



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
27.02.2002 Bulletin 2002/09

(51) Int Cl.7: **F02P 3/02**

(21) Application number: **01306945.5**

(22) Date of filing: **15.08.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

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(30) Priority: **18.08.2000 JP 2000248825**

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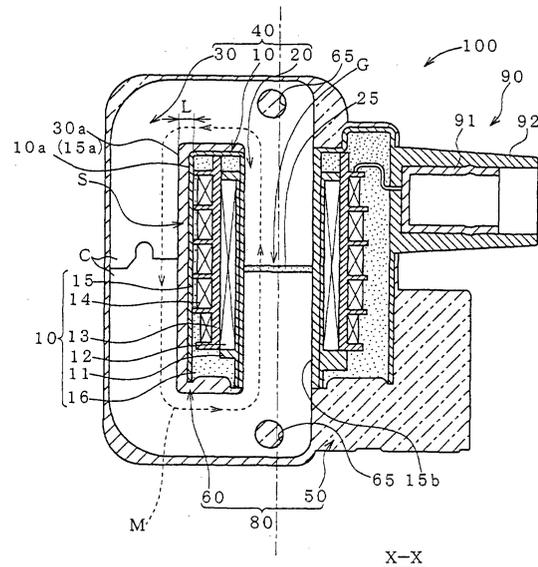
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(54) **Ignition coil and ignition unit using the same**

(57) An ignition coil 100 includes a coil section 10—which in turn includes a coil case 15, a primary coil 12 and a secondary coil 14 accommodated within the coil case 15, and an insulating molded layer 16 filling the coil case 15—and a coil core C including a center core section 20 and a yoke section 30. The ignition coil 100 is mounted on an engine body EB such that the coil core C is insulated from the engine body EB, by means of a mounting section 70. The mounting section 70, together with an insulating filling section 60 filling at least partially a gap S formed between the coil section 10 and the coil core C, which face each other, is integrally formed of a polymeric material through integral injection molding. That is, the ignition coil 100 is mounted on the engine body EB by means of the mounting section 70, which, together with the insulating filling section 60 filling the gap S formed between the coil section 10 and the coil core C, which face each other, is integrally formed of a polymeric material through integral injection molding.

Consequently there is disclosed an ignition coil of excellent durability and reliability that is capable of suppressing occurrence of leakage between a secondary coil and a coil core and suppressing generation of corona discharge across a gap between a coil section and the coil core to thereby suppress erosion of, for example, a coil case, which accommodates the primary and secondary coils, even when the maximum-voltage generation capability of the secondary coil is enhanced as a result of, for example, increase in discharge voltage of a spark plug, and the ignition coil is operated continuously for a long period of time, as well as to provide an ignition unit using the ignition coil.

Fig. 4



Description

[0001] The present invention relates to a closed-magnetic-path-type ignition coil and to an ignition coil using the same.

[0002] An ignition coil is used to supply high voltage (high voltage for discharge) of, for example, several tens of kilovolts to a spark plug for igniting, through generation of spark, mixture introduced into a combustion chamber of an engine. An ignition coil has a coil core of diversified shape. Known ignition coils include an ignition coil whose coil core forms an open magnetic path (hereinafter called an open-magnetic-path-type ignition coil), and an ignition coil whose coil core forms a closed magnetic path (hereinafter called a closed-magnetic-path-type ignition coil). An open-magnetic-path-type ignition coil involves high magnetic resistance, since an external portion (located in the atmosphere) of the coil core serves as a magnetic path, causing generation of magnetic leakage. As a result, loss may arise with respect to voltage supplied to a spark plug. In order to reduce magnetic leakage for suppression of loss with respect to supply voltage to a spark plug, a closed-magnetic-path-type ignition coil (disclosed in, for example, Japanese Patent Application Laid-Open (*kokai*) No. 9-312226) is used. FIG. 7 of the accompanying drawings shows a general cross-sectional structure of a closed-magnetic-path-type ignition coil having a secondary coil disposed radially outward of a primary coil.

[0003] A closed-magnetic-path-type ignition coil 150 shown in FIG. 7 includes a coil section 110, a center core section 120, and a yoke section 130. The coil section 110 includes a coil case 115 having an axial bore 115b formed therein, and a primary coil 112 and a secondary coil 114 accommodated within the coil case 115 in such a manner as to be concentrically wound around the axis of the coil case 115 (i.e., around the axial bore 115b). The center core section 120 is disposed inside the coil section 110 along the axis of the coil case 115 (i.e., along the axial bore 115b). The yoke section 130 is disposed outside the coil section 110 and connects opposite ends of the center core section 120 to thereby form, together with the center core section 120, a closed magnetic path M. In the coil section 110, the primary coil 112 is wound on the outer cylindrical surface of a primary bobbin 111 assuming a cylindrical shape and made of resin. The secondary coil 114 is wound in a divided condition on the outer cylindrical surface of a secondary bobbin 113 assuming a cylindrical shape and made of resin. The primary coil 112 and the secondary coil 114 are accommodated within the coil case 115 made of resin in such a manner as to be concentrically wound around the axis of the coil case 115 and such that the primary coil 112 is disposed radially inward of the secondary coil 114. An insulating resin is injected into the coil case 115 and solidified to form an insulating resin layer 116, which fills a gap between the primary coil 112, the secondary coil 114, and the coil case 115 to thereby

integrate them. Reference numeral 140 denotes a high-voltage tower connected electrically to the high-voltage side of the secondary coil 114 for leading high voltage externally (to, for example, a spark plug). Reference numeral 141 denotes a high-voltage terminal.

[0004] The center core section 120 disposed inside the coil section 110 and the yoke section 130 disposed outside the coil section 110 are formed in the following manner. Two E-shaped coil cores C, each being constructed from silicon steel laminations, are arranged such that corresponding leg portions thereof face each other to thereby form a closed magnetic path M. The center core section 120 has a gap G provided between the facing central leg portions of the E-shaped coil cores C, for the purpose of adjusting mutual inductance of the closed magnetic path M. The yoke section 130 has four mounting holes H formed therein at the corresponding four corners for use in mounting the closed-magnetic-path-type ignition coil 150 on an engine body at an ignition-coil mounting position. By means of the mounting holes H formed in the yoke section 130 and fastening components, such as bolts to be inserted through the mounting holes H, the closed-magnetic-path-type ignition coil 150 is mounted at the mounting position, and the coil core C is connected to the grounded engine body to thereby be grounded.

[0005] The coil portion 110 of the closed-magnetic-path-type ignition coil 150 involves, for example, the following two problems in relation to durability.

(1) Impairment in insulating performance as a result of increase in electric field intensity: The closed-magnetic-path-type ignition coil 150 is mounted on an engine body by use of the mounting holes H formed in the yoke section 130 such that the ignition coil 150 is mounted directly on the engine body. Thus, the coil core C serves as a grounding point. In this case, the distance L between the grounding point and the high-voltage side of the secondary coil 114 cannot be increased, because of structural restriction. As a result, in many cases, when high voltage is generated at the secondary coil 114, electric field intensity over the distance L increases (to, for example, 20 kV/mm or higher). When (dielectric breakdown strength of) the coil case 115 or the insulating resin layer 116 disposed between the secondary coil 114 and the coil core C becomes unable to endure the increase in electric field intensity, leakage may arise between the secondary coil 114 and the coil core C along the direction of the electric field. Specifically, discharge voltage of a spark plug increases with consumption of an electrode of the spark plug. Such an increase in discharge voltage or the like directly causes increase in electric field intensity between the secondary coil 114 and the coil core C. Thus, when the ignition coil 150 is used continuously for a long period of time under such a condition that discharge voltage of the spark plug

increases, leakage arises between the secondary coil 114 and the coil core C, potentially causing impairment in the coil case 115 and the insulating resin layer 116 and resulting in impairment in durability of the ignition coil 150.

(2) Erosion of coil section caused by corona discharge: In the closed-magnetic-path-type ignition coil 150, high electric field intensity is established between the coil core C, which is a conductive portion, and the secondary coil 114, which generates high voltage. When a gap S is present therebetween, in actual use, air present in the gap S may be ionized, thereby inducing corona discharge. As shown in FIG. 7, in the closed-magnetic-path-type ignition coil 150, the secondary coil 114 is disposed radially outward of the primary coil 112. In this case, corona discharge is likely to arise across the gap S between an inner surface 130a of the yoke section 130 and an outer surface 115a of the coil case 115, which face each other. That is, a portion of the gap S between the coil section 110 and the coil core C across which corona discharge is expected to arise is that between the inner surface 130a of the yoke section 130 and the outer surface 115a of the coil case 115, which face each other. When the ignition coil 150 is used continuously for a long period of time, heat of corona discharge and ozone generated during corona discharge impair the coil case 115 and the insulating resin layer 116, causing gradual erosion of resin, which constitutes the coil case 115 and the insulating resin layer 116. Eventually, dielectric breakdown arises.

[0006] In recent years, a stationary gas engine has been becoming popular. A stationary gas engine is used in plants, buildings, hospitals, hotels, etc. as an energy source for use in a cogeneration system, which utilizes exhaust heat and combustion heat to thereby improve energy utilization efficiency, and is also used in households, offices, etc. as a drive unit for a gas heat pump (GHP) for operating a small-sized air conditioner.

[0007] The primary requirement for such a stationary gas engine is reliability, since, in a certain application, the stationary gas engine may be used in direct relation to a so-called lifeline. Specifically, as compared with an automobile gasoline engine, the stationary gas engine is operated for a very long period of time (for example, 24-hour continuous operation). Thus, an ignition coil (closed-magnetic-path-type ignition coil) must exhibit sufficient durability, particularly in terms of (1) and (2) described above. Since a gas engine uses gaseous fuel, which is higher in insulating performance than liquid fuel, such as gasoline, a spark discharge gap of a spark plug is narrowed so as to lower discharge voltage. However, discharge voltage increases gradually with consumption of an electrode of the spark plug. Therefore, in an ignition coil of a gas engine, inevitably the maximum-voltage generation capability of the secondary coil

must be set higher than that of an ignition coil of a gasoline engine. Also, because of application to continuous operation for a long period of time, impairment in insulating performance (dielectric breakdown) induced by increased electric field intensity as described above in (1) and degradation of, for example, the coil case induced by generation of corona discharge as described above in (2) become likely to arise.

[0008] An object of the present invention is to provide an ignition coil of excellent durability and reliability that is capable of suppressing occurrence of leakage between a secondary coil and a coil core and suppressing generation of corona discharge across a gap between a coil section and the coil core even when the maximum-voltage generation capability of the secondary coil is enhanced as a result of, for example, increase in discharge voltage of a spark plug, and the ignition coil is operated continuously for a long period of time, as well as to provide an ignition unit using the ignition coil.

[0009] To achieve the above object, an ignition coil of the present invention comprises:

a coil section comprising a coil case, a primary coil and a secondary coil accommodated within the coil case in such a manner as to be concentrically wound around the axis of the coil case, and an insulating molded layer filling the coil case; and a coil core comprising a center core section disposed inside the coil section along the axis of the coil case, and a yoke section disposed outside the coil section and connecting opposite ends of the center core section so as to form, together with the center core section, a closed magnetic path.

[0010] The ignition coil is characterized in that a mounting section for mounting the ignition coil on an engine body and an insulating filling section are integrally formed of a polymeric material so as to insulate the coil core from the engine body. The insulating filling section fills at least partially a gap formed between the coil section and the coil core as a result of the coil section and the coil core facing each other.

[0011] That is, the ignition coil of the present invention comprises a coil section—which in turn comprises a coil case, a primary coil and a secondary coil accommodated within the coil case, and an insulating molded layer filling the coil case—and a coil core comprising a center core section and a yoke section. The ignition coil is mounted on an engine body such that the coil core is insulated from the engine body, by means of a mounting section which, together with an insulating filling section to be described later, is integrally formed of a polymeric material (e.g. through integral injection molding). Accordingly, there is no need to directly mount the coil core on the engine body while the coil core is grounded to the engine body, as in conventional practice. Since the ignition coil is mounted on the engine body such that the coil core is insulated from the engine body by means of

the mounting section, no restriction is imposed on the distance between the secondary coil and a grounding point; i.e., the distance can be determined freely according to the position of the mounting section on the ignition coil. Thus, electric field intensity between the secondary coil and the grounding point can be reduced effectively. Therefore, even when the maximum-voltage generation capability of the secondary coil is enhanced as a result of, for example, increase in discharge voltage of a spark plug, and the ignition coil is operated continuously for a long period of time, no leakage arises between the secondary coil and the coil core, thereby enhancing durability of the ignition coil.

[0012] Since the mounting section and the insulating filling section are integrally formed of a polymeric material through integral injection molding, in contrast to a conventional ignition coil, the coil core imposes no restriction on the mounting section. The position, shape, and quantity of the mounting section can be adjusted readily and freely according to the geometric condition around the ignition-coil mounting position and the number of ignition coils to be mounted. In the case of a conventional ignition coil whose coil core serves as a mounting section, when the position of the mounting section is to be changed according to an engine body, the shape of the entire ignition coil, including the shape of the coil core, must be modified. However, in the case of the present invention in which the mounting section is formed of a polymeric material through integral injection molding, mere adjustment of the integrally molded

portion enables coping with a change in a mounting position on the engine body, thereby minimizing modification of the shape of the ignition coil, including modification of the shape of the coil core, and thus reducing cost.

[0013] Further, according to the present invention, the insulating filling section formed of a polymeric material integrally with the mounting section fills the gap between the coil section and the coil core, whereby degradation and erosion of the coil section (specifically, the coil case, the insulating molded layer, etc.), which would otherwise result from corona discharge, become unlikely to arise, thereby enhancing durability of the ignition coil.

[0014] Herein, the insulating filling section partially fills the gap formed between the coil section and the coil core as a result of the coil section and the coil core facing each other. The term "partially" means filling of at least a portion of the gap between the coil section and the coil core at which generation of corona discharge is expected. A portion of the gap between the coil section and the coil core across which corona discharge is expected to arise is where a local potential gradient along the direction of the electric field in the portion exceeds the dielectric strength of an air layer filling the portion. That is, the insulating filling section fills an air layer portion (gap) between the coil section and the coil core which establishes conditions for generation of corona discharge in the ignition coil, thereby preventing generation of corona discharge. Notably, the dielectric strength of an air layer

depends on the rate of raising voltage applied, duration of application of voltage, the temperature, humidity, and pressure of the air layer, etc. Generally, the dielectric strength of an air layer is said to be 3 kV/mm under standard conditions; i.e., at 20°C and 1 atmosphere.

[0015] Specifically, in the case of an ignition coil in which the secondary coil is disposed radially outward of the primary coil, the insulating filling section must fill at least a gap formed between the outer surface of the coil section and the inner surface of the yoke section, which face each other. In this type of ignition coil, since the high-voltage side of the secondary coil is located at the outer side of the coil section, corona discharge is likely to arise across the gap formed between the outer surface of the coil section and the inner surface of the yoke section, which face each other.

[0016] In the case of an ignition coil in which the secondary coil is disposed radially inward of the primary coil, the insulating filling section must fill at least a gap formed between the inner surface of the coil section and the outer surface of the center core section, which face each other. In this type of ignition coil, since the high-voltage side of the secondary coil is located at the inner side of the coil section, corona discharge is likely to arise across the gap formed between the inner surface of the coil section and the outer surface of the center core section, which face each other.

[0017] Preferably, the insulating filling section fills substantially the entire gap formed between the coil section and the coil core, which face each other. This structural feature renders the present invention equivalently applicable to either an ignition coil having the secondary coil disposed radially outward of the primary coil or an ignition coil having the secondary coil disposed radially inward of the primary coil, thereby enhancing applicability.

[0018] Preferably, an insulating cover section covering substantially the entire coil core, together with the insulating filling section and the mounting section, is integrally formed of a polymeric material. This structural feature protects the coil core from corrosion which would otherwise result from, for example, rust, and from damage which would otherwise result from impact caused by, for example, dropping.

[0019] Preferably, in order to enhance heat resistance (softening point), insulating filler (e.g., glass fiber) is added to a polymeric material; specifically, a thermoplastic resin, to be used in the integral injection molding. Preferably, the insulating filler content of the thermoplastic resin is adjusted to 10-40% by weight, and the softening point of the thermoplastic resin is not lower than 120°C, thereby further enhancing durability of the ignition coil.

[0020] When the insulating filler is added in excess of 40% by weight, fluidity of the thermoplastic resin during integral injection molding is impaired; as a result, for example, the insulating filling section may fail to fill a predetermined gap. When the insulating filler is added in

an amount of less than 10% by weight, reliability of the ignition coil in terms of heat resistance may be impaired. When the softening point of the thermoplastic resin is lower than 120°C, reliability of the ignition coil in terms of heat resistance may be impaired.

[0021] Preferably, the thermoplastic resin to be used in integral injection molding comprises at least any one of polybutylene terephthalate resin (hereinafter called PBT resin), polyphenylene sulfide resin (hereinafter called PPS resin), and polyethylene terephthalate resin (hereinafter called PET resin). These resins exhibit good fluidity even when insulating filler, such as glass fiber, is added thereto, and thus exhibit excellent moldability. Generally, glass-fiber-containing PBT resin, whose softening point is 200-220°C, is most widely used for integral injection molding.

[0022] An ignition unit of the present invention comprises:

the ignition coil described above; and
a spark plug to be attached to the engine body, electrically connected to the secondary coil of the ignition coil, and adapted to generate spark discharge upon reception of high voltage for discharge from the ignition coil.

[0023] As a result of great enhancement of the durability (life) of the ignition coil as mentioned previously, the durability of the ignition unit can be enhanced. Since the ignition coil exhibits excellent reliability, the ignition coil can generate high voltage for discharge without involvement of loss, and the spark plug can reliably generate spark discharge. Accordingly, through use of the ignition unit in a stationary gas engine, which must exhibit high reliability and sufficient durability, the features of the present invention can be utilized to the full extent.

[0024] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

FIG. 1 is a conceptual view of an ignition unit for use in a gas engine according to an embodiment of the present invention;
FIG. 2 is a perspective view of an ignition coil for use in the ignition unit of FIG. 1;
FIG. 3 is a plan view of the ignition coil of FIG. 2;
FIG. 4 is a sectional view taken along line X-X of FIG. 2;
FIG. 5 is a sectional view taken along line Y-Y of FIG. 2;
FIG. 6 is an explanatory view showing an integral injection molding process for the ignition coil of FIG. 2;
FIG. 7 is a sectional view showing a conventional ignition coil;
FIG. 8 is a graph showing test results;
FIG. 9 is a perspective view showing schematically relative arrangement between a coil section and a

coil core and sectional views taken along line Z-Z of the perspective view.

[0025] Reference numerals are used to identify items shown in the drawings as follows:

5
10
15
20
25
30
35
40
45
50
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10: coil section
10a: outer surface of coil section
10b: inner surface of coil section
12: primary coil
14: secondary coil
15: coil case
15a: outer surface of coil case
15b: shaft bore
16: thermosetting insulating resin layer (insulating molded layer)
20: center core section
20a: outer surface of center core section
25: nonmagnetic spacer
30: yoke section
30a: inner surface of yoke section
40: body section
50: insulating cover section
60: insulating filling section
70: mounting section
71: mounting bore
80: integrally molded section
90: high-voltage tower
91: high-voltage terminal
92: high-voltage protector
100: ignition coil
200: spark plug
400: ignition unit
C: coil core
EB: engine body
G: gap
M: closed magnetic path
S: gap

[0026] FIG. 1 shows an ignition unit 400 for use in a gas engine according to an embodiment of the present invention. An engine E is a stationary gas engine. The ignition unit 400 includes a spark plug 200 for igniting gas fuel (mixture) introduced into a combustion chamber CR of the engine E by means of spark; a closed-magnetic-path-type ignition coil 100 (hereinafter may be called merely an ignition coil) for supplying to the spark plug 200 high voltage for discharge corresponding to discharge voltage required to generate spark discharges by means of the spark plug 200; and a high-voltage cord 300 for transmitting high voltage from the ignition coil 100 to the spark plug 200. In the case of a direct ignition type in which the spark plug 200 is connected directly to the ignition coil 100, the high-voltage cord 300 is not needed.

[0027] The ignition coil 100, whose enlarged view is shown in FIG. 2, is secured on an engine body EB at an ignition-coil mounting position by means of mounting

sections 70, which, together with an insulating cover section 50 covering a body section 40 (see FIG. 4), which will be described later, substantially in its entirety, is integrally injection-molded from a thermoplastic resin (e.g., PBT resin). Specifically, a fastening component 72, such as a bolt, is inserted through a mounting bore 71 formed in each mounting section 70 and screw-engaged with a threaded bore formed in the engine body EB, thereby securing the ignition coil 100 at the ignition coil mounting position (see FIG. 2). A metallic reinforcement ring 73 is fitted to the inner wall surface of the mounting bore 71 so as to reinforce the mounting section 70 against crush of the mounting section 70 which might otherwise be caused by a fastening force. The shape and number of the mounting sections 70 and the position of the mounting sections 70 on the insulating cover section 50 are adjusted appropriately during integral injection molding in view of the ignition coil mounting position, to thereby cope with diversified ignition coil mounting positions easily and freely. Reference numeral 1 denotes an input section for a primary coil (see FIG. 4), which will be described later. One end of a plus-side input cord 5 is connected to a plug-side input terminal 4, and one end of a minus-side input cord 3 is connected to a minus-side input terminal 2. The other end of the plus-side input cord 5 is connected to a plus-side terminal of a battery (not shown), and the other end of the minus-side input cord 3 is connected to the collector of an igniter (not shown).

[0028] A high-voltage tower 90 projecting unidirectionally from the body section 40 includes a high-voltage terminal 91 and a high-voltage protector 92. The high-voltage terminal 91 is electrically connected to the high-voltage side of a secondary coil (see FIG. 4), which will be described later, and receives one end of the high-voltage cord 300, to thereby supply high voltage to an external component from the secondary coil. The insulating high-voltage protector 92 covers the high-voltage terminal 91 and is integrally molded together with a coil case (FIG. 4), which will be described later.

[0029] Referring back to FIG. 1, the spark plug 200 includes a cylindrical metallic shell 201; an insulator 202 fitted into the interior of the metallic shell 201; a center electrode 203 disposed within the insulator 202; and a ground electrode 204 whose one end is bonded to the metallic shell 201 and the other end of which is bent such that a side wall surface thereof faces an end portion of the center electrode 203. A spark discharge gap g is formed between the end face of the center electrode 203 and the side wall surface of the ground electrode 204. A threaded portion 205 of the metallic shell 201 is screwed into a cylinder head SH of the engine E so as to project the spark discharge gap g into the combustion chamber CR. A plug-side terminal 206 is formed at an end of the center electrode 203 opposite the spark discharge gap g . The other end of the high-voltage cord 300 is connected to the plug-side terminal 206.

[0030] FIGS. 2 to 5 show an embodiment of the

closed-magnetic-path-type ignition coil 100 according to the present invention for use in the ignition unit 400 of FIG. 1. FIG. 2 is a perspective view; FIG. 3 is a plan view; FIG. 4 is a sectional view taken along line X-X of FIG. 3; and FIG. 5 is a sectional view taken along line Y-Y of FIG. 3. The configuration of the closed-magnetic-path-type ignition coil 100 will next be described with reference to mainly FIGS. 4 and 5.

[0031] The body section 40 of the ignition coil 100 includes a coil section 10 which, in turn, includes a coil case 15 and a primary coil 12 and a secondary coil 14 accommodated within the coil case 15 in such a manner as to be concentrically wound around the axis of the coil case 15; a center core section 20 disposed inside the coil section 10 along the axis of the coil section 10; and a yoke section 30 disposed outside the coil section 10 and connecting opposite ends of the center core section 20 so as to form, together with the center core section 20, a closed magnetic path M. In the coil section 10, the primary coil 12 is wound on the outer cylindrical surface of a cylindrical primary bobbin 11 made of a thermoplastic resin, and the secondary coil 14 is wound on the outer cylindrical surface of a cylindrical secondary bobbin 13 having a plurality of winding grooves and made of a thermoplastic resin. The primary coil 12 is formed such that an enameled wire having a diameter of 0.3-1.0 mm is wound in approximately 100-200 turns in layers. The secondary coil 14 is formed such that an enameled wire having a diameter of 0.03-0.1 mm is wound in a total of approximately 5000-20000 turns in a divided manner.

[0032] The primary coil 12 and the secondary coil 14 are accommodated concentrically within the coil case 15 made of a thermoplastic resin (e.g., PBT resin) such that the primary coil 12 is disposed radially inward of the secondary coil 14. A thermosetting resin is injected into the thus-prepared coil case 15 and is then cured through application of heat, thereby forming a thermosetting insulating resin layer (e.g., epoxy resin layer) 16 (insulating molded layer) and thus filling gaps between the primary coil 12, the secondary coil 14, and the coil case 15 with the thermosetting insulating resin layer 16 for integration. More specifically, the thermosetting insulating resin layer 16 is formed in the following manner. Before integral injection molding is carried out, the primary coil 12 and the secondary coil 14 are disposed in place within the hollow coil case 15. Then, a thermosetting resin, such as epoxy resin, in a liquid state is impregnated into the thus-prepared coil case 15 under vacuum to thereby form the thermosetting insulating resin layer 16. Through vacuum impregnation with a thermosetting resin, the insulating resin can be distributed throughout the coil case 15, thereby establishing reliable insulation within the coil case 15.

[0033] Two U-shaped coil cores C, each being constructed from a plurality of silicon steel laminations C0, are arranged such that corresponding leg portions thereof face each other, thereby forming the center core section 20 and the yoke section 30 arranged in an an-

nular form and thus forming the closed magnetic path M. Accordingly, the coil case 15 of the coil section 10 is disposed in such a manner as to be partially present in a space surrounded by the closed magnetic path M and such that the inner wall surface of a central axial bore 15b surrounds the center core section 20. The center core section 20 has a gap G provided between the facing central leg portions of the U-shaped coil cores C, for the purpose of adjusting mutual inductance of the closed magnetic path M. The gap G is adjusted to, for example, 1 mm. A nonmagnetic spacer 25 made of a thermosetting resin (e.g., adhesive containing a predominant amount of epoxy resin) is fitted into the gap G. The nonmagnetic spacer 25 prevents a change in mutual inductance which would otherwise be caused by the gap G becoming narrower than a set value (so-called crushing phenomenon of gap G) as a result of the coil core C being pressed from outside by the pressure of an injected molding material (e.g., PBT resin) when an integrally molded section 80 is formed through integral injection molding. Since the nonmagnetic spacer 25 must be cured before integral injection molding so as to maintain the gap G at a predetermined value and must not change in dimension when temperature rises during integral injection molding, the nonmagnetic spacer 25 is preferably formed of a thermosetting resin, such as epoxy resin.

[0034] The thus-configured body section 40 is covered substantially in its entirety by the insulating cover section 50 made of a thermoplastic resin (e.g., PBT resin, PPS resin, or PET resin). A gap S formed between the coil section 10 and the coil core C (the center core section 20 and the yoke section 30) inside the closed magnetic path M is filled with an insulating filling section 60 made of a thermoplastic resin (e.g., PBT resin, PPS resin, or PET resin). The insulating filling section 60, together with the insulating cover section 50 and the mounting section 70, is formed through integral injection molding, thereby forming the integrally molded section 80. Notably, the integrally molded section 80 is formed through insert molding. Specifically, the body section 40 is set beforehand within a mold, and then a thermoplastic resin material is injected into the mold. Accordingly, herein, "integral injection molding" is synonymous with "insert molding."

[0035] A method for manufacturing the ignition coil 100 will next be described.

(1) Step of assembling coil section 10

[0036] The secondary bobbin 13 on which the secondary coil 14 has been wound is disposed to surround the primary bobbin 11 on which the primary coil 12 has been wound. Then, the coil case 15 (see FIG. 4) formed of a thermoplastic resin (e.g., PBT resin) through insert molding and having the axial bore 15b formed therein is disposed in such a manner that the coil case 15 surrounds the secondary bobbin 13, thereby assembling

the coil section 10. Notably, the primary coil 12 and the secondary coil 14 are accommodated within the coil case 15 in such a manner as to be concentrically wound around the axis of the coil case 15 (i.e., around the axial bore 15b; see FIG. 4).

(2) Step of assembling body section 40 and disposing nonmagnetic spacer 25

[0037] While leg portions of the two U-shaped coil cores C are inserted into the axial bore 15b extending along the axis of the coil case 15 to thereby form the center core section 20, the yoke section 30 is formed outside the coil section 10 (coil case 15), thereby assembling the body section 40. The gap G is formed at an axially middle portion of the center core section 20, which is formed of butting leg portions of the two U-shaped coil cores C; and the leg portions of the yoke section 30 side are integrally engaged, thereby forming an annular shape. Notably, in order to fill the gap G with the nonmagnetic spacer 25 made of adhesive containing a predominant amount of a thermosetting resin (e.g., epoxy resin), the nonmagnetic spacer 25 is applied beforehand to the leg portion of one U-shaped coil core C.

(3) Step of injecting insulating resin material into coil case 15

[0038] The assembled body section 40 is placed in a mold. Then, a liquid thermosetting insulating resin (e.g., epoxy resin) is injected into the coil case 15 while vacuum impregnation is carried out.

(4) Step of curing nonmagnetic spacer 25 and insulating resin layer 16 through application of heat

[0039] Heat is applied to the body section 40 contained in the mold, thereby thermally curing the nonmagnetic spacer 25 to thereby maintain the gap G at a predetermined value and thermally curing the thermosetting insulating resin material to thereby form the thermosetting insulating resin layer 16.

(5) Step of integral injection molding (insert molding) (see FIG. 6)

[0040] The body section 40 and the reinforcement rings 73 (see FIG. 2) are arranged in place within a mold D. After the mold D is closed and clamped, a PBT resin material P softened at a temperature of approximately 220-260°C is injected into the mold D at an injection pressure of approximately 5-10 MPa. The PBT resin material P fills the gap S formed between the coil section 10 and the coil core C (center core section 20 and yoke section 30) to thereby form the insulating filling section 60. The PBT resin material P also forms the insulating cover section 50 covering the body section 40. Further-

more, the PBT resin material P, together with the reinforcement rings 73, forms the corresponding mounting sections 70. In this manner, these sections are integrated into the integrally molded section 80 (see FIG. 4). In the case where mounting holes 65 are formed in the coil core C as practiced conventionally, the mounting holes 65 are also filled with the PBT resin material P. Subsequently, as in the case of an ordinary injection molding process, a dwelling step, a cooling step, and a mold-parting step follow sequentially, thereby obtaining the ignition coil 100. Thus, the insulating cover section 50, the insulating filling section 60, and the mounting sections 70 are integrally formed of PBT resin through integral injection molding, thereby yielding the integrally molded section 80. The PBT resin material P contains glass fiber, which serves as insulating filler, in an amount of 10-40% by weight (e.g., 15% or 30% by weight) and is adjusted so as to have a softening point of not lower than 200°C.

[0041] The insulating cover section 50 of the integrally molded section 80 covers the body section 40 substantially in its entirety, thereby yielding a rust preventive function and a protective or cushioning function against impact caused by, for example, dropping.

[0042] The insulating filling section 60 has the following feature. According to the present embodiment, the secondary coil 14 is disposed radially outward of the primary coil 12 such that the primary and secondary coils 12 and 14 are concentrically wound. Since the high-voltage side of the secondary coil 14 is located relatively at the outer side of the coil section 10, corona discharge is likely to be induced across the gap S formed between an outer surface 10a of the coil section 10 (an outer surface 15a of the coil case 15) and an inner surface 30a of the yoke section 30, which face each other. Since the glass-fiber-containing PBT resin material P of good fluidity is used for injection molding, the PBT resin material P flows very smoothly within the mold D. Thus, the PBT resin material P is distributed throughout the gap S formed between the outer surface 15a of the coil case 15 and the inner surface 30a of the yoke section 30, which face each other. As a result, the insulating filling section 60 is formed in such a manner as to fill the gap S formed between the coil core C and the coil case 15 and the thermosetting insulating resin layer 16 (coil section 10), which face each other, thereby reliably preventing generation of corona discharge.

[0043] The mounting section 70, which serves as a grounding point for grounding to the engine body EB, is formed through integral injection molding together with the insulating filling section 60 (and further together with the insulating cover section 50), while the coil core C (body section 40) is insulated. Thus, there is no need to mount the body section 40 on the engine body EB, while grounding the body section 40 to the engine body EB, by use of mounting holes formed in the coil core C as practiced conventionally. The grounding point is shifted from the coil core C to the mounting section 70. Accord-

ingly, the distance between the secondary coil 14 and the grounding point is a distance L' (see FIG. 5) between the secondary coil 14 and the mounting section 70 (reinforcement ring 73), which is longer than the conventional one; specifically, a distance L (see FIG. 4) between the secondary coil 14 and the coil core C. As a result, electric field intensity between the secondary coil 14 and the grounding point (reinforcement ring 73) decreases, and thus leakage becomes unlikely to arise. Notably, the coil core C is not grounded to the engine body EB and is covered substantially in its entirety by the insulating cover section 60 to thereby be held apart from the surface of the engine body EB.

[0044] In the case where the insulating cover section 50 is formed of a thermosetting resin, such as epoxy resin, through integral injection molding, the insulating cover section 50 becomes likely to suffer formation of a thin-walled portion stemming from variations in wall thickness, since a thermosetting resin is relatively greater in thermal shrinkage than a thermoplastic resin. When the ignition coil 100 is subjected to repeated heat cycles, stress is concentrated on a thin-walled portion of the insulating cover section 50, potentially causing cracking in the thin-walled portion (impairment in heat cycle resistance). By contrast, when the insulating cover section 50 is formed of a thermoplastic resin through integral injection molding, formation of a thin-walled portion is prevented through suppression of variations in wall thickness. The thus-formed insulating cover section 50 exhibits good appearance and improved heat cycle resistance.

[0045] Next, the gap S, which is formed between the coil section 10 and the coil core C and is to be filled with the insulating filling section 60, will be described with reference to FIG. 9 showing schematically the relative arrangement between the coil section 10 and the coil core C. The coil section 10 and the coil core C face each other to thereby form the gap S therebetween. A portion of the gap S across which corona discharge is expected to arise depends on the type of an ignition coil as described below. As seen from FIG. 4, the above-described embodiment of the present invention belongs to the type described below in (1).

(1) In the type in which the secondary coil 14 is disposed radially outward of the primary coil 12, the high-voltage side of the secondary coil 14 is located relatively at the outer side of the coil section 10. Accordingly, corona discharge is likely to arise, inside the closed-magnetic-path M, across a gap S1 formed between the outer surface 10a of the coil section 10 (the outer surface 15a of the coil case 15) and the inner surface 30a of the yoke section 30, which face each other (see FIG. 9(b)). Thus, in this type of ignition coil, the insulating cover section 60 must fill at least the gap S1.

(2) In the type in which the secondary coil 14 is disposed radially inward of the primary coil 12, the

high-voltage side of the secondary coil 14 is located relatively at the inner side of the coil section 10. Accordingly, corona discharge is likely to arise across a gap S2 formed between an inner surface 10b of the coil section 10 (an inner surface 15b of the coil case 15) and an outer surface 20a of the center core section 20, which face each other (see FIG. 9(c)). Thus, in this type of ignition coil, the insulating cover section 60 must fill at least the gap S2.

Experimental Example

[0046] In order to verify the effect of the present invention, a durability test on an ignition coil was carried out. Two body sections 40 shown in FIG. 4 were prepared. One of the body sections 40 was treated as described below to thereby prepare two kinds of test samples.

(A) Integral injection molding as shown in FIG. 6 was conducted on the body section 40 at an injection pressure of 8 MPa by use of PBT resin material having a temperature of 220°C, thereby yielding the ignition coil 100 having the integrally molded section 80 formed on the body section 40. [Example A]
(B) The other ignition coil has the other body section 40 which remains untreated. [Comparative Example B]

[0047] The thus-obtained test samples A and B were electrically connected to respective spark plugs via respective high-voltage cords connected to the respective high-voltage towers 90. While the test samples A and B were placed in a high-temperature oven, the spark plugs were caused to generate spark discharges for continuous durability test. The number of operations (the number of discharges) until the ignition coils broke down due to dielectric breakdown was counted. The test conditions are as follows.

- Ambient temperature: 80°C
- Drive frequency: 150 Hz
- Average discharge voltage: 30 kV

[0048] The test results are shown in FIG. 8. As shown in FIG. 8, the number of operations until coil breakdown (durability) of an ignition coil is approximately 3.5 billion for Example A and approximately 0.9 billion for Comparative Example B. The durability of Example A is approximately 4 times that of Comparative Example B.

[0049] The above embodiment is described while mentioning a U-shaped coil core assuming. However, the present invention is not limited thereto. The coil core may be E-shaped as shown in FIG. 7 and may assume any other shapes. According to the above embodiment, a gap in a closed-magnetic-path is formed in the center core section. However, the present invention is not limited thereto. The gap may be formed in the yoke section.

Also, a plurality of gaps may be formed. Furthermore, an ignition coil according to the present invention is applicable to a so-called core type or shell type in terms of the relative position between the coil section and the coil core.

Claims

1. An ignition coil (100) comprising:

a coil section (10) comprising a coil case (15), a primary coil (12) and a secondary coil (14) accommodated within said coil case (15) in such a manner as to be concentrically wound around an axis of said coil case (15), and an insulating molded layer (16) filling said coil case (15); and

a coil core (C) comprising a center core section (20) disposed inside said coil section (10) along the axis of said coil case (15), and a yoke section (30) disposed outside said coil section (10) and connecting opposite ends of said center core section (20) so as to form, together with said center core section (20), a closed magnetic path (M);

said ignition coil (100) being **characterized in that** a mounting section (70) for mounting said ignition coil (100) on an engine body (EB) and an insulating filling section (60) are integrally formed of a polymeric material so as to insulate said coil core (C) from the engine body (EB), said insulating filling section (60) filling at least partially a gap (S) formed between said coil section (10) and said coil core (C).

2. An ignition coil (100) according to Claim 1, wherein said secondary coil (14) is disposed radially outward of said primary coil (12), and said insulating filling section (60) fills at least a gap (S) formed between an outer surface (10a) of said coil section (10) and an inner surface (30a) of said yoke section (30).

3. An ignition coil (100) according to Claim 1, wherein said secondary coil (14) is disposed radially inward of said primary coil (12), and said insulating filling section (60) fills at least a gap (S2) formed between an inner surface (10b) of said coil section (10) and an outer surface (20a) of said center core section (20).

4. An ignition coil (100) according to any one of Claims 1 to 3, wherein said insulating filling section (60) fills substantially the entire gap formed between said coil section (10) and said coil core (C).

5. An ignition coil (100) according to any one of Claims

- 1 to 4, wherein an insulating cover section (50), covering substantially the entire coil core (C), is integrally formed together with said insulating filling section (60) and said mounting section (70), of said polymeric material. 5
6. An ignition coil (100) according to any one of Claims 1 to 5, wherein the entirety of said polymeric material is formed of a single material. 10
7. An ignition coil (100) according to any one of Claims 1 to 6, wherein said polymeric material comprises a thermoplastic resin. 15
8. An ignition coil (100) according to Claim 7, wherein said thermoplastic resin contains insulating filler. 20
9. An ignition coil (100) according to Claim 8, wherein an insulating filler content of said thermoplastic resin is in the range of from 10 to 40% by weight. 25
10. An ignition coil (100) according to any one of Claims 7 to 9, wherein said thermoplastic resin has a softening point of not lower than 120°C. 30
11. An ignition coil (100) according to any one of Claims 7 to 10, wherein said thermoplastic resin comprises at least any one of polybutylene terephthalate resin, polyphenylene sulfide resin, and polyethylene terephthalate resin. 35
12. An ignition unit comprising:
 an ignition coil (100) according to any one of Claims 1 to 11; and 40
 a spark plug (200) to be attached to said engine body (EB), electrically connected to said secondary coil (14) of said ignition coil (100), and adapted to generate spark discharge upon reception of high voltage for discharge from said ignition coil (100). 45
13. An ignition unit according to Claim 12, wherein said engine is a stationary gas engine. 50
- 55

Fig. 1

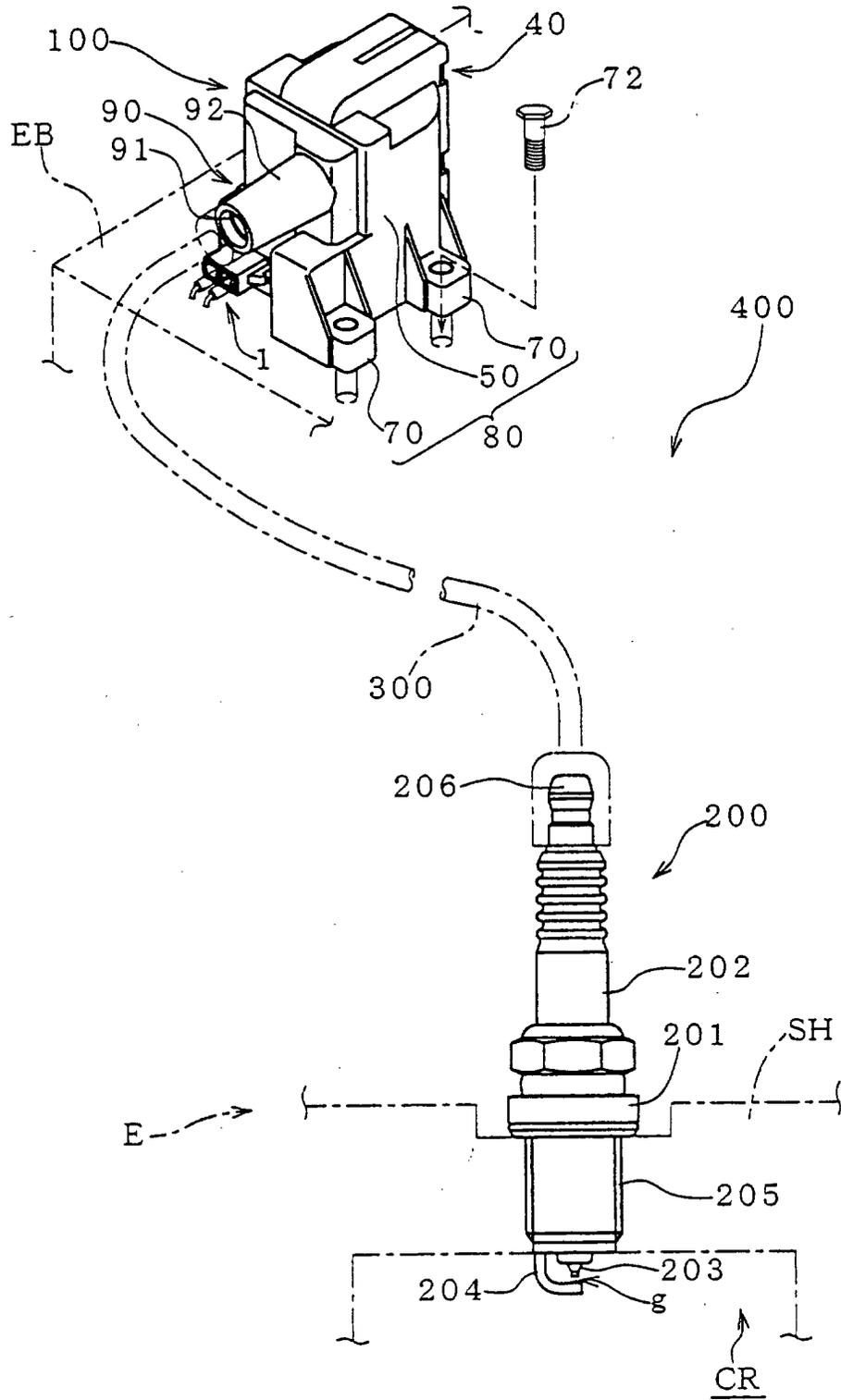


Fig. 2

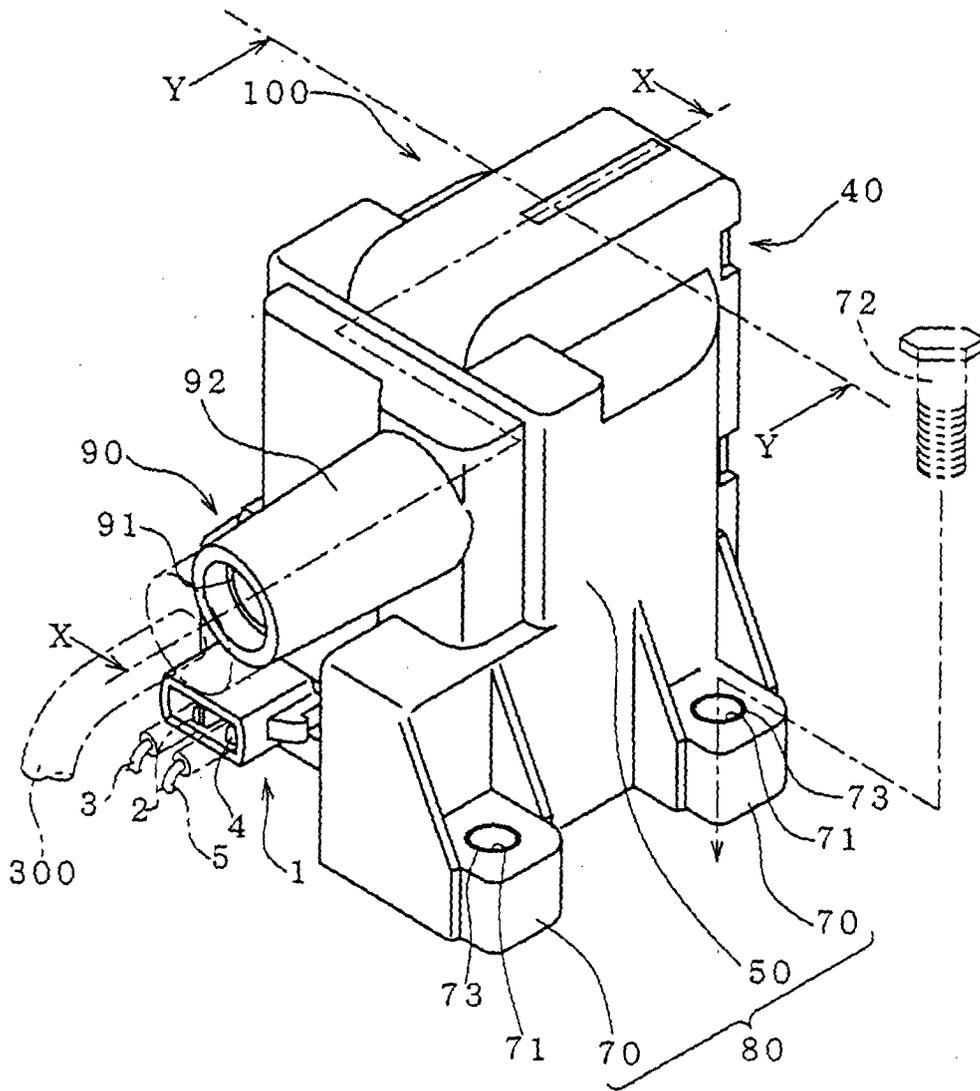


Fig. 3

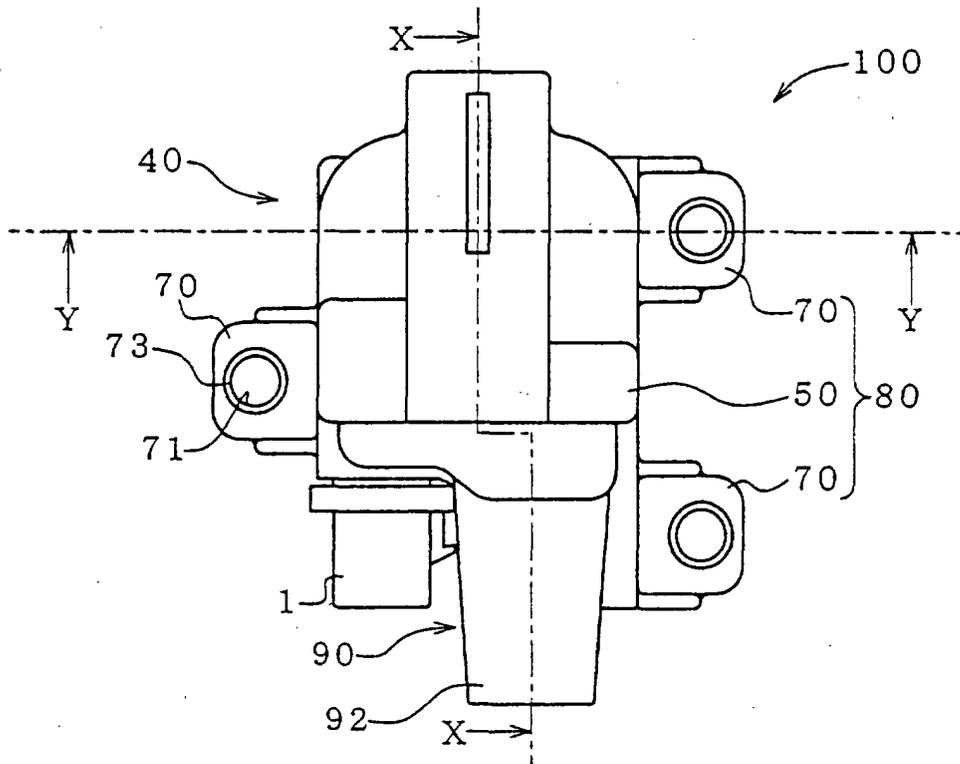


Fig. 4

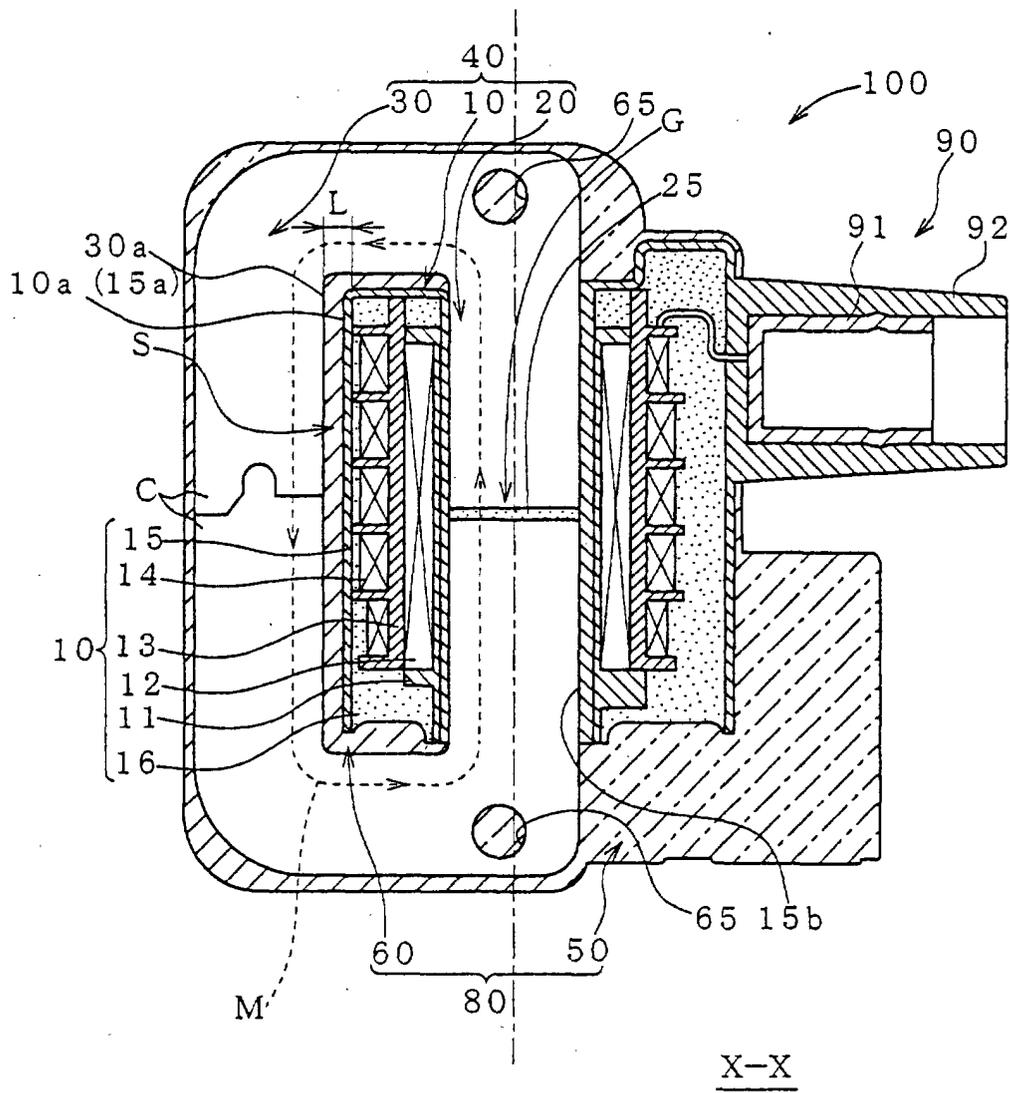


Fig. 7

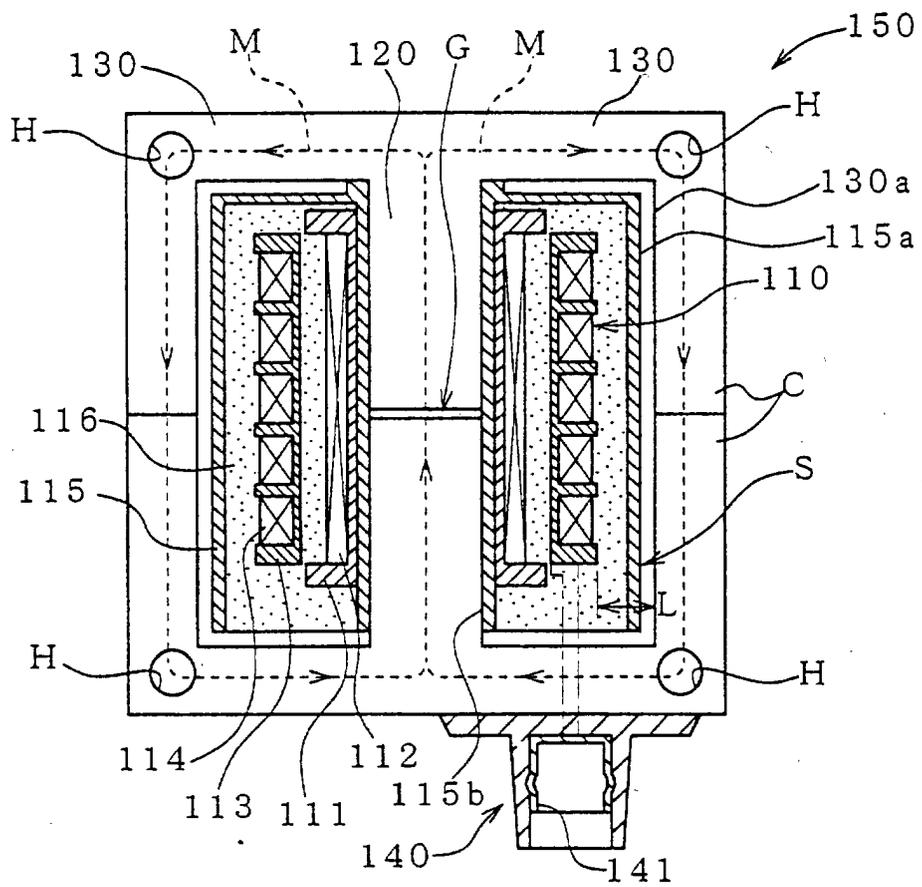


Fig. 8

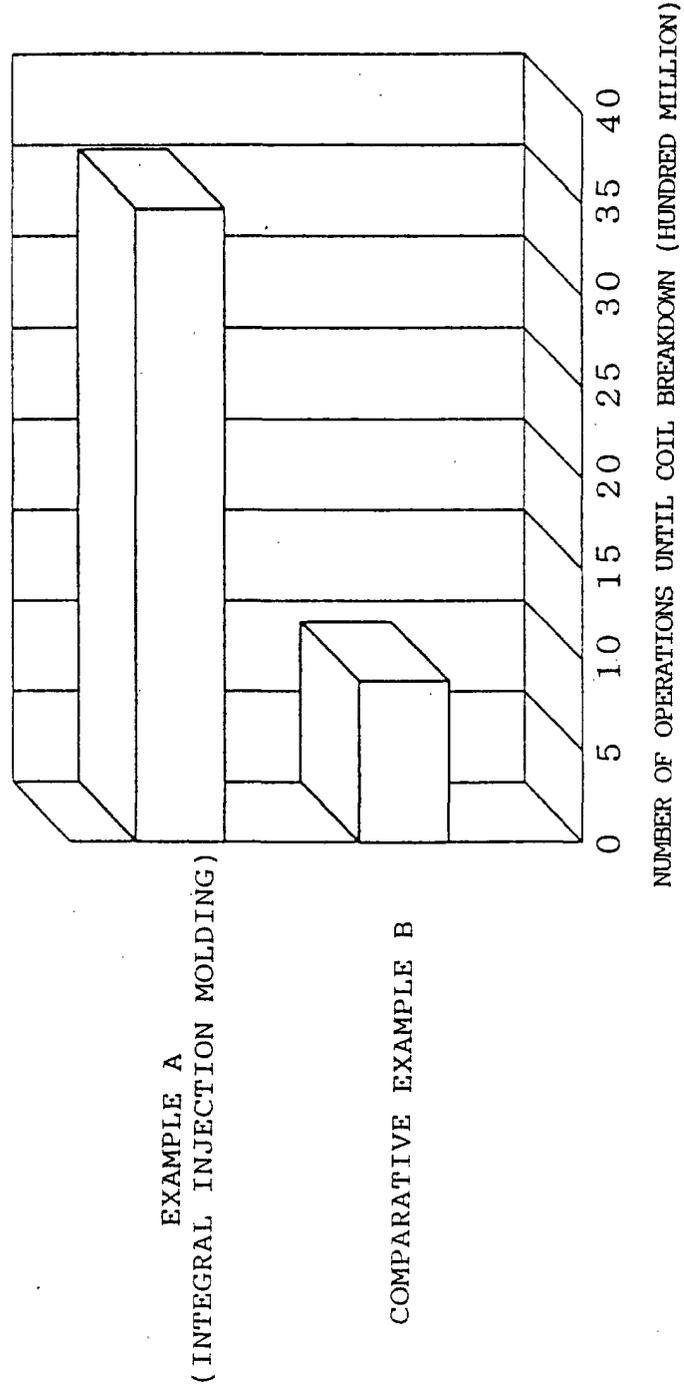


Fig. 9 (a)

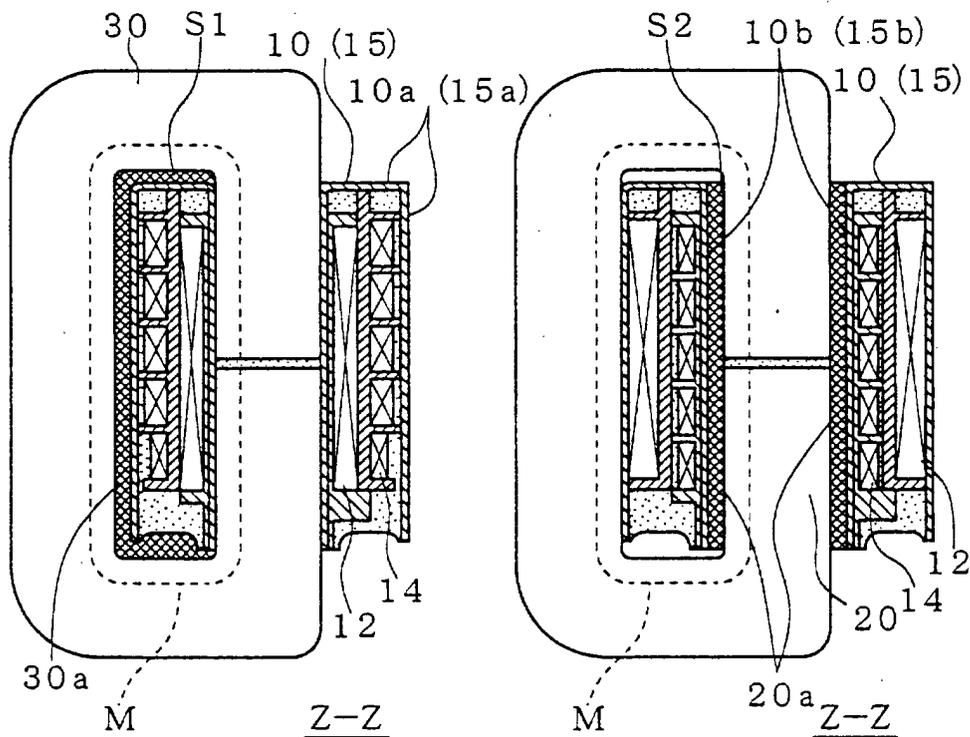
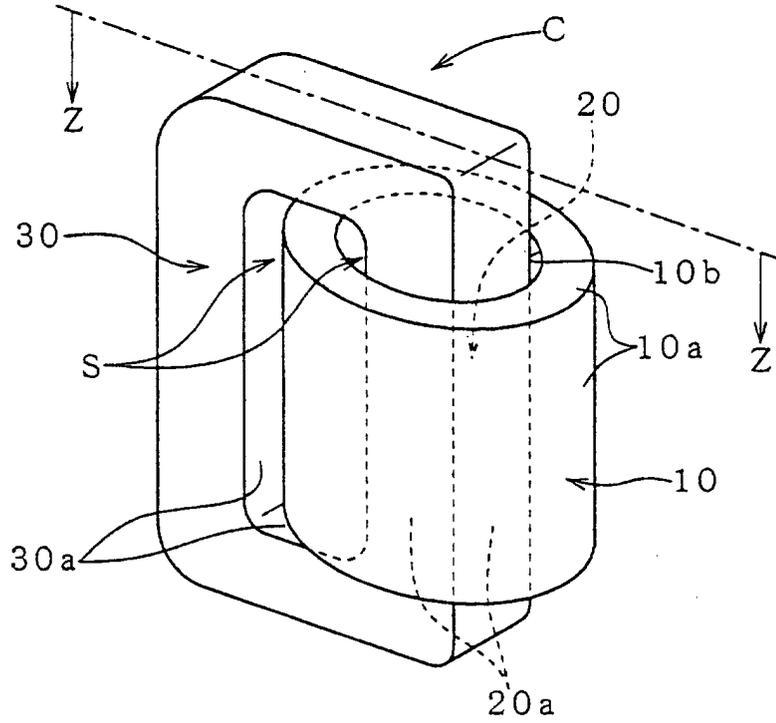


Fig. 9 (b)

Fig. 9 (c)