion 53 and the tool engagement portion 51 of the metal shell 50, and a rear end portion of the flange portion 19 and the second trunk portion 18 of the insulator 10. On the rear end side of the space SP, the second packing 6 is disposed. On the front end side of the space SP, the third packing 7 is disposed. In the present embodiment, the packings 6 and 7 are each a C-ring made of iron (another material may be used). The portion between the two packings 6 and 7 in the space SP is filled with powder of the talc 9.

[0026] When the spark plug 100 is manufactured, the crimp portion 53 is crimped so as to be bent inward. The crimp portion 53 is then pressed toward the front end side. Thus, the deformable portion 58 is deformed, and the insulator 10 is pressed toward the front end side, in the metal shell 50, through the packings 6 and 7 and the talc 9. The first packing 8 is pressed between the reduced outer diameter portion 15 and the reduced inner diameter portion 56, and seals a portion between the metal shell 50 and the insulator 10. Thus, the gas in a combustion chamber of the internal combustion engine is inhibited from leaking out through the portion between the metal shell 50 and the insulator 10. Further, the metal shell 50 is fixed to the insulator 10.

[0027] The ground electrode 30 includes a ground electrode body 33 and a ground electrode tip 38. The ground electrode body 33 is a rod-shaped member that is electrically connected to the metal shell 50. The ground electrode body 33 is formed by using, for example, Ni or an alloy (e.g., NCF600, NCF601) containing Ni as a main component. As with the center electrode body 26, the ground electrode body 33 may include a core material that is embedded therein and formed of copper or an alloy containing copper as a main component, having higher thermal conductivity than Ni or an a alloy containing Ni as a main component. The ground electrode tip 38 is formed by using, for example, Pt (platinum) or an alloy containing Pt as a main component, specifically, Pt-20Ir alloy (platinum alloy containing 20% by mass of iridium) or the like.

A-2. Configuration in the vicinity of front end of spark plug

[0028] With reference to FIGS. 2 and 3, the configuration in the vicinity of the front end of the spark plug 100 will be described in further detail. FIG. 2 is an enlarged cross-sectional view of the vicinity of the front end of the spark plug 100. The enlarged cross-sectional view shown in FIG. 2 is a cross-sectional view, taken along a cross section including the axis CL, of the vicinity of the front end of the spark plug 100 in the state of being mounted to a mounting hole PH of a head EH of an internal combustion engine. FIG. 3 is a view of the spark plug 100 as seen from the front end side toward the rear end direction BD. To avoid the complexity of illustration, FIG. 3 shows the front end tube portion 55 of the metal shell 50 and a front end surface 13s of the leg portion 13 of the insulator 10, and illustration of the other components has been omitted.

[0029] The front end tube portion 55 is exposed in the combustion chamber of the internal combustion engine when the spark plug 100 is mounted to the internal combustion engine. More specifically, as shown in FIG. 2, substantially the entire front end tube portion 55 protrudes from an inner wall surface IS of the head EH toward the inside of the combustion chamber when the spark plug 100 is mounted to the mounting hole PH of the head EH of the internal combustion engine.

[0030] The front end of the insulator 10 (i.e., the front end of the leg portion 13) is located on the side forward of the front end of the front end tube portion 55. The front end of the center electrode body 26 and the center electrode tip 28 are located on the side forward of the front end of the insulator 10.

[0031] One end of the ground electrode body 33 is a connection end 31 that is connected to the front end of the metal shell 50, for example, by resistance welding so as to allow the ground electrode 30 and the metal shell 50 to be electrically connected. The other end of the ground electrode body 33 is a free end 32. The ground electrode body 33 extends in the front end direction LD from the connection end 31 connected to the metal shell 50, and is bent toward the axis CL. The ground electrode body 33 then extends in a direction perpendicular to the axis CL, to reach the free end 32.

[0032] One side surface, of a portion of the ground electrode body 33, on the free end 32 side that extends in a direction perpendicular to the axis CL opposes the center electrode tip 28 in the axial direction on the axis CL. The ground electrode tip 38 is welded to the aforementioned side surface of the ground electrode body 33 at a position opposing the center electrode tip 28. The ground electrode tip 38 forms a spark gap between itself and the center electrode tip 28.

[0033] The through holes 551 formed in the front end tube portion 55 described above are formed so as to allow passage of gas that has been drawn into the combustion chamber of the internal combustion engine. As shown in FIG. 3, the plurality of through holes 551 have circumferential positions different from one another such that the circumferential positions at the front end tube portion 55 are dispersed. Specifically, the plurality of through holes 551 are disposed such that two through holes 551 having circumferential positions adjacent to each other form an equal circumferential angle θ therebetween. In the example shown in FIG. 3, the number of through holes 551 is four, and therefore θ = 90 degrees.

[0034] In FIG. 3, the position at which the connection end 31 of the ground electrode body 33 is connected is indicated by dashed lines. As can be seen from this, one of the four through holes 551 is formed at a circumferential position at which the ground electrode 30 (ground electrode body 33) is connected to the metal shell 50.

[0035] FIG. 4 is an enlarged view of the vicinity of a through hole 551 shown in FIG. 2. The cross section shown in FIG. 4 can also be regarded as a cross section obtained by cutting the through hole 551 on a plane including the axis CL and the center of a first opening OP1 of the through hole 551 on the outer circumferential surface side. In the present embodiment, the cross section shown in FIG. 4 also includes the center of a second opening OP2. Each of the plurality of through holes 551 is a substantially cylindrical hole. The first opening OP1 of each through hole 551 on the outer circumferential surface side is shifted in the rear end direction BD with respect to the second opening OP2 on the inner circumferential surface side. Therefore, each of the plurality of through holes 551 is inclined with respect to both the direction of the axis CL and the direction perpendicular to the axis CL.

[0036] Each of the plurality of through holes 551 is formed such that, when seen from the first opening OP1 of the through hole 551 on the outer circumferential surface side toward the second opening OP2 of the through hole 551 on the inner circumferential surface side, the front edge TP of the insulator 10 to be visually confirmed from the first opening OP1. In the present embodiment, the front edge TP is an outer edge of the front end surface 13s of the leg portion 13 of the insulator 10.

[0037] For example, in the cross section shown in FIG. 4, a direction parallel to a line connecting the center of the first opening OP1 with the center of the second opening OP2 is taken as AR1. Of a group of straight lines that are parallel to the direction AR1, pass through the through hole 551, and do not pass through a wall portion, of the front end tube portion 55, at which no through hole 551 is formed, the straight line furthest in the rear end direction BD is taken as L11, and the straight line furthest in the front end direction LD is taken as L12. In the example shown in FIG. 4, the front edge TP of the insulator 10 and the space TA located on the side forward of the front edge TP are included between the two straight lines L11 and L12. Accordingly, in the example shown in FIG. 4, it can be understood that the front edge TP of the insulator 10 can be visually confirmed clearly when the first opening OP1 of the through hole 551 is seen along the direction AR1.

[0038] Further, as shown in FIG. 4, each of the plurality of through holes 551 is formed such that the insulator 10 is not visible from the first opening OP1 when the first opening OP1 is seen along the direction AR2 perpendicular to the axis CL.

[0039] For example, in the cross section shown in FIG. 4, a straight line that is parallel to the direction AR2 and passes through the rear end of the first opening OP1 is taken as L21. A straight line that is parallel to the direction AR2 and passes through the front end of the first opening OP1 is taken as L22. In the example shown in FIG. 4, it can be understood that all straight lines that are located between the two straight lines L21 and L22 and parallel to the direction AR2 pass through a wall portion, of the front end tube portion 55, in which no through hole 551 is formed. Accordingly, in the example shown in FIG. 4, when the first opening OP1 of the through hole 551 is seen along the direction AR2, only the inner wall 551w of the through hole 551 is visible, and the insulator 10 cannot be visually confirmed.

[0040] With the spark plug 100, the provision of the front end tube portion 55 protruding into the combustion chamber described above allows an ignition portion (i.e., a spark gap) of the spark plug 100 to protrude into the combustion chamber, without excessively increasing the length of the ground electrode body 33. By causing the ignition portion to protrude into the combustion chamber so as to be located at a position away from the inner wall surface IS of the head EH, it is possible to inhibit the growth of a flame from being impeded by flame-quenching effect of the inner wall, thus enhancing the ignitability of the spark plug 100. An excessive increase in the length of the ground electrode body 33 leads to an increased length to the connection end 31 to the metal shell 50 serving as the heat conduction starting point of the ground electrode body 33, thus resulting in reduced heat conduction performance. Further, an excessive increase in the length of the ground electrode body 33 results in reduced durability against vibration and impact. The provision of the front end tube portion 55 makes it possible to avoid such troubles.

[0041] A shock wave (pressure) that is higher than that normally occurs may occur in the combustion chamber as a result of, for example, the occurrence of abnormal combustion. The provision of the front end tube portion 55 can inhibit such a shock wave occurring during abnormal combustion from directly impacting the leg portion 13 of the insulator 10, thus making it possible to inhibit the insulator 10 from being damaged.

[0042] On the other hand, as a result of the front end tube portion 55 being formed, it is difficult for intake gas drawn into the combustion chamber of the internal combustion engine to flow into the vicinity of the front end of the insulator 10 (front end of the leg portion 13). Intake gas has a lower temperature than, for example, combustion gas, and thus is suitably used for cooling the insulator 10. If intake gas does not flow into the vicinity of the front end of the insulator 10, heat generated in the ignition portion is confined, so that the temperature of the front end portion of the insulator 10 is excessively increased, making it likely to cause the so-called pre-ignition. The four through holes 551 formed in the front end tube portion 55 are provided for preventing such a trouble so as to enhance the anti-pre-ignition performance.

[0043] According to the above embodiment, as described above, the front edge TP of the insulator 10 can be visually confirmed when seen from the first opening OP1 of the through hole 551 of the front end tube portion 55 on the outer circumferential surface side toward the second opening OP2 of the through hole 551 on the inner circumferential surface side. Accordingly, intake gas that has passed through the through hole 551 from the first opening OP1 side is directed toward the front end of the front end tube portion 55. Therefore, the intake gas inside the combustion chamber passes through the through hole 551 of the front end tube portion 55 from the outer circumferential surface side, and is blown toward the front end of the insulator 10. As a result, the intake gas inside the combustion chamber can be used so as to effectively cool the front end of the insulator 10. Accordingly, the occurrence of pre-ignition caused by the front end of the insulator 10 being excessively heated can be inhibited, thus making it possible to enhance the anti-pre-ignition performance of the spark plug 100.

[0044] Furthermore, with the spark plug 100 of the above embodiment, the front end tube portion 55 has four through holes 551 having circumferential positions different from one another. As a result, the front end of the insulator 10 can be effectively cooled, regardless of the circumferential position at which the spark plug 100 is mounted to the internal combustion engine.

[0045] To describe more specifically, a flow direction AR (FIG. 2) of intake gas in the combustion chamber is, for example, a direction extending from an intake port (not shown) toward an exhaust port (not shown) of the internal combustion engine. To allow intake gas flowing along the flow direction AR to efficiently pass through the through hole 551 from the first opening OP1 side, the through hole 551 is preferably formed in the front end tube portion 55 at a circumferential position at which the direction extending from the first opening OP1 toward the axis CL is parallel to the flow direction AR. However, depending, for example, on the relationship between an internal thread formed in the mounting hole PH of the head EH and an external thread formed at the screw portion 52 of the spark plug 100, the circumferential position of the through hole 551 in the combustion chamber may not always necessarily be constant. If the front end tube portion 55 has four or more through holes 551 having circumferential positions different from one another, it is highly likely that at least one through hole 551 is disposed in the combustion chamber at the above-described preferable circumferential position, or a position close to the preferable circumferential position. As a result, the front end of the insulator 10 can be efficiently cooled as described above.

[0046] Further, as described above, the through hole 551 is formed such that the insulator 10 is not visible from the first opening OP1 when the first opening OP1 is seen from the direction AR2 perpendicular to the axis CL. For example, the through hole 551 is formed such that only the inner wall 551w of the through hole 551 is visible from the first opening OP1 when the first opening OP1 is seen from the direction AR2. As a result, it is possible to inhibit a shock wave (pressure) generated by abnormal combustion of the internal combustion engine from directly impacting the insulator 10 thorough the through hole 551. Accordingly, it is possible to prevent damage to the insulator 10 caused by abnormal combustion of the internal combustion engine, in particular, damage to the leg portion 13 having a relatively small thickness.

[0047] Furthermore, with the spark plug 100 of the above embodiment, one through hole 551 is formed at a circumferential position at which the ground electrode 30 is connected to the metal shell (FIG. 3). Intake gas flowing toward the insulator 10 from a side close to the circumferential position at which the ground electrode 30 is connected tends to be obstructed by the ground electrode 30 (in particular, the ground electrode body 33). By providing the through hole 551 at a circumferential position at which the ground electrode 30 is connected, it is possible to guide, to the insulator 10, the intake gas flowing from a side close to the circumferential position toward the insulator 10. As a result, it is possible to enhance the anti-pre-ignition performance more effectively.

B. Modifications

[0048]

(1) The through hole 551 of the above embodiment has a diameter that is constant from the first opening OP1 to the second opening OP2, and therefore, the area of the first opening OP1 and the area of the second opening OP2 are equal. Alternatively, the area of the first opening OP1 may be larger than the area of the second opening OP2.

FIG. 5 is a view illustrating a metal shell 50b according to a modification. The metal shell 50b shown in FIG. 5 includes a front end tube portion 55b having a through hole 551b. The through hole 551b includes an equal diameter bore 553 on the inner circumferential surface side and a diameter enlarged bore 552 on the outer circumferential surface side. The equal diameter bore 553 has a constant diameter regardless of the axial direction of the bore. The diameter enlarged bore 552 has a diameter increasing from the inner circumferential surface side (the equal diameter bore 553 side) toward the outer circumferential surface side. Therefore, in the through hole 551b shown in FIG. 5, the area of the first opening OP1 is larger than the area of the second opening OP2.

FIG. 6 is a view illustrating a metal shell 50c according to a modification. The metal shell 50c shown in FIG. 6 includes a front end tube portion 55c having a through hole 551c. The through hole 551c includes a small equal diameter bore 555 on the inner circumferential surface side and a large equal diameter bore 554 on the outer circumferential surface side. The small equal diameter bore 555 has a constant diameter regardless of the axial position of the bore.

The large equal diameter bore 554 has a diameter that is constant regardless of the axial position of the bore and is larger than the diameter of the small equal diameter bore 555. Therefore, as with the through hole 551b shown in FIG. 5, the area of the first opening OP1 is larger than the area of the second opening OP2 in the through hole 551c shown in FIG. 6.

According to the present modifications, the area of the first opening OP1 is larger than the area of the second opening OP2. Accordingly, the flow rate of the intake gas introduced from the first opening OP1 into the through holes 551b and 551c can be increased, making it possible to increase the flow velocity of the intake gas blown from the second opening OP2 to the front end of the insulator 10. As a result, the front end of the insulator 10 can be further efficiently cooled.

As can be understood from the straight lines L11 and L12 shown in FIGS. 5 and 6, the through holes 551b and 551c according to the present modifications are formed such that, when seen from the first openings OP1 of the through holes 551b and 551c on the outer circumferential surface side toward the second openings OP2 of the through holes 551b and 551c on the inner circumferential surface side, the front edge TP of the insulator 10 can be visually confirmed from the first opening OP1, as with the through hole 551 of the embodiment. As can be understood from the straight lines L21 and L22 shown in FIGS. 5 and 6, the through holes 551b and 551c according to the present modifications are formed such that, when the first opening OP1 is seen along the direction AR2 perpendicular to the axis CL, the insulator 10 is not visible from the first opening OP1 and only the inner walls 551wb and 551wc of the through holes 551b and 551c are visible, as with the through hole 551 of the embodiment.

(2) FIG. 7 is a view illustrating a metal shell 50d according to a modification. The metal shell 50d shown in FIG. 7 includes a front end tube portion 55d having a through hole 551c. The through hole 551c shown in FIG. 7 is the same as the through hole 551c shown in FIG. 6, and thus is denoted by the same reference numeral in FIG. 7. The length, in the axial direction, of the front end tube portion 55d shown in FIG. 7 is longer than the length of the front end tube portion 55c shown in FIG. 6. Therefore, a front end 55s of each of the metal shells 50, 50b, and 50c in the above embodiment and the modifications shown in FIGS. 5 and 6 is located on the side rearward (the rear end direction BD side) of the front end 13s of the insulator 10. However, in the present modification, a front end 55sd of the metal shell 50d shown in FIG. 7 is located on the side forward (the front end direction LD side) of the front end 13s of the insulator 10. As a result, as seen from the direction AR2 perpendicular to the axial direction, the entire front end portion of the insulator 10 is surrounded by the front end tube portion 55d, so that it is possible to effectively inhibit a shock wave (pressure) generated by abnormal combustion of the internal combustion engine from directly impacting the insulator 10. As a result, it is possible to effectively prevent damage to the insulator 10 caused by abnormal combustion of the internal combustion engine.

The front end tube portion 55d shown in FIG. 7 has the through hole 551c that is the same as the through hole shown in FIG. 6. Accordingly, even if the entire front end portion of the insulator 10 is surrounded by the front end tube portion 55, the front end of the insulator 10 can be effectively cooled with the intake gas passing through the through hole 551c. Therefore, the anti-pre-ignition performance is not compromised.

(3) Although the number of the through holes 551 is four in the above embodiment, the present invention is not limited thereto. The number of the through holes 551 may be greater than four, for example, five or six. Alternatively, the number of the through holes 551 may be less than four, for example, one, two, or three. When a plurality of the through holes 551 are provided, it is preferable that their circumferential positions are different from one another such that the circumferential positions at the front end tube portion 55 are dispersed, as in the embodiment. For example, when the number of the through holes 551 is two, three, five, or six, the circumferential angle θ between two through holes 551 having circumferential positions adjacent to each other is preferably 180 degrees, 120 degrees, 72 degrees, or 60 degrees, respectively, or may be angles close to these angles. Preferably, at least one through hole 551 is formed at a circumferential position at which the ground electrode 30 (ground electrode body 33) is connected.

(4) In the above embodiment, the through hole 551 is formed such that, when the first opening OP1 is seen from the direction AR2 perpendicular to the axis CL, the insulator 10 is not visible from the first opening OP1, as shown in FIG. 4. However, the insulator 10 may be visible.

(5) In the above embodiment, the through hole 551 is formed such that, when seen from the first opening OP1 toward the second opening OP2 along the direction AR1 that is parallel to a straight line connecting the center of the first opening OP1 with the center of the second opening OP2, the front edge TP of the insulator 10 can be visually confirmed from the first opening OP, as shown in FIG. 4. The through hole 551 may be formed such that, when seen along one of any directions, other than the direction AR1, that extend from the first opening OP1 toward the second opening OP2, the front edge TP of the insulator 10 can be visually confirmed from the first opening OP1.

(6) The shape of the through hole 551 is not limited to the shape described in the above embodiment.

For example, the through hole 551 may be a hole having a prismatic shape with a triangular or square cross section.

(7) The specific configuration of the spark plug 100 according to the above embodiment is merely an example, and another configuration may be used. For example, various configurations can be used for a firing end of the spark plug. For example, the spark plug may be of a type in which the ground electrode and the center electrode 20 oppose each other in a direction perpendicular to the axis, to form a gap. For example, the material of the insulator 10 and the material of the metal terminal 40 are not limited to the materials described above. For example, the insulator 10 may be formed by using, a ceramic containing another compound (e.g., AlN, ZrO_2 SiC, TiO_2, Y_2O_3 etc.) as a main component, in place of a ceramic containing alumina (Al_2O_3) as a main component.

[0049] The present invention has been described above with reference to the embodiment and the modifications. However, the present invention is not limited to the above embodiment and modifications at all, and may be embodied in various forms without departing from the gist of the invention.

[Description of Reference Numerals]

[0050]

5: gasket; 6: packing; 6: second packing; 7: third packing; 8: first packing; 9: talc; 10: insulator; 12: axial bore; 13: leg portion; 13s: front end surface; 15: reduced outer diameter portion; 16: reduced inner diameter portion; 17: first trunk portion; 18: second trunk portion; 19: flange portion; 20: center electrode; 23: head portion; 24: flange portion; 25: leg portion; 26: center electrode body; 28: center electrode tip; 30: ground electrode; 31: connection end; 32: free end; 33: ground electrode body; 38: ground electrode tip; 40: metal terminal; 41: cap mounting portion; 42: flange portion; 43: leg portion; 50, 50b to 50d: metal shell; 51: tool engagement portion; 52: screw portion; 53: crimp portion; 54: seat portion; 55, 55b to 55d: front end tube portion; 56: reduced inner diameter portion; 58: deformable portion; 59: insertion hole; 60: first conductive seal layer; 70: resistor; 80: second conductive seal layer; 100: spark plug; 551, 551b, 551c: through hole; OP1: first opening; OP2: second opening

Claims

1. A spark plug (100) comprising:

   a center electrode (20) extending in a direction of an axis (CL);
   an insulator (10) that has an axial bore (12) extending therethrough in the direction of the axis (CL) and holds the center electrode (20) in the axial bore (12);
   a metal shell (50, 50b, 50c, 50d) that is disposed around the insulator (10) in a radial direction and holds the insulator (10); and
   a ground electrode (30) that is electrically connected to the metal shell (50, 50b, 50c, 50d) and forms a gap between the ground electrode (30) and the center electrode (20), wherein
   the metal shell (50, 50b, 50c, 50d) includes a front end tube portion (55, 55b, 55c, 55d) that is exposed in a combustion chamber of an internal combustion engine when mounted to the internal combustion engine,
   the front end tube portion (55, 55b, 55c, 55d) has a through hole (551, 551b, 551c) extending therethrough from an outer circumferential surface to an inner circumferential surface thereof and through which gas drawn into the combustion chamber passes, and
   a front edge (TP) of the insulator (10) can be visually confirmed when seen from a first opening (OP1) of the through hole (551, 551b, 551c) on the outer circumferential surface side toward a second opening (OP2) of the through hole (551, 551b, 551c) on the inner circumferential surface side.

2. The spark plug (100) according to claim 1, wherein the first opening (OP1) has an area larger than an area of the second opening (OP2).

3. The spark plug (100) according to claim 1 or 2, wherein
   the front end tube portion (55, 55b, 55c, 55d) has four or more of the through holes (551, 551b, 551c) having circumferential positions different from one another.

4. The spark plug (100) according to any one of claims 1 to 3, wherein
   the through hole (551, 551b, 551c) is formed such that the insulator (10) is not visible from the first opening (OP1) when the first opening (OP1) is seen along a direction perpendicular to the axis (CL).

5. The spark plug (100) according to any one of claims 1 to 3, wherein
   the through hole (551, 551b, 551c) is formed such that only an inner wall (551w, 551wb, 551wc) of the through hole (551, 551b, 551c) is visible from the first opening (OP1) when the first opening (OP1) is seen from a direction perpendicular to the axis (CL).

6. The spark plug (100) according to any one of claims

1 to 5, wherein a front end (55s) of the metal shell (50, 50b, 50c, 50d) is located on a side forward of a front end (13s) of the insulator (10).

7. The spark plug (100) according to any one of claims 1 to 6, wherein the through hole (551, 551b, 551c) is formed at at least a circumferential position at which the ground electrode (30) is connected to the metal shell (50, 50b, 50c, 50d).

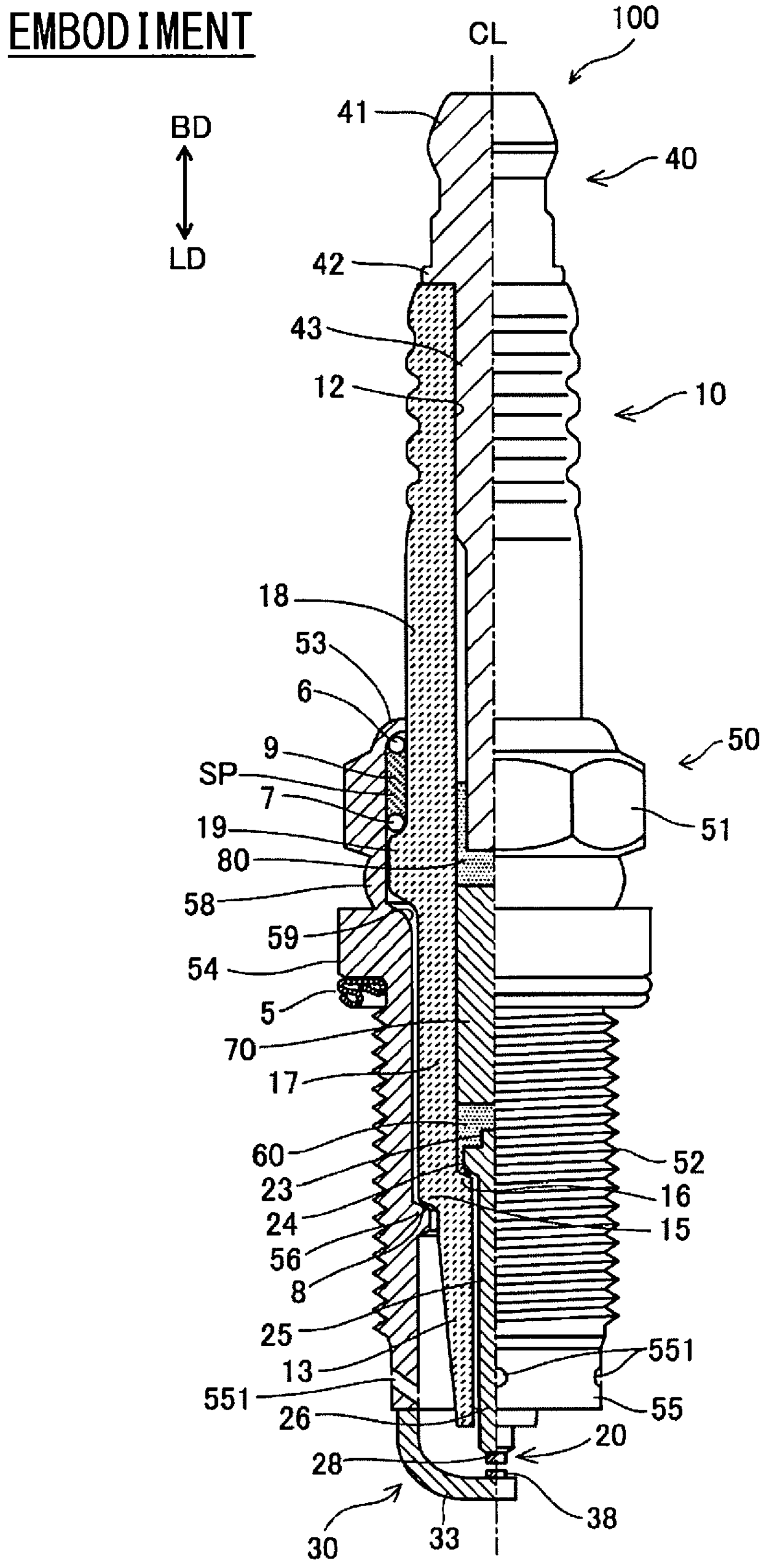
EMBODIMENT
BD
LD
CL
100
41
40
42
43
12
10
18
53
6
9
SP
7
19
80
58
59
54
5
70
17
60
23
24
56
8
25
13
551
26
28
30
33
50
51
52
16
15
551
55
20
38

FIG. 1

EMBODIMENT

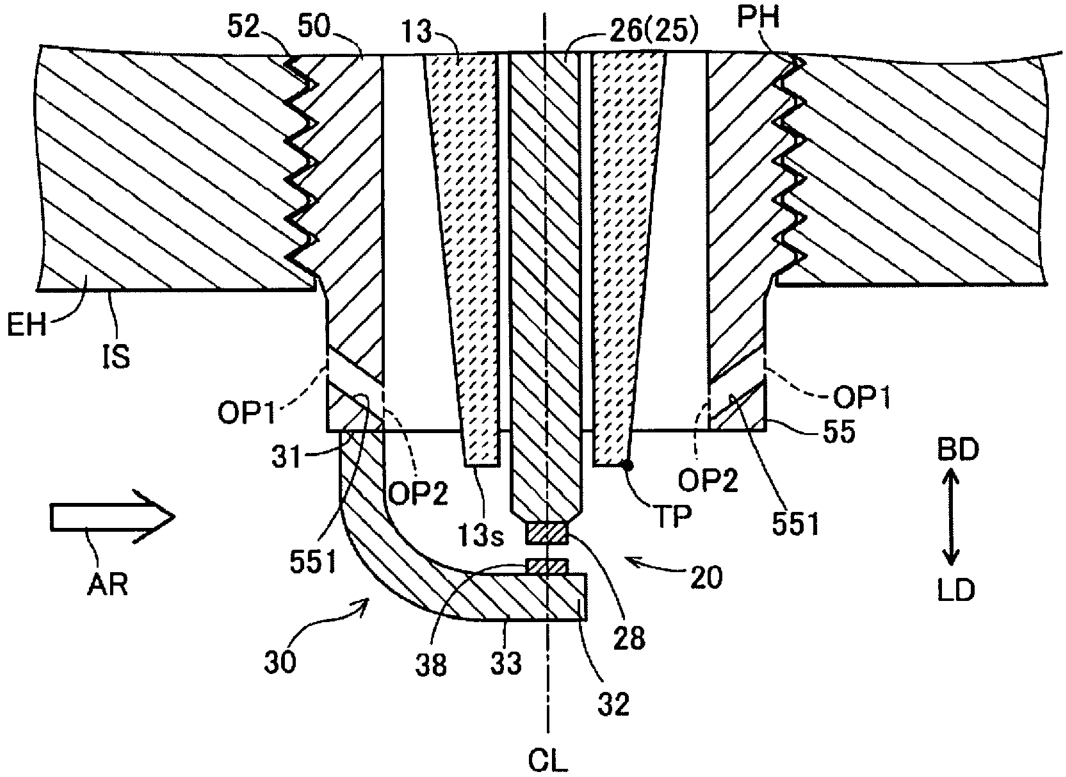

FIG. 2

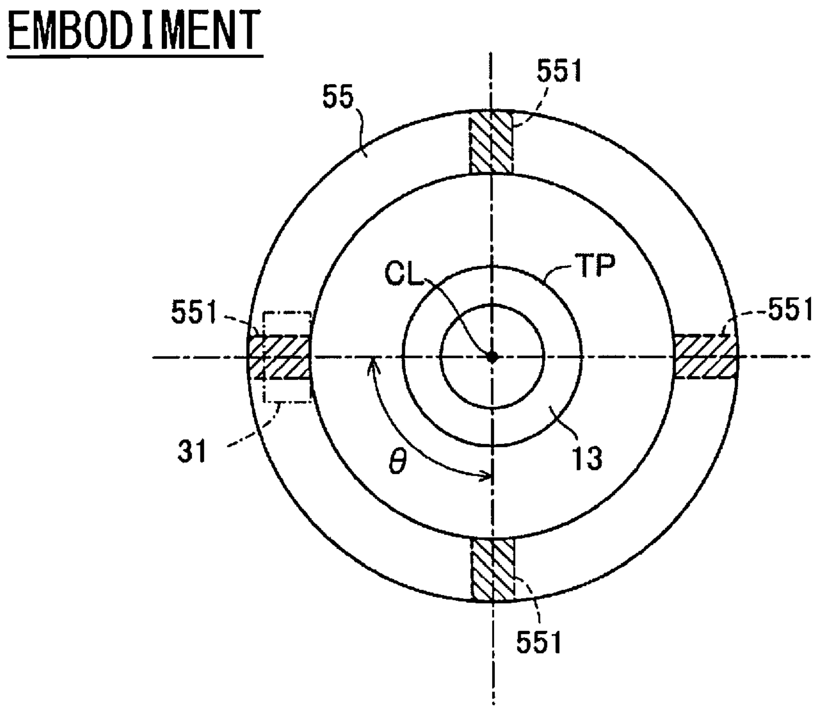

FIG. 3

EMBODIMENT

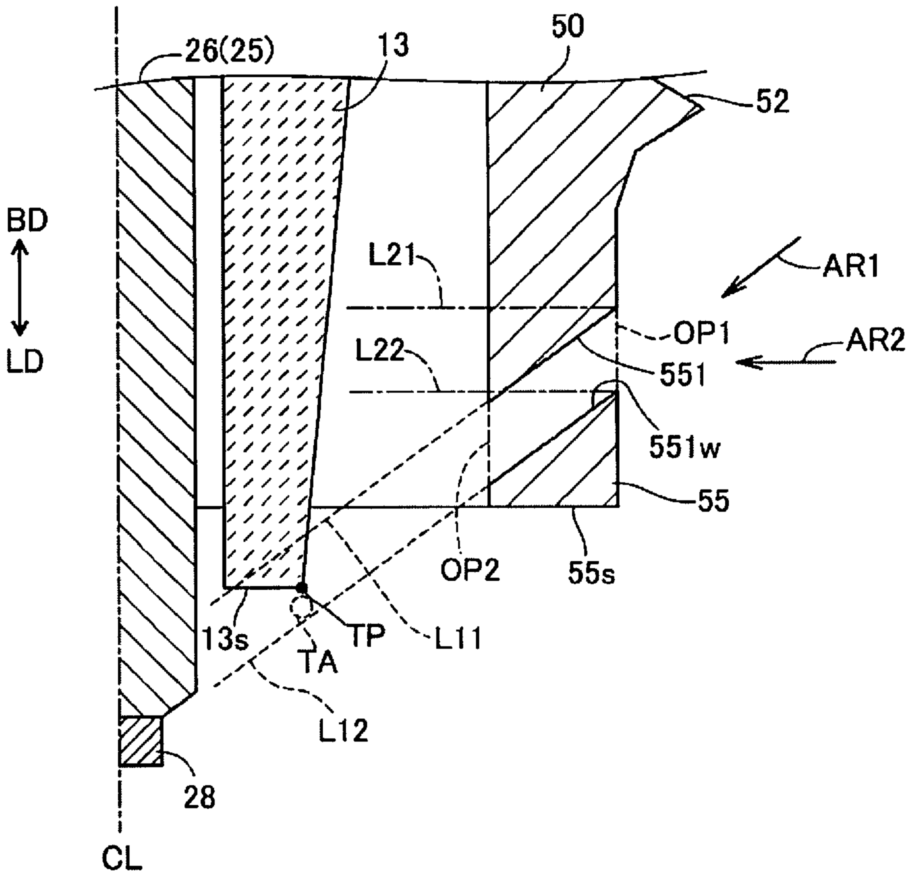

FIG. 4

MODIFICATION

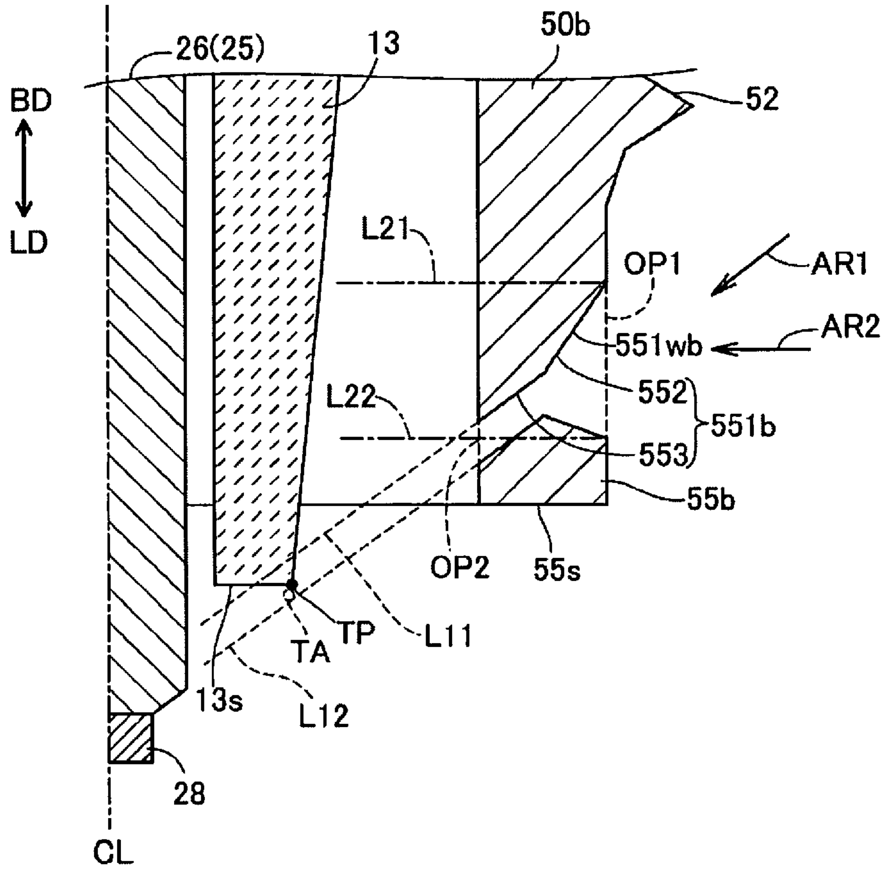

FIG. 5

MODIFICATION

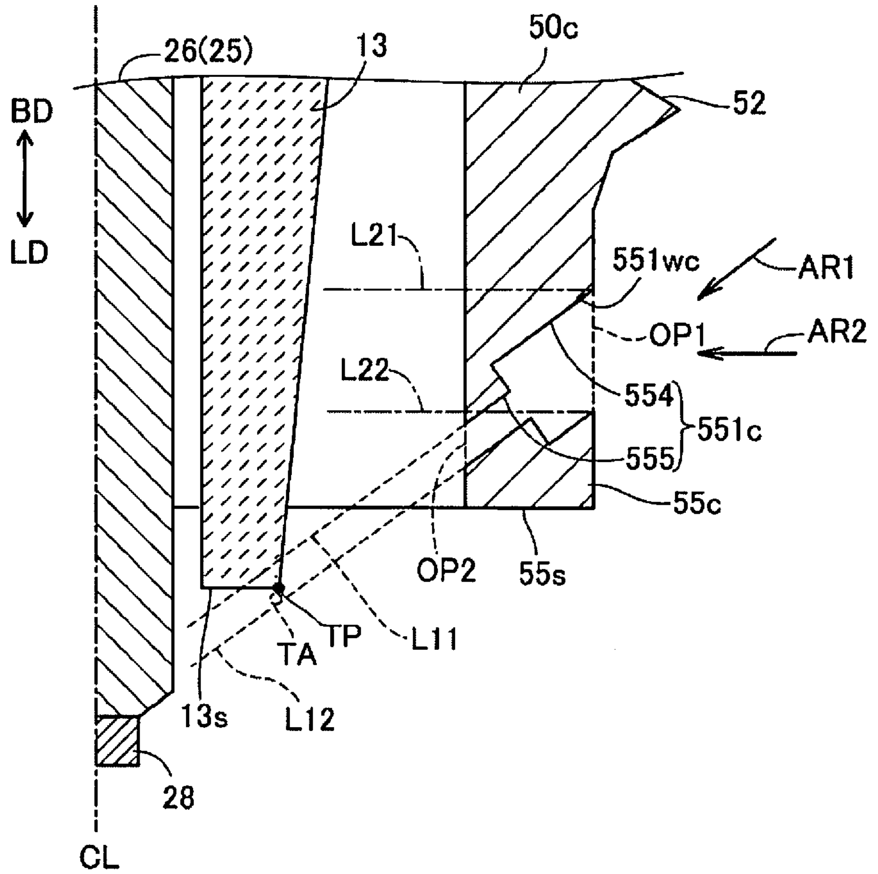

FIG. 6

MODIFICATION

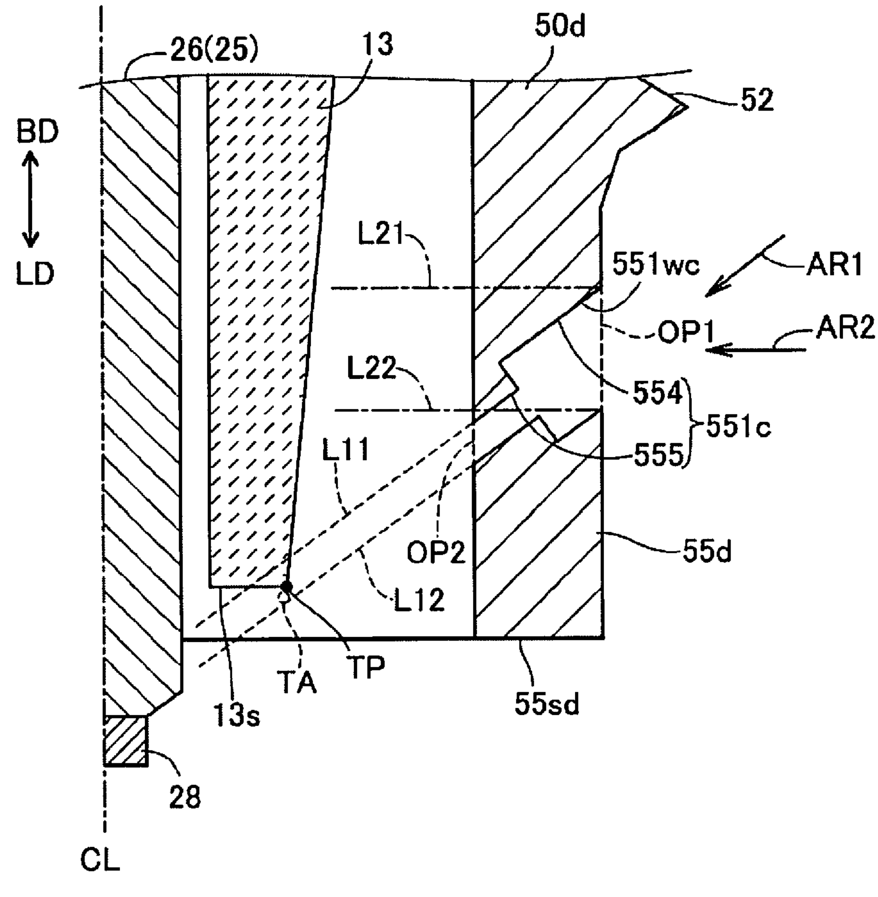

FIG. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 15 6798

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	DE 89 08 502 U1 (TAE HAK PARK, KOREA) 7 September 1989 (1989-09-07) * page 3, paragraph 2 - paragraph 4; figures 1,2 * -----	1-3,7 4-6	INV. H01T13/16
X A	EP 0 071 577 A1 (ESPADA ANSTALT [LI]) 9 February 1983 (1983-02-09) * page 2, line 12 - page 3, line 20; figure 1 * -----	1-4,6 5,7	
A	GB 2 404 422 A (FEDERAL MOGUL IGNITION UK LTD [GB]) 2 February 2005 (2005-02-02) * abstract; figure 5 * -----	1	
A	US 2015/194793 A1 (YAMANAKA KOUJI [JP]) 9 July 2015 (2015-07-09) * abstract; figures 1-8 * -----	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01T

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	10 July 2017	Ruppert, Christopher

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 15 6798

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-07-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 8908502 U1	07-09-1989	DE 8908502 U1	07-09-1989
		JP H0222594 U	15-02-1990
EP 0071577 A1	09-02-1983	AU 8655682 A	03-02-1983
		BR 8204434 A	19-07-1983
		EP 0071577 A1	09-02-1983
		JP S5826926 A	17-02-1983
GB 2404422 A	02-02-2005	DE 602004003972 T2	11-10-2007
		EP 1671405 A1	21-06-2006
		GB 2404422 A	02-02-2005
		WO 2005015702 A1	17-02-2005
US 2015194793 A1	09-07-2015	JP 6015678 B2	26-10-2016
		JP 2015130302 A	16-07-2015
		US 2015194793 A1	09-07-2015

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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

- WO 2008102842 A **[0003]**