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

(11) EP 3 229 331 A2

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
11.10.2017 Bulletin 2017/41

(21) Application number: **15865499.6**

(22) Date of filing: **07.12.2015**

(51) Int Cl.:
H01T 13/20 *(2006.01)* ***F02P 13/00*** *(2006.01)*
F02P 23/04 *(2006.01)* ***H01P 7/04*** *(2006.01)*

(86) International application number:
PCT/JP2015/084280

(87) International publication number:
WO 2016/088899 (09.06.2016 Gazette 2016/23)

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

(30) Priority: **05.12.2014 JP 2014247363**
12.12.2014 JP 2014252510
27.02.2015 JP 2015038771

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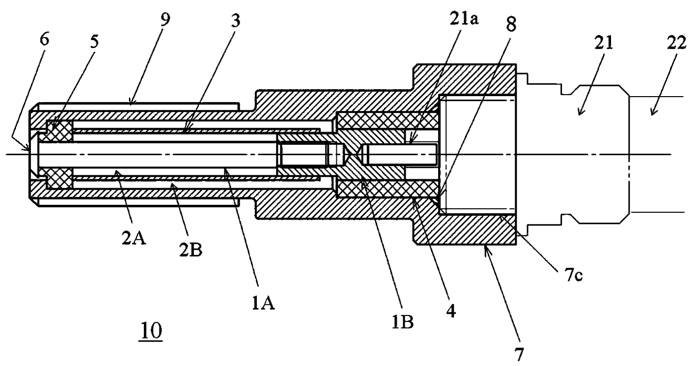
(54) IGNITION DEVICE, IGNITION SYSTEM, AND CONNECTOR

(57) To provide an ignition device that can improve an air-fuel ratio in an internal combustion engine without a device size enlargement or a high cost performance. The ignition device comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a second center conductor in a cylindrical manner formed between the center conductor and the ground conductor, insulated from the ground conductor, connected to the center conductor at a rear end side, while spaced away from the center conductor at a front end side, an electromagnetic wave resonation structure formed by the center conductor and the second center conductor, and a projecting discharge electrode part formed at a side surface of a distal end part of the center conductor. A potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

FIG 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to an ignition device that is used in an internal combustion engine and ignites fuel, or relates to a connector for the ignition device.

BACKGROUND ART

[0002] In these days, electric cars in that only electricity is used as motor power and gas fuel or liquid fuel is not used, and vehicles that use fuel such as natural gas in smaller CO_2 emission amount, have been practically in use. However, it is difficult to advance diffusion of such vehicles smoothly because cost for vehicle main body is high compared to gasoline-powered vehicles, and infrastructures such as charging station and natural gas station are still insufficient. Accordingly, demand for gasoline-powered vehicles is still much high, and various technical developments for improving air-fuel-ratio, i.e., good mileage and lean burn in gasoline-powered vehicles are currently performed in popular. Moreover, the technical development of natural gas vehicles is keenly or fiercely competitive, and improvement of the air-fuel-ratio has been a large key success factor.

[0003] Closely related to the above situation, the applicant has advanced development of achieving air-fuel-ratio technique improvement by applying microwave to the internal combustion engine works (referring to, for example, Patent Document 1). According to the Patent Document 1, the art of expanding the ignited flame by microwave irradiation after fuel ignition by using spark plug, is disclosed.

PRIOR ART DOCUMENT(S)

PATENT DOCUMENT

[0004] Patent Document 1: Japanese Patent Publication No. 4876217

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED

[0005] However, according to the patent document 1, the high voltage circuit for driving the spark plug, and the high frequency circuit for generating the microwave, i.e., two circuits, are required, and therefore, there are demerits of the device size enlargement and the cost high performance.

[0006] The present invention is made in view of the above points.

MEASURES FOR CARRYING OUT THE INVENTION

[0007] An ignition device of one type of the present invention comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a second center conductor in a cylindrical manner provided between the center conductor and the ground conductor, insulated from the ground conductor, connected to the center conductor at a rear end side, while separated from the center conductor at a front end side, an electromagnetic wave resonation structure formed by the center conductor and the second center conductor, and a projecting discharge electrode part formed on a side surface of a distal end of the center conductor. A potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

[0008] An ignition device of other type of the present invention comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a second center conductor in a cylindrical manner provided between the center conductor and the ground conductor, insulated from the ground conductor, connected to the center conductor at a rear end side, while separated from the center conductor at a front end side, an electromagnetic wave resonation structure formed by the center conductor and the second center conductor, a projecting discharge electrode part formed on a side surface of a distal end of the center conductor, and a screw part for engaging with an inner wall of a spark-plug-mounting-port at an outer circumference side of the ground conductor. A potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

[0009] An ignition device of another type of the present invention comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a projecting discharge electrode part formed on a side surface of a distal end of the center conductor, and an insulator in an annular manner arranged between the center conductor and the ground conductor. An outflow/inflow part for permitting an outflow and an inflow of air-fuel mixture is provided on the insulator in the annular manner.

[0010] A connector for connecting an ignition device to a cable comprises an impedance matching circuit thereinside so as to match an impedance of an electromagnetic wave resonation structure inside the ignition device and an impedance of the cable. The ignition device comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, the electromagnetic wave resonation structure, and a projecting discharge electrode part formed on a side surface of a distal end of the center conductor. A potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

[0011] An ignition system comprises an ignition device and a controller configured to control the ignition device, the ignition device including a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a projecting discharge electrode part formed on a side surface of a distal end of the center conductor, an insulator in an annular manner arranged between the center conductor and the ground conductor, and an annular space provided at frontward of the insulator, and provided at rearward of the discharge electrode part. The controller at least performs two operation modes, a normal operation mode and a second operation mode, the normal operation mode for driving the ignition device by a first duty ratio, and the second operation mode for driving the ignition device by a second duty ratio larger than the first duty ratio and eliminating deposits accumulated in the annular space therefrom.

EFFECT OF INVENTION

[0012] According to the present invention, an ignition device in that a device size enlargement and a high cost performance can be prevented, and an air-fuel ratio can be improved, can be provided.

BRIEF EXPLANATION OF THE DRAWINGS

[0013]

Fig. 1 illustrates a front view of a partial cross section of an ignition device 10 regarding a first embodiment.
Fig. 2 illustrates an enlarged view of a distal end part of an ignition device 1A regarding Fig. 1.
Fig. 3 illustrates the front view of the partial cross section of an ignition device 30 regarding a second embodiment.
Fig. 4 illustrates the front view of the partial cross section of an ignition device 40 regarding a forth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIEMENTS

[0014] In below, embodiments of the present invention are illustrated in details based on figures. Note that, following embodiments are essentially desirable examples, and the scope of the present invention, the application product, or the use does not intend to be limited.

(First Embodiment)

[0015] Referring to Fig. 1, an ignition device 10 of a first present embodiment comprises a center conductor 1, a second center conductor 3, an insulator 4, an insulator 5, a discharge electrode 6, a casing 7, and an O-ring 8.

[0016] The center conductor 1 is divided into a front side conductor 1A (in below, merely referred to "center conductor 1A") and a rear side conductor 1B (in below, merely referred to "center conductor 1B"), and they are formed in a stick manner. The material thereof is conductive metal such as tungsten, molybdenum, brass, stainless (SUS), tantalum, and beryllium copper. At a distal end of the center conductor 1B, an insert hole is provided so as to insert a rear end of the center conductor 1A into. At a rear end of the center conductor 1B, an insert hole is provided so as to insert a center pin 21a of a coaxial connector 21 into. The coaxial connector 21 corresponds to a connector to a coaxial cable 22 configured to transmit a microwave generated by a microwave oscillator, not illustrated.

[0017] As illustrated in Fig. 2, the discharge electrode 6 in circular-truncated-cone-shape is jointed at the distal end part of the center conductor 1A. A material such as copper, nickel alloy, is used for the discharge electrode 6. The jointing method of the discharge electrode 6 with the center conductor 1A is, for example, laser welding or screw fastening. The discharge electrode 6 is in shape of convex as directing to forward side, and therefore, the rear end part has a larger diameter, and the rear end is the closest to the casing 7. Accordingly, the discharge is caused between the rear end part and the casing 7.

[0018] The second center conductor 3 is made of cylindrical conductor. The material thereof is conductive metal such as tungsten, molybdenum, brass, stainless (SUS), tantalum, and beryllium copper. The second center conductor 3 is connected at the rear end side thereof to the center conductor 1B, while the distal end side thereof is connected to the insulator 5. The center part of the second center conductor 3 is, facing to the center conductor 1A, spaced at distance by the annular space 2A, while, facing to the casing 7, spaced at distance by the space 2B.

[0019] The insulator 4 is positioned between the center conductor 1B at the rear end and the casing 7. The insulator 4 electrically insulates the center conductor 1B at the rear end from the casing 7. The material of the insulator 4 is, for example, ceramics based on aluminum (Al_2O_3), steatite, silicon nitride.

[0020] The insulator 5 is also made of ceramics based on aluminum (Al_2O_3), steatite, silicon nitride, for example. The insulator 5 is formed in an annular manner between the center conductor 1A at the front end and the casing 7. The insulator 5 electrically insulates the center conductor 1A from the casing 7, and improves a structural strength of the ignition device 10. Moreover, the insulator 5 is connected to the tip end side of the second center conductor 3, and functions as a part of the microwave transmission line as described later.

[0021] The casing 7 is made of the cylindrical conductor, and the material thereof is, for example, tungsten, molybdenum, brass, stainless (SUS), tantalum, and beryllium copper. The part 7a at the distal end of the casing 7 facing to the rear end of the discharge electrode 6, the part having the largest diameter of sharpening part in the circular-truncated-cone, functions as a ground electrode. The discharge is caused when a potential difference between the sharpening part of the discharge electrode 6 and the ground electrode part 7a becomes a predetermined value or higher. Moreover, the casing 7 also has a function of the housing that incorporates the center conductor 1 thereinto, and prevents the microwave propagating through the center conductor 1 from leaking toward outside. Therefore, safety and the microwave transmission efficiency are secured. A recess portion 7c is formed at the rear end part of the casing 7 so as to insert the coaxial connector 21 thereinto. Further, a screw part 9 for engaging with a spark-plug-mounting-port is formed on a surface of outer circumference of the casing 7.

[0022] Between the casing 7 and the insulator 4, the o-ring 8 is mounted so as to fill up the space therebetween and secure and maintain an air-tightness.

[0023] A step portion 7b is formed on the tip end part of the casing 7 so as to prevent the center conductor 1 and etc. from coming-off.

[0024] Next, "how the microwave propagates" is explained later on the ignition device 10 having the above configuration.

[0025] The microwave inputted into the ignition device 10 from the coaxial connector 21 propagates on the surface of the center conductor 1B based on so called "skin-effect," and then, enters the second center conductor 3. The microwave propagates on outer surface of cylindrical-shape-second-center-conductor 3, and then, reaches to the front end side of the second center conductor 3. Here, the "skin-effect" means a phenomenon that current density in the conductor surface is high when "AC", i.e., alternating current flows through the conductor, and current density is low when away from the surface. Specifically, in a case of the electromagnetic wave having a high frequency such as the microwave, the current concentrates to the surface.

[0026] The second center conductor 3 length is designed to be a quarter-wavelength of microwave, where the length does not directly or simply mean "microwave length divided by four accurately," but considering also the refractive index of the second center conductor 3. Then, if the design is performed such that a node of the microwave reaches to the rear end side of the second center conductor 3, an anti-node of the microwave is positioned at the front end side of the second center electrode 3, and then, the potential can be increased. Thereby, the potential at the distal end part of the ignition device 10, especially, the potential at the discharge electrode 6 can be increased, and the discharge can be caused between the discharge electrode 6 and the ground electrode part 7a.

[0027] The microwave reached to the front end side of the second center conductor 3, next, propagates on an inner surface of the cylindrical second center electrode 3, and goes to rear end side of the second center conductor 3. As described above, since the second center conductor 3 length is quarter-wavelength of microwave, the node of the microwave becomes positioned at the rear end side of the second center conductor 3. Then, the microwave reached to the rear end of the second center conductor 3, propagates on the surface of the center conductor 1A, and flows toward the front end side again. The center conductor 1A length is also designed so as to be quarter-wavelength of the microwave. Therefore, the anti-node of microwave is positioned at the front end of the center conductor 1A, and the potential is increased. Moreover, since the microwave propagating on the outer surface of the second center conductor 3 and the microwave propagating on the surface of the center conductor 1A become homeomorphic relation in phase, these microwaves resonate, and the potential at the front end of the center conductor 1A and at the second center conductor 3 further becomes increased.

[0028] That is, the ignition device 10 thereinside has a microwave resonation structure comprising the second center conductor 3, the center conductor 1A, and the annular space 2A. Then, the discharge electrode 6 potential is boosted by use of the microwave resonation structure, and as the result, the difference in potential between the discharge electrode 6 and the ground electrode part 7a becomes increased. When difference in potential exceeds a predetermined value, the discharge is caused between the discharge electrode 6 and the ground electrode part 7a.

[0029] According to the present embodiment, the coaxial cable 22 is directly connected to the rear end side of the center conductor 1. However, in fact, since an impedance of the ignition device 10 differs from that of the coaxial cable 22, an impedance matching circuit so as to adjust and make up for the difference is preferably interposed therebetween. For example, the coaxial connector 21, the center conductor 1 at the rear end side, the insulator 4 and etc., may form a circuit with a desirable frequency characteristic so as to function as an impedance matching circuit. Or, the impedance matching circuit may be formed at the coaxial connector 21 part.

[0030] The impedance can be matched also by providing a stub tuner at outside. Actually, the inventors performed a characteristic-confirmation-experiment for the ignition device 10 by using the structure of the stub tuner provided at outside. As a result, the inventors succeeded in occurrence of discharge between the discharge electrode 6 and the ground electrode part 7a. Further, fuel ignition based on the discharge by the ignition device 10, where the fuel is air-mixture of methane with air, was succeeded by the inventors.

[0031] Further, the ignition device 10 of the present embodiment differs from normal spark plug in that the microwave is used as power supply. Therefore, the discharge in high speed can continuously be caused, and non local thermodynamic equilibrium plasma can be generated in an arbitral timing. The larger amount of plasma over longer time period compared to the conventional spark plug can be generated, and therefore, the air-fuel-ratio can also be improved. In other word, the spark plug for fuel ignition and the microwave irradiation means for ignited flame expansion referred in the Patent Document 1, can be combined together as the ignition device 10. Therefore, the high voltage circuit for driving the spark plug, and the high frequency circuit for generating the microwave, i.e., two circuits, are not required, and therefore, both the system size miniaturization and the cost reduction can be achieved. Moreover, since the function of spark plug and the function of the microwave irradiation means can be combined together as one component, a plurality of mounting ports are not required to be provided to the cylinder head, and therefore, one mounting port is sufficient.

[0032] An outflow/inflow part for permitting an outflow or inflow of air, exactly, air-fuel mixture, is provided on the insulator 5. The outflow/inflow part is formed, for example, by providing a plurality of insert holes, or providing a slit in a radial manner. Thereby, the fuel and air can be entered in the annular space 2B extending in an axial direction, formed between the second center conductor 3 and the casing 7. Further, the annular space 2B can be utilized as a cavity. When the discharge at the discharge electrode 6 makes the air-fuel mixture ignite, the cavity inside becomes high in pressure. The cavity side becomes high in pressure, and then, the flame ignited in the vicinity of the discharge electrode 6 diffuses toward the combustion chamber, and then, the combustion performance is promoted.

[0033] In replace of providing the outflow/inflow part on the insulator 5, the outflow/inflow part may be provided on an inner circumference surface of the casing 7.

[0034] Moreover, an inclination surface for controlling combustion-gas-injection-direction inside the cavity may be provided at the outflow/inflow part.

[0035] Moreover, in the present embodiment, the center conductor 1 is constituted of two parts, i.e., conductors 1A and 1B, but the center conductor 1 may be formed by a single component. However, the tip part 1a of the center conductor 1A is formed in circular-truncated-cone-shape and the diameter thereof is made in thicker and larger. Therefore, when the conductors 1A and 1B are formed in a single component, the cylindrical second center conductor 3 having a diameter thinner and smaller than the circular truncated cone part, cannot be arranged. Accordingly, in the present embodiment, conductor part is divided into two parts, i.e., the conductor 1A and the conductor 1B, the rear end side of the conductor 1A is inserted into the inside of the second center conductor 3, and then, the conductor 1A is inserted into an insert hole of the conductor 1B, and thereby, an assembling work can easily be performed.

(Second Embodiment)

[0036] Referring to Fig. 3, the structure of a casing 71 of an ignition device 30 of the present embodiment differs from the structure of the casing 7 of the ignition device 10 of the first embodiment. Moreover, a providing of a housing member 72 is not disclosed in the first embodiment.

[0037] The housing member 72 corresponds to a main body metal fitting of the normal spark plug, and a screw part 73 is mounted around the outer circumference thereof. In other word, the inside thereof is replaced to the ignition device of the present invention, while utilizing the main body metal fitting of the spark plug being available in a market place.

[0038] Thereby, the ignition device 30 can be mounted to the spark-plug-mounting-port of the conventional gasoline engine. Moreover, since the main body metal fitting of the secondhand spark plug can originally be reused, designing or manufacturing of the main body metal fitting becomes unnecessary, and cost reduction for the ignition device designing can be achieved.

[0039] That is, in the ignition device 10 of the first embodiment, the attachment to the spark-plug-mounting-port, i.e., plug hole, is performed by using the screw part 9 provided on the outer circumference of the casing 7. However, with the ignition device 30 of the present embodiment, the housing member 72 is also utilized to attach to the plug hole. Accordingly, the shape of casing is different from the first embodiment.

(Third Embodiment)

[0040] Again back to Fig. 2, an annular space 15 is formed at a rearward of the distal end part 1a of the center conductor 1 of the ignition device 10. If the annular space 15 is not existed or provided, and the front surface of the insulator 5 is positioned between the discharge electrode 6 and the ground electrode part 7a, deposits such as soot, carbon, or oil generated on fuel combustion adhere to the front surface of the insulator 5. As the result, the discharge cannot properly be caused between the discharge electrode 6 and the ground electrode part 7a. Accordingly, the annular space 15 is provided at a rearward of gap between the discharge electrode 6 and the ground electrode part 7a, and soot and etc. are temporarily accumulated or evacuated into the annular space 15. Thereby, a discharge failure problem can be resolved. However, if the ignition device 10 is operated during a predetermined time period, the accumulated or evacuated soot and etc. are gradually filled up with the annular space 15, and as the result, the discharge cannot properly be performed. Therefore, an ashing is preferably performed on a regular basis.

[0041] The above ashing is performed by the following steps, i.e., driving the ignition device 10 by microwave with high output or with high duty ratio, heating up the vicinity of the discharge electrode 6, burning out completely the accumulated soot in the annular space, and then blowing off soot by using, for example, an airflow generated inside the combustion chamber. During normal operation, a time period of discharge by the ignition device 10 is a period at most several percent degree of one cycle, 720° of four cycle engine. On the other hand, the driving at the ashing may be performed in an continuous wave CW mode or 30 percent duty ratio, for example.

(Fourth Embodiment)

[0042] Referring to Fig. 4, an ignition device 40 of a present embodiment differs from the ignition device 10 of the first embodiment in that the second center conductor 3 is not provided with. Other structure is similar to the ignition device 10 of the first embodiment. However, the difference in this structure results in the microwave resonation structure difference.

[0043] The microwave inputted into the ignition device 40 from the coaxial connecter 21 propagates on the surface of the center conductor 1B, and then enters the center conductor 1A. Then, the microwave propagates on the surface of the center conductor 1A, and reaches to the front end side.

[0044] The length of the center conductor 1A is designed so as to be quarter-wavelength of the microwave. Accordingly, if the design is performed such that the node of the microwave reaches to the rear end of the center conductor 1A, the anti-node of microwave is positioned at the front end of the center conductor 1A, and the potential can be increased. Thereby, the potential at the distal end of the ignition device 40, especially, the potential at the discharge electrode 6 can be increased, and the discharge can be caused between the discharge electrode 6 and the ground electrode part 7a.

[0045] In other word, the microwave resonation structure comprising the center conductor 1A, the casing 7, and the annular space 2A, is formed inside the ignition device 40. Then, by use of the microwave resonation structure, the potential at the discharge electrode 6 is boosted. As the result, the potential difference between the discharge electrode 6 and the ground electrode part 7a becomes increased, and the discharge is caused between the discharge electrode 6 and the ground electrode part 7a when the potential difference exceeds a predetermined value.

[0046] As above, the embodiments of the present invention are explained. The scope of the present invention is absolutely defined based on inventions described in the claims, and should not be limited to the above embodiments.

[0047] For example, the example in which the matching circuit configured to attain the impedance matching between the ignition device 10 and the coaxial cable 22 is formed in the coaxial connecter 21 part, is explained as above. However, the impedance matching circuit may be formed at the coaxial connecter 21 part.

EXPLANATION OF REFERENCES

[0048]

1. Center Conductor
3. Second Center Conductor
4. Insulator
5. Insulator
6. Discharge Electrode
7. Casing
8. O-ring
9. Screw Part
10. Ignition Device
21. Coaxial Connector
22. Coaxial Cable
30. Ignition Device
40. Ignition Device
71. Casing
72. Housing
73. Screw Part

Claims

1. An ignition device comprising:

a center conductor configured to propagate an electromagnetic wave on a surface thereof;
a ground conductor for surrounding the center conductor;
a second center conductor in a cylindrical manner provided between the center conductor and the ground conductor, insulated from the ground conductor, connected to the center conductor at a rear end side, while separated from the center conductor at a front end side;
an electromagnetic wave resonation structure formed by the center conductor and the second center conductor; and
a projecting discharge electrode part formed on a side surface of a distal end of the center conductor,
wherein a potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

2. The ignition device according to claim 1,

wherein a screw part for engaging with an inner wall of a spark-plug-mounting-port is formed at an outer circumference side of the ground conductor.

3. An ignition device comprising:

a center conductor configured to propagate an electromagnetic wave on a surface thereof;
a ground conductor for surrounding the center conductor;
a second center conductor in a cylindrical manner provided between the center conductor and the ground conductor, insulated from the ground conductor, connected to the center conductor at a rear end side, while separated from the center conductor at a front end side;
an electromagnetic wave resonation structure formed by the center conductor and the second center conductor;
a projecting discharge electrode part formed on a side surface of a distal end of the center conductor; and
a screw part for engaging with an inner wall of a spark-plug-mounting-port at an outer circumference side of the ground conductor,
wherein a potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

4. The ignition device according to claim 1 or claim 3,

wherein the center conductor can be divided into a first conductor including the discharge electrode part at a distal end side, and a second conductor at a rear end side.

5. An ignition device comprising:

a center conductor configured to propagate an electromagnetic wave on a surface thereof;
a ground conductor for surrounding the center conductor;
a projecting discharge electrode part formed on a side surface of a distal end of the center conductor; and
an insulator in an annular manner arranged between the center conductor and the ground conductor,
wherein an outflow/inflow part for permitting an outflow and an inflow of air-fuel mixture is provided on the insulator in the annular manner.

6. A connector for connecting an ignition device to a cable comprising:

an impedance matching circuit thereinside so as to match an impedance of an electromagnetic wave resonation structure inside the ignition device and an impedance of the cable, and
wherein the ignition device comprises a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, the electromagnetic wave resonation structure, a projecting discharge electrode part formed on a side surface of a distal end of the center conductor, and a potential at the discharge electrode part is boosted by use of the electromagnetic wave resonation structure, and a discharge is caused between the discharge electrode part and the ground conductor.

7. An ignition system comprising an ignition device and a controller configured to control the ignition device, the ignition device including a center conductor configured to propagate an electromagnetic wave on a surface thereof, a ground conductor for surrounding the center conductor, a projecting discharge electrode part formed on a side surface of a distal end of the center conductor, an insulator in an annular manner arranged between the center conductor and the ground conductor, and an annular space provided at frontward of the insulator, and provided at rearward of the discharge electrode part,

wherein the controller at least performs two operation modes, a normal operation mode and a second operation mode, the normal operation mode for driving the ignition device by a first duty ratio, and the second operation mode for driving the ignition device by a second duty ratio larger than the first duty ratio and eliminating deposits accumulated in the annular space therefrom.

FIG 1

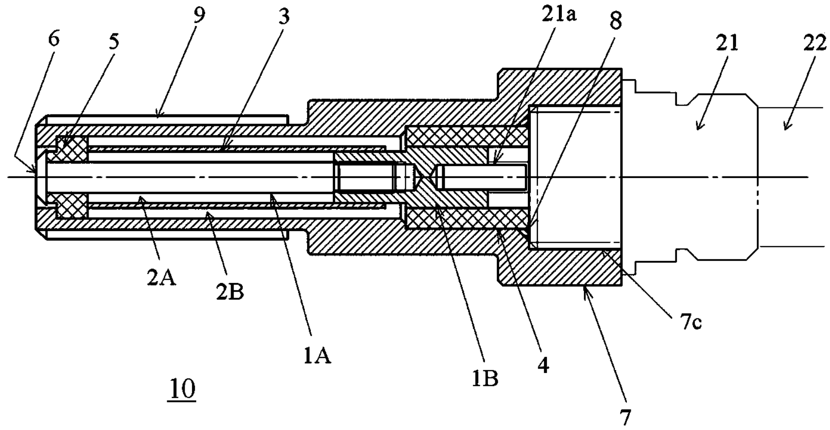


FIG 2

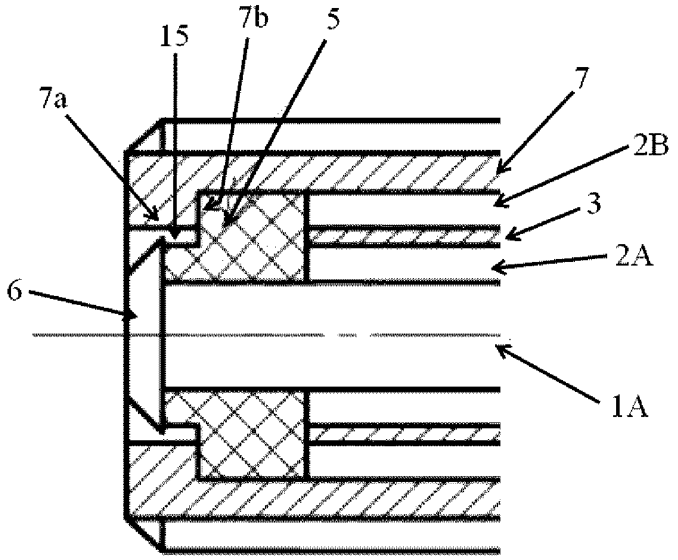


FIG 3

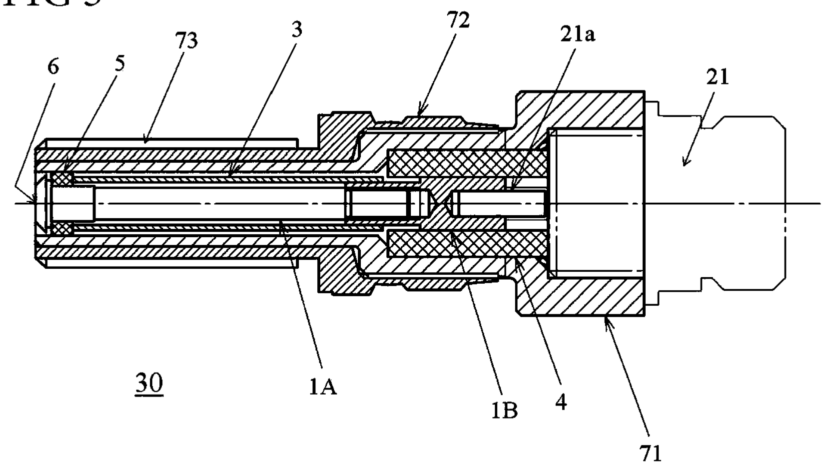
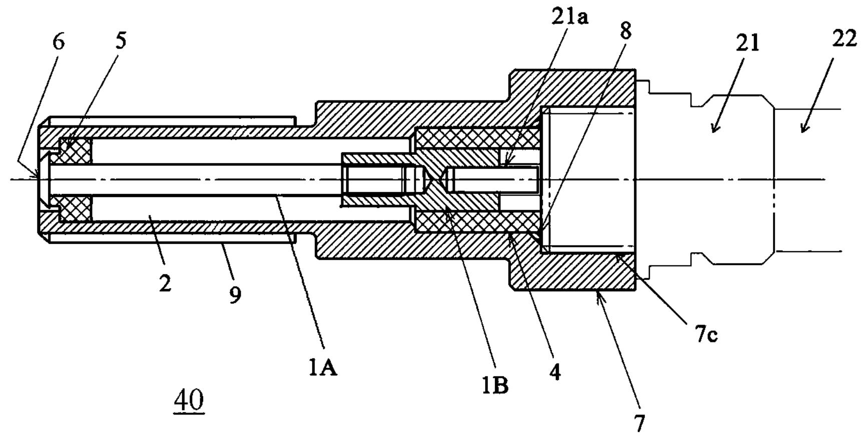


FIG 4



REFERENCES CITED IN THE DESCRIPTION

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