A method of manufacturing an insulating member 2 for a spark plug, the insulating member 2 including an axial hole 4 extending in an axial direction, in which a center electrode 5 is held at a front end side of the axial hole and a terminal 6, e.g. a metal terminal, is held at a rear end side of the axial hole. The method includes: a pressurized forming step of compressing raw powder PM to form a molding CP1 having a hole portion HL, of which a rear end side is opened and a front end side is closed; a support pin inserting step of inserting a rod-shaped support pin 61 into the hole portion 112 from the rear end side of the molding; and a grinding step of grinding an outer circumferential surface of the molding CP1 inserted with the support pin 61 to form an unfired insulating member IP having a shape of the insulating member 2, wherein after the pressurized forming step and before the grinding step, a front end removal step of cutting a front end portion of the molding or grinding the front end portion in an axial direction to penetrate the hole portion is included.
Description

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority from Japanese Patent Application No. 2009-043697, which was filed on February 26, 2009, the disclosure of which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to a spark plug for use in an internal combustion engine, an insulating member for the spark plug which is used in the spark plug, and a method of manufacturing the same.

BACKGROUND

[0003] A spark plug for an internal combustion engine is installed in the internal combustion engine, and is used to ignite an air-fuel mixture in a combustion chamber. In general, the spark plug includes an insulating member having an axial hole, a center electrode inserted into the front end side of the axial hole, a terminal electrode (terminal shell) inserted into the rear end side of the axial hole, a metal shell installed on the outer circumference of the insulating member, and a ground electrode installed on the front end portion of the metal shell and forming a spark discharge gap between the center electrode and the ground electrode.

[0004] Further, the insulating member for the spark plug is generally manufactured by the following. That is, raw powder including alumina as a main component thereof is filled in a cavity of a cylindrical rubber mold for shaping, and a rod-shaped press pin is inserted into the cavity. The raw powder is pressurized and compressed by applying hydraulic pressure to the rubber mold for shaping in a diameter direction, thereby obtaining a molding. After a support pin is inserted into a hole portion serving as the axial hole, of which a rear end side is opened and a front end side is closed, from the rear end side, the grinding rotation roller having a predetermined shape of the insulating member on the outer circumference is rotated around a center shaft parallel with the axis as a rotation axis, and is brought in contact with the molding. Accordingly, the molding is ground to obtain an unfired insulating member having the shape of the insulating member. After that, the unfired insulating member is fired to obtain the insulating member. In a grinding process of the molding, it is required to communicate the hole portion to form the axial hole. For this reason, the grinding is started from the front end portion of the molding, of which a grinding amount is relatively large in comparison with other portions.

[0005] However, if the grinding is started from the front end portion of the molding, high stress is applied to the proximal end portion of the support pin. It causes the support pin to be deformed or broken down. In addition, according to the deformation of the support pin, the thickness of the unfired insulating member is varied in a circumferential direction, so that the withstanding voltage performance or mechanical strength of the insulating member may be deteriorated.

[0006] Consequently, in order to prevent deformation or breakdown of the support pin, a method of increasing the rigidity of the support pin by relatively enlarging the outer diameter of the support pin has been proposed (e.g., Patent Document 1).


SUMMARY

[0008] However, there is a demand for a compact spark plug (reduced in diameter), and thus it is desirable to reduce the diameter of the insulating member. In a case of employing the above method, since the outer diameter of the support pin is necessarily maintained to some extent, the thickness of the insulating member has to be thinned in order to reduce the diameter of the insulating member. As a result, there is a concern that the mechanical strength or withstanding voltage performance of the insulating member is not sufficiently ensured.

[0009] In view of the above-described circumstances, a method according to claim 1, an insulating member according to claim 11, and spark plugs according to claims 12 and 13 are proposed. Further advantages, features, aspects and details of the invention are evident from the dependent claims, the description and the drawings.

An advantage of aspects of the invention is to provide a method of manufacturing an insulating member for a spark plug which can form the insulating member with high precision by reliably preventing deformation or breakdown of a support pin and can meet a demand for a compact spark plug. Also, an insulating member for the spark plug manufactured by the same method and having the related advantages, and a spark plug for an internal combustion engine including the insulating member for the spark plug are provided.

[0010] Hereafter, configurations suitable for achieving the above-described advantages will be described in an itemized fashion. Each configuration may be combined with any other configuration or aspect unless clearly indicated to the contrary. In particular any feature indicated as being preferred or advantageous may be combined with any other feature or features indicated as being preferred or advantageous, both in the configurations and in the embodiments that are described further below. In addition, when necessary, operations and effects peculiar to each configuration will be added.

[0011] Configuration 1. According to this Configuration, a method of manufacturing an insulating member for a spark plug (hereinafter referred to as ‘insulating member’) including an axial hole extending in an axial direction, in which a center electrode is held at a front end side of the axial hole and a (e.g. metal) terminal is
held at a rear end side of the axial hole, is characterized by including a pressurized forming step of compressing raw powder to form a molding having a hole portion, of which a rear end side is opened and a front end side is closed; a support pin inserting step of inserting a rod-shaped support pin into the hole portion from the rear end side of the molding; and a grinding step of grinding an outer circumferential surface of the molding inserted with the support pin to form an unfired insulating member having a shape of the insulating member. According to a variant of configuration 1, after the pressurized forming step and before the grinding step, a front end removing step of cutting a front end portion of the molding and/or grinding the front end portion in an axial direction to penetrate the hole portion is included.

[0012] According to the Configuration 1, in the front end removing step before the grinding step, the front end portion of the molding is cut and/or ground from the axial direction (front end side) (toward the rear end side) to penetrate the hole portion. Consequently, it is not necessary to start the grinding from the front end portion of the molding in the next grinding step. That is, it is possible to start the grinding from other portions except for the front end portion of the molding in the grinding step. For this reason, it is possible to reliably suppress high stress from being applied to the proximal end portion of the support pin, thereby reliably preventing damage or breakdown of the support pin. As a result, the insulating member can be formed with high precision.

[0013] Further, according to the Configuration 1, since the support pin is hardly ever deformed and it is not necessary to enlarge the diameter of the support pin, the diameter of the axial hole can be reduced. As a result, in a case in which the outer diameter of the insulating member is set to be small in order to meet the downsizing of the spark plug, it is possible to sufficiently ensure the thickness of the insulating material. That is, according to the Configuration, it is possible to perform the downsizing of the spark plug, while sufficiently ensuring the mechanical strength or withstanding voltage required for the insulating member.

[0014] Configuration 2. According to this Configuration, a method of manufacturing an insulating member for a spark plug including an axial hole extending in an axial direction, in which a center electrode is held at a front end side of the axial hole and a (e.g. metal) terminal is held at a rear end side of the axial hole, is characterized by including a pressurized forming step of compressing raw powder to form a molding having a hole portion, of which a rear end side is opened and a front end side is closed; a support pin inserting step of inserting a rod-shaped support pin into the hole portion from the rear end side of the molding; and a grinding step of grinding an outer circumferential surface of the molding inserted with the support pin to form an unfired insulating member having a shape of the insulating member. According to a first variant of configuration 2, in the pressurized forming step, supposing that a length of the molding along the axis is L, a portion, of which a grinding amount is maximized in the grinding step, exists in a range of 2L/3 from the rear end of the molding. According to a second variant of configuration 2, a maximum-grinding-portion of the molding extends within a range of 2L/3 from the rear end of the molding, wherein the maximum-grinding-portion is defined by having a larger or equal grinding amount during the grinding step than any other axis-longitudinal portion of the molding.

[0015] In this instance, the expression 'portion, of which a grinding amount is maximized in the grinding step' means a portion on a plane perpendicular to the axis, of which a value (in this instance, the value means the outer diameter of the molding in a case in which the unfired molding does not exist on the plane) subtracting a distance from the rear end of the molding refers to the range anywhere between the rear end and the position at the length from the rear end of the molding, the distance being measured along the axial axis.

[0016] According to the Configuration 2, in the pressurized forming process, the molding is formed in such a manner that the portion, of which the grinding amount is maximized in the grinding process, exists in the range of 2L/3 from the rear end of the molding. For this reason, the grinding starts at the portion existing in the range of 2L/3 from the rear end of the molding in the grinding process. Consequently, it is possible to reliably suppress high stress from being applied to the proximal end portion of the support pin, thereby reliably preventing damage or breakdown of the support pin. As a result, the insulator can be manufactured with high precision.

[0017] Further, as described above, since it is not necessary to increase the diameter of the support pin, it is possible to downsize the spark plug while the thickness of the insulating member is sufficiently ensured.

[0018] Configuration 3. According to this Configuration, a method of manufacturing an insulating member for a spark plug including an axial hole extending in an axial direction, in which a center electrode is held at a front end side of the axial hole and a (e.g. metal) terminal is held at a rear end side of the axial hole, is characterized by including a pressurized forming step of compressing raw powder to form a molding having a hole portion, of which a rear end side is opened and a front end side is closed; a support pin inserting step of inserting a rod-shaped support pin into the hole portion from the rear end side of the molding; and a grinding step of grinding an outer circumferential surface of the molding inserted with the support pin to form an unfired insulating member having a shape of the insulating member, wherein in the grinding step, supposing that a length of the molding along the axis is L, grinding is started from a portion of the molding which is placed in a range of L/3 from the rear end of the molding, and a portion of the rear end side more than L/3 from the front end of the molding...
comes into contact with the grinding member before the grinding amount reaches 10% of the total grinding amount in the grinding step.

[0019] According to the Configuration 3, in the grinding process of the molding, first, the grinding is started from the front end side (the portion placed in the range of L/3 from the front end of the molding) of the molding. The rear end (the portion in the rear end side than L/3 from the front end of the molding) of the molding comes into contact with the grinding member (e.g., grinding rotation roller) at the step in which the grinding amount is 10% or less of the total grinding amount in the grinding step, or, in other word, in which the integrated grinding amount, integrated along the axial length, is 10% or less of the total, or final, integrated grinding amount in the grinding step. That is, in the initial step of the grinding step, the grinding member comes into contact with the front end portion and the rear end portion of the molding, thereby preventing high stress from being continuously applied to the support pin. For this reason, it is possible to reliably prevent the support pin from being deformed or broken down, and thus it is possible to form the insulating member with high precision. Further, since it is not necessary to increase the diameter of the support pin, it is possible to downsize the spark plug while the thickness of the insulating member is sufficiently ensured.

[0020] Further, in a case in which the grinding is started from the rear end portion of the molding, it is necessary to relatively thicken the rear end portion, so that the total grinding amount may be increased in the grinding step. According to the Configuration 3, since the rear end portion can be relatively thickened, it is possible to suppress the total grinding amount. As a result, it is possible to suppress the increase of the manufacturing cost.

[0021] Configuration 4. According to this Configuration, a method of manufacturing an insulating member for a spark plug including an axial hole extending in an axial direction, in which a center electrode is held at a front end side of the axial hole and a (e.g., metal) terminal is held at a rear end side of the axial hole, is characterized by including a pressurized forming step of compressing raw powder to form a molding having a hole portion, of which a rear end side is opened and a front end side is closed; a support pin inserting step of inserting a rod-shaped support pin into the hole portion from the rear end side of the molding; and a grinding step of grinding an outer circumferential surface of the molding inserted with the support pin to form an unfired insulating member having a shape of the insulating member, wherein in the grinding step, supposing that a length of the molding along the axis is L, a portion of the molding which is placed in a range of 2L/3 from the rear end of the molding comes firstly into contact with the grinding member.

[0022] According to the Configuration 4, the grinding is started from the portion of the molding which is placed in a range of 2L/3 from the rear end of the molding. Consequently, the same working effect as that of the Configuration 2 is obtained.
member against the molding. Consequently, it is possible
to further prevent the deformation or breakdown of the
support pin.

[0030] In addition, the distance of the axis between the
center portion of the outer circumferential surface of the
pressing member along the axis line and the portion, of
which the grinding amount is maximized, in the range of
2L/3 from the rear end of the molding is L/5 or less. That
is, the pressing member is placed so as to approach as
much as possible a portion, which is firstly ground, of the
rear end portion of the molding. Consequently, in the
grinding process, it is possible to reduce the load applied
to the support pin from the grinding rotation roller or the
pressing member, thereby further effectively preventing
the deformation or the like of the support pin.

[0031] Further, the above-described technical thought may
be embodied as the insulating member set forth in the
Configuration 8 or the spark plug set forth in the Con-
figuration 9.

[0032] Configuration 8. The insulating member for the
spark plug according to this Configuration is charac-
terized in that the insulating member is manufactured by
the manufacturing method according to any one of the
above-described Configurations 1 to 7.

[0033] Since the insulating member for the spark plug
according to the Configuration 8 is manufactured by the
manufacturing method according to the above-described
Configuration 1 or the like, it is possible to prevent a vari-
ation in thickness from happening, thereby obtaining su-
perior mechanical strength and withstanding voltage per-
formance.

[0034] Configuration 9. The spark plug for an internal
combustion engine according to this Configuration is char-
terized by including the insulating member for the
spark plug according to the above-described Configura-
tion 8.

[0035] Since the spark plug according to the Configura-
tion 9 includes the insulating member with superior me-
chanical strength and withstanding voltage performance,
itis possible to improve the durability and prolong the
lifespan.

[0036] Configuration 10. The spark plug for the internal
combustion engine according to this Configuration is char-
terized by including, in the Configuration 9, a cen-
ter electrode installed at the front end side of the axial
hole, a metal terminal installed at the rear end side of the
axial hole, a metal shell of a substantially cylindrical
shape which is provided on the outer circumference of the
insulating member and has a threaded portion for
engaging in a threaded manner with an attaching hole of
a head of the internal combustion engine, and a glass
seal layer formed by a glass powder mixture and sealing
at least a space between the metal terminal and the in-
sulating member in the axial hole, wherein the length of
the insulating member for the spark plug in the direction
of the axis is set to 65 mm or more, the maximum outer
diameter of the glass seal layer is set to 3.4 mm or less,
and the outer diameter of the threaded portion is set to
M12 or less.

[0037] Recently, there has been demand for a spark
plug with a reduced diameter and prolonged length, and
further, it is possible to manufacture the insulating mem-
ber in a relatively elongated shape. At the time of manu-
facturing the insulating member, it is necessary to rel-
atively elongate the support pin, but if the support pin is
elongated, the strength of the support pin is lowered, and
in the grinding process, the stress applied to the proximal
end portion of the support pin from the grinding member
is increased. That is, there is more concern about the
deformation or breakdown of the support pin at the time
of manufacturing the elongated insulating member.

[0038] According to the Configuration 10, the length of
the insulating member for the spark plug in the direction
of the axis is set to 65 mm or more, the maximum outer
diameter of the glass seal layer is set to 3.4 mm or less,
and the outer diameter of the threaded portion is set to
M12 or less. That is, since the spark plug according to
this Configuration includes a relatively elongated insulat-
ing member, there is concern about the deformation or
the like of the support pin in the grinding process. How-
ever, it is possible to further reliably suppress the defor-
mation or the like of the support pin by applying the re-
spective configurations. In other words, the respective
configurations are particularly advantageous when the
spark plug with the reduced diameter and the extended
length is manufactured.

Further aspects of the invention are also directed to ap-
paratures for carrying out the disclosed methods and
including apparatus parts for performing each described
method steps. These method steps may be performed
by way of hardware components, a computer pro-
grammed by appropriate software, by any combination
of the two or in any other manner. Furthermore, aspects
of the invention are also directed to methods by which
the described apparatus operates. They include method
steps for carrying out every function of the apparatus or
manufacturing every part of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] Illustrative aspects of the invention will be de-
scribed in detail with reference to the following figures
wherein:

Fig. 1 is a partially-sectioned, front view showing the
configuration of a spark plug;
Fig. 2 is a flowchart showing a method of manufac-
turing an insulator;
Fig. 3 is a cross-sectional view of a rubber press
machine to illustrate a filling process;
Fig. 4 is a cross-sectional view of a rubber press
molding to illustrate insertion of a press pin;
Fig. 5 is a cross-sectional view of a rubber press
molding to illustrate drawing of a molding after a pres-
surized forming process;
Fig. 6 is a front view showing the configuration of a
molding according to a first embodiment;
Fig. 7 is a schematic view showing a molding after insertion of a support pin and before a grinding process;
Fig. 8 is a schematic view showing a position relationship between a molding and a grinding rotation roller at a start of a grinding process;
Fig. 9 is a schematic view showing unfired insulator formed after a grinding process;
Fig. 10 is a front view showing the configuration of a molding according to a second embodiment;
Fig. 11 is a schematic view for reference to illustrate a case in which a molding comes in contact with a grinding rotation roller;
Fig. 12 is a flowchart showing a method of manufacturing an insulator according to a second embodiment;
Fig. 13 is a front view showing the configuration of a molding after a process of removing a distal end;
Fig. 14 is a front view showing the configuration of a molding according to a third embodiment; and
Fig. 15 is a schematic view showing an initial step of a grinding process according to a third embodiment.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE PRESENT INVENTION

[Embodiment 1]

[0040] An embodiment will now be described with reference to the drawings. Fig. 1 is a partially-sectioned, front view of a spark plug for an internal combustion engine (hereinafter, referred to as ‘spark plug’) 1. Notably, in Fig. 1, the spark plug 1 is depicted in such a manner that the direction of an axis CL1 which passes through the center of the spark plug 1 coincides with the vertical direction in Fig. 1. Further, in the following description, the lower side of Fig. 1 will be referred to as the front end side of the spark plug 1, and the upper side of Fig. 1 will be referred to as the rear end side of the spark plug 1.

[0041] The spark plug 1 is constituted of a cylindrical insulator 2 serving as an insulating member for a spark plug, and a cylindrical metal shell 3 holding the insulator 2 therein.

[0042] As is well known, the insulator 2 is made of alumina or the like through baking. The insulator 2 includes in its outer configuration portion a rear end-side barrel portion 10 formed on the rear end side thereof, a large-diameter portion 11 protruding radially outward at a position closer to the distal end side than the rear end-side barrel portion 10, an intermediate barrel portion 12 formed closer to the distal end side than the large-diameter portion 11 and having a diameter smaller than that of the large-diameter portion 11, and a long leg portion 13 formed closer to the distal end side than the intermediate barrel portion 12 and having a diameter smaller than that of the intermediate barrel portion 12.

Of the insulator 2, the large-diameter portion 11, the intermediate barrel portion 12, and the major part of the long leg portion 13 are accommodated within the metal shell 3. A stepped portion 14 of a tapered shape is formed at a connection portion between the leg portion 13 and the intermediate barrel portion 12. The insulator 2 is engaged with the metal shell 3 at the stepped portion 14.

[0043] Further, the insulator 2 has an axial hole 4 which extends through the insulator 2 along the axis CL1. A center electrode 5 is inserted into and fixed to a front end side of the axial hole 4. The center electrode 5 includes an inner layer 5A made of copper or a copper alloy, and an outer layer 5B made of a Ni alloy containing nickel as a main component thereof. In addition the center electrode 5 is formed in a rod-like shape (cylindrical columnar shape) as a whole, and the distal end surface of the center electrode 5 is formed flat and protrudes from the distal end portion of the insulator 2. Further, a noble metal tip 31 of a cylindrical columnar shape which is made of a noble metal alloy is joined to a distal end portion of the center electrode 5.

[0044] Further, a terminal electrode 6 is inserted into and fixed to a rear end side of the axial hole 4 in such a manner that the terminal electrode 6 projects from the rear end of the insulator 2.

[0045] Further, a cylindrical columnar resistor 7 is disposed between the center electrode 5 and the terminal electrode 6 of the axial hole 4. Both end portions of the resistor 7 are electrically connected to the center electrode 5 and the terminal electrode 6, respectively, via electrically conductive glass seal layers 8 and 9, respectively. In this instance, the glass seal layer 9 corresponds to a glass seal layer of the invention.

[0046] The metal shell 3 is made of metal such as low carbon steel and is formed in a cylindrical shape. A threaded portion (external threaded portion) 15 for mounting the spark plug 1 onto an engine head is formed on the outer circumferential surface of the metal shell. A seat portion 16 is formed on the outer circumferential surface of the rear end side of the threaded portion 15. A ring-shaped gasket 18 is fitted into a threaded neck portion 17 at the rear end of the threaded portion 15. A tool engagement portion 19 having a hexagonal cross-section shape is provided at the rear end side of the metal shell 3 so that a tool, such as a wrench, engages with the tool engagement portion 19 when the spark plug 1 is mounted to the engine head. Further, a crimping portion 20 is provided at the rear end side of the metal shell to hold the insulator 2 at the rear end portion.

[0047] Further, a tapered stepped portion 21 with which the insulator 2 is engaged is provided on the inner circumferential surface of the metal shell 3. The insulator 2 is inserted into the metal shell 3 from its rear end side toward the front end side. In a state where the stepped portion 14 of the insulator 2 is engaged with the step portion 21 of the metal shell 3, a rear end-side opening portion of the metal shell 3 is crimped radially inward. That is, the crimping portion 20 is formed, so that the
insulator 2 is fixed. In this instance, an annular plate packing 22 is interposed between the stepped portion 14 of the insulator 2 and the stepped portion 21 of the metal shell 3. Thus, the airtightness of a combustion chamber is secured, so that a fuel air mixture which enters the clearance between the inner circumferential surface of the metal shell 3 and the long leg portion 13 of the insulator 2 exposed to the interior of the combustion chamber is prevented from leaking to the outside.

Moreover, in order to render the sealing by the crimping more complete, on the rear end side of the metal shell 3, annular ring members 23 and 24 are interposed between the metal shell 3 and the insulator 2, and powder of talc 25 is charged in the space between the ring members 23 and 24. That is, the metal shell 3 holds the insulator 2 via a plate packing 22, the ring members 23 and 24, and the talc 25.

A ground electrode 27 is joined to a front end portion 26 of the metal shell 3. A middle portion of the ground electrode 27 is bent and a lateral surface thereof faces the center electrode 5. A noble metal chip 32 of a cylindrical columnar shape, which is made of noble metal alloy, is joined to a distal end portion of the ground electrode 27. A spark discharge gap 33 is formed between the two tips 31 and 32, in which spark discharge occurs along a direction approximately perpendicular to the axis CL1.

In this embodiment, as the outer diameter of the threaded portion 15 is M12 or less (e.g., M10 or less), the threaded portion is relatively reduced in diameter. For this reason, the insulator 2 inserted into the metal shell 3 is relatively reduced in outer diameter. From the viewpoint of sufficiently ensuring the thickness of the insulator 2, the inner diameter of the axial hole 4 is relatively small. Consequently, the maximum outer diameter of the glass seal layer 9 disposed in the axial hole 4 is 3.4 mm or less. Further, the insulator 2 is extended in length, and more specifically, the length of the insulator 2 is 65 mm or more in the direction of axis CL1.

Next, a method of manufacturing the spark plug 1 configured as described above will be described. First, the metal shell 3 is pre-fabricated. That is, cold forging operation is performed on a cylindrical columnar metal material (e.g., iron material or stainless steel material such as S17C or S25C) so as to form a through hole therein and impart a rough shape to the metal material. Subsequently, cutting operation is performed on the metal material so as to impart a predetermined outer shape to the metal material to thereby obtain a metal shell intermediate.

Subsequently, the ground electrode 27 made of a Ni alloy is resistance-welded to the front end surface of the metal shell intermediate. Since a so-called “sagging” is produced as a result of the welding, the “sagging” is removed. Subsequently, the threaded portion 15 is formed in a predetermined region of the metal shell intermediate by means of rolling. Thus, the metal shell 3 to which the ground electrode 27 has been welded is obtained. Zinc plating or nickel plating is performed on the metal shell 3 to which the ground electrode 27 has been welded. Notably, in order to improve corrosion resistance, chromate treatment may be performed on the surface.

Next, the insulator 2 is fabricated. A method of fabricating the insulator 2 will be described in detail with reference to the flowchart of Fig. 2. First, in a raw powder forming process in S10, a powdery matter containing alumina (aluminum oxide) powder as a main component thereof and a sintering auxiliary agent is mixed with an acrylic binder, and then is wet-mixed by using water as a solvent to adjust slurry. The adjusted slurry is spray-dried to obtain raw powder.

In a filling process of a step S20, the obtained raw powder is filled in the rubber pressing machine 41 shown in Fig. 3. The rubber pressing machine 41 includes an internal rubber mold 43 of a cylindrical shape having a cavity 42 extending in the direction of an axis CL2, an external rubber mold 44 of a cylindrical shape installed on the outer circumference of the internal rubber mold 43, a machine body 45 installed on the outer circumference of the external rubber mold 44, and a bottom cover 46 and a lower holder 47 which close a lower opening portion of the cavity 42. Further, the machine body 45 is provided with a liquid channel 45a, and hydraulic pressure is applied to the outer circumferential surface of the external rubber mold 44 in a diameter direction through the liquid channel 45a, thereby contracting the cavity 42 in the diameter direction.

Returning to the description of the manufacturing method, in a filling process, the cavity 42 of the internal rubber mold 43 is filled with the raw powder PM. Then, as shown in Fig. 4, a press pin 51 is placed in the cavity 42. The proximal end side of the press pin 51 is integrally installed with an upper holder 52, and the upper holder 52 is fitted into the upper opening portion of the cavity 42 to close the cavity 42 in a sealed state.

Next, in a pressurized forming process of a step S30, since the hydraulic pressure is applied through the liquid channel 45a, the pressure is applied from the outer circumferential side of the internal rubber mold 43 and the external rubber mold 44, so that the cavity 42 is contracted. Thus, the raw powder PM is compressed and formed. After a lapse of a predetermined time, the application of the hydraulic pressure is released, the internal rubber mold 43 and the external rubber mold 44 are elastically returned, so that the contracted cavity 42 is returned to original size. As shown in Fig. 5, if the press pin 51 is lifted up from the rubber pressing machine 41 in the direction of the axis CL2, a molding CP1 formed by compressing the raw powder PM is extracted from the cavity 42 together with the press pin 51. After that, if the press pin 51 is relatively rotated with respect to the molding CP1, the press pin 51 is extracted from the molding CP1. A hole portion HL of the molding CP1 which is formed by extracting the press pin 51 constitutes the axial
hole 4.

[0057] In the pressurized forming process, as shown in Fig. 6, supposing that the length of the molding CP1 in the axis CL1 is L, the molding CP1 is formed in such a manner that a portion (in the same figure, a portion marked by a scattered point pattern), of which a value subtracting the outer diameter of the unfired insulating member IP obtained by a grinding process described below from the outer diameter of the molding CP1 is maximized, that is, a portion for maximum grinding MG, exists in the range of 2L/3 from the rear end of the molding CP1. In other words, the molding CP1 is formed in such a manner that the portion for maximum grinding MG, of which a grinding amount is maximized in a grinding process of a step S50 described below, exists in the range of 2L/3 from the rear end of the molding CP1. Further, the length of the portion for maximum grinding MG in the axis CL1 is set to be equal to or more than 5 mm and equal to or less than 20 mm.

[0058] Next, in a support pin inserting process of a step S40, as shown in Fig. 7, a support pin 61 is inserted into the hole portion HL of the obtained molding CP1. In a grinding process of a step S50, the grinding is performed on the molding CP1. More specifically, as shown in Fig. 8, the grinding is performed on the molding CP1 by inserting the molding CP1 between a grinding rotation roller 62 which rotates around a CL3 parallel with the axis CL1 as a center axis, and has a shape corresponding to the shape of the insulator 2 on the outer circumferential portion, and a pressing member 63 has a circular cross-sectional shape and supports the molding CP1 against a frictional force received from the grinding rotation roller 62. As described above, the molding CP1 has the portion for maximum grinding MG in the range of 2L/3 from the rear end, of which the grinding amount is maximized in the grinding process of the step S50. For this reason, at the start of the grinding, the portion for maximum grinding MG of the molding CP1 comes in contact with the grinding rotation roller 62. In this instance, the pressing member 63 is within the range of 2L/3 from the rear end of the molding CP1, and is positioned at a position in which the distance S of the axis CL1 between a center portion 63M of the outer circumference portion of the pressing member 63 and the portion for maximum grinding MG is 1/5 or less of the length L of the molding CP1.

[0059] By performing the grinding process, as shown in Fig. 9, the unfired insulating member IP having the axial hole 4 formed by penetration of the hole portion HL is formed in the same shape as the insulator 2. After that, the support pin 61 is separated from the unfired insulating member IP. In a baking process of a step S60, the obtained unfired insulating member IP is input and baked in the firing furnace to obtain the insulator 2.

[0060] Further, the center electrode 5 is fabricated, separately from the metal shell 3 and the insulator 2. That is, a forging process is performed on a Ni alloy with a copper alloy placed at a center portion thereof so as to enhance a heat radiation performance, thereby fabricating the center electrode 5.

[0061] The insulator 2 and the center electrode 5 which are obtained by the above description, and the resistor 7 and the terminal electrode 6 are sealed and fixed by the glass seal layers 8 and 9. In general, the glass seal layers 8 and 9 are formed of a mixture of borosilicate glass and metal powder. The mixture is charged in the axial hole 4 of the insulator 2 in such a manner that the resistor 7 is disposed between upper and lower layers of the mixture. While the mixture is pressed from the rear side via the terminal electrode 6, the mixture is heated within the firing furnace, so that the mixture is fired. In this instance, a glaze layer may be simultaneously formed on the surface of the rear end-side barrel portion 10 of the insulator 2 through firing. Alternatively, the glaze layer may be formed in advance.

[0062] After that, the insulator 2 fabricated as described above and having the center electrode 5 and the terminal electrode 6, and the metal shell 3 fabricated as described above and having the ground electrode 27 are assembled together. More specifically, the insulator 2 is fixed by crimping radially inward the rear end-side opening portion of the metal shell 3 which is relatively thin, i.e., by forming the crimping portion 20.

[0063] Finally, the spark discharge gap 33 between the distal end portion of the center electrode 5 and the distal end portion of the ground electrode 27 is adjusted by bending the ground electrode 27, thereby obtaining the spark plug 1.

[0064] As described above in detail, according to this embodiment, in the pressurized forming process, the molding CP1 is formed in such a manner that the portion for maximum grinding MG, of which the grinding amount is maximized in the grinding process, exists in the range of 2L/3 from the rear end of the molding CP1. That is, the grinding starts at the portion existing in the range of 2L/3 from the rear end of the molding CP1. Consequently, it is possible to reliably suppress high stress from being applied to the proximal end portion of the support pin 61, thereby reliably preventing damage or breakdown of the support pin 61. As a result, the insulator 2 can be manufactured with high precision.

[0065] Further, since the support pin 61 is hardly ever deformed and it is not necessary to enlarge the diameter of the support pin 61, the diameter of the axial hole 4 can be reduced. As a result, as this embodiment, in order to meet the downsizing of the spark plug 1, it is possible to sufficiently ensure the thickness of the insulator 2 in a case in which the outer diameter of the insulator 2 is set to be small. That is, according to this embodiment, it is possible to perform the downsizing of the spark plug 1, while sufficiently ensuring the mechanical strength or withstanding voltage required for the insulator 2.

[0066] In addition, the unfired insulating member IP is formed by bringing the molding CP1 in contact with the rotating grinding rotation roller 62. In this embodiment, the molding CP1 is supported by the pressing member 63. Accordingly, it is possible to perform the grinding
process of the molding CP1 with even higher precision, and thus it is possible to form the insulator 2 with even higher precision.

[0067] Further, since the pressing member 63 is positioned in the range of the 2L/3 from the rear end of the molding body CP1, it is possible to suppress high stress from being applied to the support pin 61 due to the fact the pressing member 63 comes into contact with the molding CP1, thereby reliably preventing damage or breakdown of the support pin 61.

[0068] In addition, the distance S between the middle portion 63M of the pressing member 63 and the portion for maximum grinding MG in the axis CL1 is set to L/5 or less. That is, the pressing member 63 is placed in such a manner that it approaches the portion (the portion for maximum grinding MG) initially ground in the rear end-side portion of the molding CP1. Accordingly, at the grinding process, it is possible to decrease the load applied to the support pin 61 from the grinding rotation roller 62 or the pressing member 63, thereby further effectively preventing the deformation of the support pin 61.

[0069] Moreover, the width of the portion for maximum grinding MG is set to be sufficiently long at 5 mm or more. Accordingly, in the grinding process, it is possible to disperse the pressure applied to the portion for maximum grinding MG, and thus it is possible to reliably prevent the molding CP1 from breaking down on the portion for maximum grinding MG as the origin. Further, since the width of the portion for maximum grinding MG is set to 20 mm or less, it is possible to prevent the grinding amount from remarkably increasing, thereby suppressing the increase of the manufacturing cost.

[Embodiment 2]

[0070] The second embodiment will be now described with reference to the drawings, on the basis of the difference between the first embodiment and the second embodiment.

[0071] In the second embodiment, in particular, the shape of a molding CP2 is different in the manufacture of the insulator 2. That is, in the first embodiment, the middle portion of the molding CP1 is formed to have a relatively large diameter so as to form the portion for maximum grinding MG, of which the grinding amount is maximized in the grinding process, in the range of 2L/3 from the rear end. On the contrary, in the second embodiment, since the internal shape of the cavity 42 is changed, the middle portion of the molding CP2 is formed to have a relatively small diameter, as shown in Fig. 10. Consequently, as shown in Fig. 11, in a case in which the molding CP2 comes into contact with the grinding rotation roller 62 while the axis CL1 of the molding CP2 is parallel with the axis CL3 of the grinding rotation roller 62, the molding CP2 is formed in such a manner that a portion MG2 (in the figure, a portion marked by a scattered point pattern) placed in the range of L3 from the front end of the molding CP2 comes into contact with the grinding rotation roller 62. That is, if the grinding process is performed on the molding CP2 in an intact state, the molding CP2 is configured in such a manner that the grinding is started from the portion MG2, so that high stress may be applied to the support pin 61.

[0072] Consequently, in the second embodiment, as shown in Fig. 12, a front end removing process of a step S35 is provided after the pressurized forming process of the step S30 before the support pin inserting process of the step S40. In the front end removing process, as shown in Fig. 13, the hole portion HL of the molding CP2 is penetrated by cutting the portion MG2 of the molding CP2 to form the axial hole 4.

[0073] As described in detail above, according to the second embodiment, the front end portion of the molding CP2 is cut in the front end removing process before the grinding process, and the hole portion HL is penetrated. Consequently, it is not necessary to start the grinding from the front end portion of the molding portion CP2 in the next grinding process. That is, in the grinding process, it is possible to start the grinding from other portions except for the front end portion of the molding CP2. For this reason, it is possible to suppress high stress from being applied to the proximal end portion of the support pin 61 in the grinding process, thereby reliably preventing the support pin 61 from being deformed or broken down. As a result, it is possible to form the insulator 2 with high precision.

[Embodiment 3]

[0074] The third embodiment will be now described with reference to the drawings, on the basis of the difference between the first embodiment and the second embodiment.

[0075] In the third embodiment, as shown in Fig. 14, in a molding CP3 there is a portion for maximum grinding MG3 (in the figure, a portion marked by a scattered point pattern), of which the grinding amount is maximized in the grinding process, in the range of L3 from the front end of the molding CP3. In the grinding process, as shown in Fig. 15, the grinding is started from the portion MG3 of the molding CP3, in which the portion SG placed in the range of 2L/3 from the rear end of the molding CP3 comes into contact with the grinding rotation roller 62 before the grinding amount reaches 10% of the total grinding amount in the grinding process. That is, in the initial step, the grinding rotation roller 62 comes into contact with the front end portion and the rear end portion of the molding CP3.

[0076] According to the third embodiment, in the grinding process of the molding CP3, first, the front end portion of the molding CP3 comes into contact with the grinding rotation roller 62, and the rear end of the molding CP3 comes into contact with the grinding rotation roller 62 at the step in which the grinding amount is 10% or less of the total grinding amount in the grinding process. That is, in the initial step of the grinding process, the grinding
rotation roller 62 comes into contact with the front end portion and the rear end portion of the molding CP3, thereby preventing high stress from being continuously applied to the support pin 61. For this reason, it is possible to reliably prevent the support pin 61 from being deformed or broken down, and thus it is possible to form the insulator 2 with high precision.

[0077] Further, in a case in which the grinding is started from the rear end portion of the molding CP3, it is necessary to relatively thicken the rear end portion, so that the total grinding amount may be increased in the grinding process. According to the third embodiment, since the rear end portion can be relatively thickened, it is possible to suppress the total grinding amount. As a result, it is possible to suppress the increase of the manufacturing cost.

[0078] It should be noted that the invention is not limited to details of above-described embodiment, and may be implemented as described below, for example. It goes without saying that it is also possible to adopt other applications and modifications which are not illustrated below.

[0079]

(a) In the embodiment, the outer diameter of the threaded portion 15 is set to M12 or below, but the outer diameter of the threaded portion 15 is not specifically limited. Further, the maximum outer diameter of the glass seal layer 9 is set to 3.4 mm or less, but the maximum outer diameter of the glass seal layer 9, that is, the inner diameter of the axial hole 4, is not specifically limited. In addition, the length of the insulator 2 in the direction of the axis CL1 is set to 65 mm or more, but it is not limited thereto. That is, the invention can be applied to the manufacture of another insulator 2 having the axial hole 4 of various diameters or total lengths.

[0080] (b) In the embodiment, the molding CP1 is supported by the pressing member 63 in the grinding process of the molding CP1, but the grinding process may be performed without forming the pressing member 63.

[0081] (c) In the second embodiment, the front end portion of the molding CP2 is cut and removed in the front end removing process. However, the front end portion of the molding CP2 may be removed by grinding the front end portion of the molding CP2 from the front end side toward the rear end side in the axial direction.

[0082] (d) In the embodiment, the noble metal tips 31 and 32 are provided on the center electrode 5 and the ground electrode 27, but both or any one of the noble metal tips 31 and 32 may be omitted.

[0083] (e) In the embodiment, the case in which the ground electrode 27 is joined to the front end portion 26 of the metal shell 3 is exemplified, but the invention is also applicable to a case in which the ground electrode is formed in such a manner as to shave off a portion of the metal shell (or a portion of a tip fitting welded in advance to the metal shell) (e.g., refer to JP-A-2006-236906).

[0084] (f) Although the tool engaging portion 19 is provided with a hexagonal cross-sectional shape, the shape of the tool engaging portion 19 is not limited thereto. For example, the tool engaging portion 19 may have a BI-HEX (modified 12-point) shape [IS022977:2005(E)] or the like.

[Description of Reference Numerals and Signs]

[0085]

1: SPARK PLUG (SPARK PLUG FOR INTERNAL COMBUSTION ENGINE)
2: INSULATOR (INSULATING MEMBER FOR SPARK PLUG)
3: METAL SHELL
4: AXIAL HOLE
5: CENTER ELECTRODE
6: TERMINAL ELECTRODE (TERMINAL SHELL)
8: GLASS SEAL LAYER
15: THREADED PORTION
61: SUPPORT PIN
62: GRINDING ROTATION ROLLER (GRINDING MEMBER)
63: PRESSING MEMBER
CL1: AXIS
CP1, CP2, CP3: MOLDING
HL: HOLE PORTION
IP: UNFIRED INSULATING MEMBER
PM: RAW POWDER

Claims

1. A method of manufacturing an insulating member (2) for a spark plug (1), the insulating member (2) including an axial hole (4) extending in an axial direction, in which a center electrode (5) is held at a front end side of the axial hole and a metal terminal is held at a rear end side of the axial hole, the method comprising:

   a pressurized forming step (S30) of compressing raw powder (PM) to form a molding (CP1) having a hole portion (HL), of which a rear end side is opened and a front end side is closed; a support pin inserting step (S40) of inserting a rod-shaped support pin (61) into the hole portion (HL) from the rear end side of the molding; and a grinding step (S50) of grinding an outer circumferential surface of the molding (CP1) inserted with the support pin (61) to form an unfired insulating member (IP) having a shape of the insulating member (2).

2. The method according to claim 1, wherein
after the pressurized forming step (S30) and before the grinding step (S40), a front end removing step of removing the front end is included, whereby the hole portion (HL) is caused to penetrate through the insulating member (IP), the front end removing step including cutting a front end portion of the molding and/or grinding the front end portion along an axial direction to penetrate the hole portion.

3. The method according to any one of claims 1 to 2, wherein in the pressurized forming step (S30), supposing that a length of the molding along the axis is L, a portion (MG), of which a grinding amount is maximized in the grinding step, exists in a range of 2L/3 from the rear end of the molding.

4. The method according to any one of claims 1 to 3, wherein in the grinding step, supposing that a length of the molding along the axis is L, grinding is started from a portion of the molding which is placed in a range of L/3 from the rear end of the molding, and a portion of the rear end side more than L/3 from the front end of the molding comes into contact with a grinding member before the grinding amount reaches 10% of the total grinding amount in the grinding step.

5. The method according to any one of claims 1 to 4, wherein in the grinding step, supposing that a length of the molding along the axis is L, a portion of the molding which is placed in a range of 2L/3 from the rear end of the molding comes firstly into contact with a grinding member.

6. The method of manufacturing the insulating member according to any one of claims 1 to 5, wherein in the pressurized forming step, supposing that a length of the molding along the axis is L, the molding is formed in such a manner that a width, in an axial direction, of the portion (MG), of which the grinding amount is maximized in the grinding step, placed in the range of 2L/3 from the rear end of the molding, is set to 5 mm or more.

7. The method of manufacturing the insulating member according to claim 6, wherein in the pressurized forming step, the width, in the axial direction, of the portion (MG) of which the grinding amount is maximized in the grinding step is set to 20 mm or less.

8. The method of manufacturing the insulating member according to any one of the claims 1 to 7, wherein in the grinding step, by bringing the molding into contact with a rotating grinding rotation roller (62) and simultaneously into contact with a pressing member (63), the molding is supported against a frictional force from the grinding rotation roller so that the outer circumferential surface of the molding is ground to obtain the unfired insulating member having the shape of the insulating member, and wherein supposing that a length of the molding along the axis is L, the pressing member (63) is placed at a range of 2L/3 from the rear end of the molding, and is positioned at a position in such a manner that a distance S along an axis between a center portion (63M) of the outer circumferential surface of the pressing member (63) along the axis line and the portion (MG), of which the grinding amount is maximized, placed in the range of 2L/3 from the rear end of the molding, is set to L/5 or less.

9. A method of manufacturing a spark plug, including: manufacturing an insulating member according to any one of the previous claims.

10. The method according to claim 9, further comprising at least one of the following:

- inserting a center electrode into the front end side of the axial hole;
- inserting a terminal electrode into the rear end side of the axial hole,
- installing a metal shell on the outer circumference of the insulating member; and
- installing a ground electrode on the front end portion of the metal shell, and forming a spark discharge gap between the center electrode and the ground electrode.

11. An insulating member for the spark plug characterized in that the insulating member is manufactured by the manufacturing method according to any one of claims 1 to 8.

12. A spark plug for an internal combustion engine characterized by including the insulating member for the spark plug according to the claim 9.

13. The spark plug for the internal combustion engine, preferably the spark plug according to claim 12, the spark plug comprising:

- an insulating member having an axis and an axial hole, the axial hole having a front end side and a rear end side;
- a center electrode installed at the front end side of the axial hole;
- a metal terminal installed at the rear end side of the axial hole;
a metal shell of a substantially cylindrical shape which is provided on the outer circumference of the insulating member and has a threaded portion for engaging in a threaded manner with an attaching hole of a head of the internal combustion engine; and a glass seal layer formed by a glass powder mixture and sealing at least a space between the metal terminal and the insulating member in the axial hole, wherein the length of the insulating member for the spark plug in the direction of the axis is set to 65 mm or more, the maximum outer diameter of the glass seal layer is set to 3.4 mm or less, and the outer diameter of the threaded portion is set to M12 or less.
FIG. 2

RAW POWDER ADJUSTING PROCESS

FILLING PROCESS

PRESSURIZED FORMING PROCESS

SUPPORT PIN INSERTING PROCESS

GRINDING PROCESS

FIRING PROCESS
FIG. 3
FIG. 4
FIG. 8
FIG. 12

RAW POWDER ADJUSTING PROCESS

FILLING PROCESS

PRESSURIZED FORMING PROCESS

FRONT END REMOVING PROCESS

SUPPORT PIN INSERTING PROCESS

GRINDING PROCESS

FIRING PROCESS
REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009043697 A [0001]