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

(11) EP 2 955 363 A1

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

(43) Date of publication:
16.12.2015 Bulletin 2015/51

(21) Application number: **13874614.4**

(22) Date of filing: **05.02.2013**

(51) Int Cl.:
F02M 27/04 *(2006.01)* ***F02B 51/04*** *(2006.01)*

(86) International application number:
PCT/JP2013/000617

(87) International publication number:
WO 2014/122686 (14.08.2014 Gazette 2014/33)

(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

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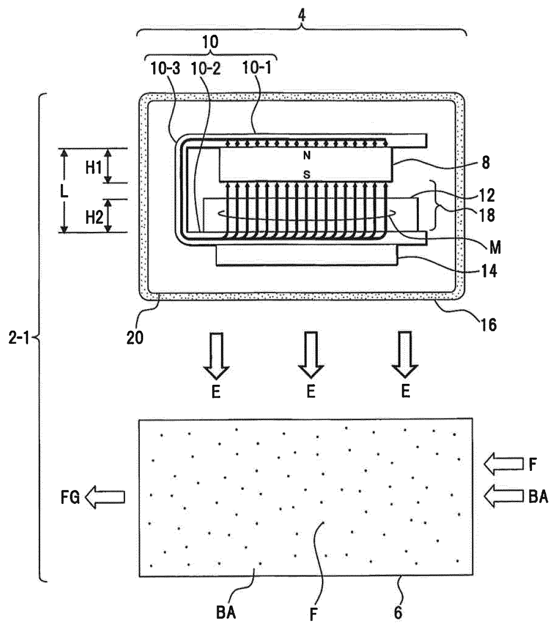
(54) **COMBUSTION PROMOTION METHOD, COMBUSTION PROMOTION DEVICE, AND HEAT ENGINE**

(57) Combustion of fuel such as diesel fuel that is combusted by a combustion apparatus such as a heat engine is improved, combustion of the fuel is accelerated, and energy that is obtained from the combustion is increased.

At least a magnet 8 and a piezoelectric element 12 are provided. A magnetic field M of the magnet 8 is applied to the piezoelectric element 12. Thereby, electromagnetic waves E that include at least far-infrared radiation are produced by the piezoelectric element 12, fuel F that is combusted is irradiated with this electromagnetic waves E, and combustion of the fuel F is accelerated. Kinetic energy that is converted from this combustion is increased.

FIG.1



EP 2 955 363 A1

Description

Technical Field

[0001] The present invention relates to methods and apparatuses for accelerating the combustion that combust liquid fuels such as diesel fuel and gaseous fuels, and heat engines.

Background Art

[0002] A heat engine such as a diesel engine and a gasoline engine converts energy of combustion of fuel into kinetic energy including mechanical energy. Power of the kinetic energy depends on the combustion of fuel. The combustion of fuel is affected by fuel, air, temperature, an air-fuel ratio and the like. Also, combustion is converted into different power of energy according to the combustion speed of fuel and a state of the combustion. Therefore, a change in a state of combustion changes power of the kinetic energy that is converted from the combustion.

[0003] It is known that magnetic force and infrared radiation, which are other than fuel and air, affect combustion of fuel in a heat engine. Concerning the relationship between combustion, and magnetic force and infrared radiation, it is known that magnetic force and far-infrared radiation are applied to air (for example, Patent Literature 1), that far-infrared radiation is applied to fuel (for example, Patent Literature 2) and that magnetism is applied to air and fuel (for example, Patent Literature 3).

[0004] Concerning combustion of fuel, it is known that a certain wave length of an electro-magnetic wave in the regime of a far infrared ray causes a resonance phenomenon for a certain chemical species of combustion activity; this contributes to promotion of combustion (for example, Non Patent Literature 1).

Prior Art Literature

Patent Literature

[0005]

Patent Literature 1: JP 2004-036571 A
Patent Literature 2: JP 2002-161817 A
Patent Literature 3: JP 2002-242769 A

Non Patent Literature

[0006] Non Patent Literature 1: "Application and Development of Combustion Promotion Technique by a Certain Wave Length in the Regime of Far Infrared Ray: The Challenge to Energy Saving and Reduction of CO_2 Emission using Electro-Magnetic Combustion Technique", Eizo jyoho media gakkai gijyutu hokoku (ITE Technical Report, The Institute of Image Information and Television Engineers), Vol. 33(7), pages 1-8

Summary of Invention

Problem to be Solved by Invention

[0007] In a heat engine that is an example of a combustion apparatus, energy of combustion increases in proportion to a combustion amount of fuel if the efficiency of combusting the fuel is not changed. When the combustion efficiency is high, a required amount of the fuel can be reduced. In other words, when the combustion efficiency is low, an amount of the fuel is more than that when the combustion efficiency is high if energy same as that when the combustion efficiency is high is desired to be obtained. There is a problem that increase of the fuel consumption increases emissions of hazardous substances, which are produced by combustion, such as carbon monoxide, hydrocarbon and nitrogen oxide, raises burdens on the environment, and increases costs.

[0008] Concerning combustion of fuel, there is a report that certain wavelengths of electro-magnetic waves in the regime of far infrared rays cause a resonance phenomenon for chemical species of combustion activity, and this contributes to the acceleration of combustion. There is also a report that electro-magnetic waves including far infrared radiation can be obtained from a piezoelectric material.

[0009] It is therefore a first object of the present invention to improve combustion of fuel and accelerate the combustion in view of the above problem and based on the above reports.

[0010] It is a second object of the present invention to accelerate combustion and increase energy that is obtained from the combustion.

Means for Solving Problem

[0011] To solve the above problem, a method of the present invention for accelerating combustion includes installing a piezoelectric element in the vicinity of a combustion chamber that combusts fuel, applying a magnetic field to the piezoelectric element, and radiating electromagnetic waves that are produced by the piezoelectric element over at least the fuel in the combustion chamber, the electromagnetic waves including far-infrared radiation. This can activate, improve and accelerate combustion. As a result, the fuel consumption is reduced.

[0012] The above method preferably may include heating or cooling the piezoelectric element to control temperature of the piezoelectric element. When the temperature of a piezoelectric element is low, the piezoelectric element may be heated so as to be within a temperature range as described above. When being overheated, the piezoelectric element may be cooled so as to be within that temperature range.

[0013] In the above method, preferably, temperature of the piezoelectric element may be controlled so as to be within a range from 40°C to 150°C.

[0014] In the above method, preferably, the magnetic field may be either a direct current magnetic field or an alternating magnetic field.

[0015] In the above method, preferably, flux density of the magnetic filed, which is applied to the piezoelectric element, may be within a range from 50 mT to 300 mT.

[0016] To solve the above problem, an apparatus of the present invention for accelerating combustion that is installed next to a combustion chamber that combusts fuel includes a piezoelectric element that produces electromagnetic waves including far-infrared radiation by effect of a magnetic field, and radiates the electromagnetic waves over at least the fuel, and a magnet that applies the magnetic field to the piezoelectric element.

[0017] The above apparatus preferably may further include a temperature control unit that heats and cools the piezoelectric element, and controls temperature of the piezoelectric element so that the temperature is within a predetermined range.

[0018] In the above apparatus, preferably, the magnet may be either an electromagnet or a permanent magnet.

[0019] The above apparatus preferably may further include a magnetic circuit that includes the magnet, wherein the piezoelectric element may be provided in a gap in the magnet circuit.

[0020] To solve the above problem, a heat engine of the present invention that converts combustion of fuel into kinetic energy includes a combustion chamber that combusts the fuel, a piezoelectric element that produces electromagnetic waves including far-infrared radiation by effect of a magnetic field, and radiates the electromagnetic waves over at least the fuel, and a magnet that applies the magnetic field to the piezoelectric element.

[0021] The above heat engine preferably may further include a temperature control unit that heats and cools the piezoelectric element to control temperature of the piezoelectric element so that the temperature is within a predetermined range.

[0022] In the above heat engine, preferably, the magnet may be either an electromagnet or a permanent magnet.

Effect of Invention

[0023] According to the present invention, any of the following effects can be obtained.

(1) Electromagnetic waves including far-infrared radiation that a piezoelectric element radiates can improve combustion of fuel, and can accelerate the combustion.

(2) The combustion efficiency is improved by improvement of the combustion, energy of the combustion can be increased, the fuel consumption can be reduced, and a burden on the environment can be reduced.

(3) Kinetic energy converted from combustion of fuel is increased, and the conversion efficiency of fuel into kinetic energy can be improved.

[0024] Other objects, features and advantages of the present invention will be more apparent by reference to the attached drawings and each embodiment.

Brief Description of Drawing

[0025]

[FIG. 1] depicts an example of a combustion apparatus according to a first embodiment.

[FIG. 2] is a cross-sectional view depicting an apparatus for accelerating combustion with its portion of a magnetic yoke horizontally sectioned.

[FIG. 3] is an example and a variation of a temperature control unit.

[FIG. 4] depicts an example of a heat engine according to a second embodiment.

[FIG. 5] depicts a fuel injection device according to a third embodiment.

[FIG. 6] depicts an example of a heat engine according to a fourth embodiment.

[FIG. 7] depicts an example of a method for manufacturing an apparatus for accelerating combustion according to a fifth embodiment;

[FIG. 8] depicts an example of a generator according to a sixth embodiment.

[FIG. 9] depicts a fact that temperature of a piezoelectric element has a relationship with combustion efficiency.

Embodiment for Carrying out Invention

First Embodiment

<Combustion Apparatus and Apparatus for Accelerating Combustion>

[0026] FIGS. 1 and 2 depict an example of a combustion apparatus according to the first embodiment. The structure depicted in FIGS. 1 and 2 is an example, and does not limit the present invention.

[0027] This combustion apparatus 2-1 is an example of the method for accelerating combustion according to the present invention. This combustion apparatus 2-1 includes an apparatus for accelerating combustion 4 and a combustion chamber 6. The combustion apparatus 2-1 combusts fuel such as diesel fuel, and is a heat engine, for example.

[0028] The combustion chamber 6 is a space for combusting fuel F. The fuel F and air BA that are for the combustion are provided for this combustion chamber 6. The air BA includes oxygen that is necessary for combustion. Exhaust gas FG that is produced by the combustion is discharged from the combustion chamber 6. For example, diesel fuel is used as this fuel F. The air that is required for combustion is supplied for combusting the fuel F. Air-fuel mixture that is mixture of gasoline and air may be used as the fuel F.

[0029] The apparatus for accelerating combustion 4 includes a magnet 8, a magnetic yoke 10, a piezoelectric element 12, a temperature control unit 14 and an exterior member 16.

[0030] The magnet 8 produces a magnetic field M. This magnetic field M applies to the piezoelectric element 12. This magnet 8 may be either a permanent magnet or an electromagnet. A permanent magnet material such as an anisotropic ferrite magnet, an isotropic ferrite magnet, a neodymium magnet, a samarium-cobalt magnet and an alnico magnet may be used as the permanent magnet. Any other magnet material also may be used as the permanent magnet.

[0031] When an electromagnet is used as the magnet 8, the magnetic field M obtained from the magnet 8 may be either a static magnetic field or an alternating magnetic field. A static magnetic field can be obtained by passing direct current through a coil that is wound around a magnetic material and magnetizing the magnetic material. As well, an alternating magnetic field can be obtained by passing alternating current and magnetizing a magnetic material.

[0032] As an example, the magnet 8 is formed cylindrically. The height of the magnet 8, H1 is less than the diameter of the magnet 8, Φ1 (FIG. 2) (H1 < Φ1). This magnet 8 may be a shape other than a cylindrical shape.

[0033] If one flat surface of this cylindrical magnet 8, that is, one of the end-faces of the cylinder is the north pole, the other is the south pole. Magnetic flux from the north pole reaches the south pole. In short, the magnetic field M is formed. When this magnet 8 is heated along with the piezoelectric element 12, the magnetic field M is produced within the range of a temperature to which the magnet 8 is heated.

[0034] The magnetic yoke 10 is magnetized by the magnet 8, and forms a magnetic circuit through which the magnetic field M, which is for applying to the piezoelectric element 12, passes. For example, soft iron may be formed into the magnetic yoke 10.

[0035] In this embodiment, the magnetic yoke 10 includes opposed parts 10-1 and 10-2, and a curved part 10-3 as an example. The opposed part 10-1 is opposed to the opposed part 10-2, which is an interval L away from the opposed part 10-1 due to the curved part 10-3. Each opposed part 10-1 and 10-2 is a rectangle of W wide and D deep, for example.

[0036] The magnet 8 is installed between the opposed parts 10-1 and 10-2 of the magnetic yoke 10. One surface of the magnet 8 adheres to the opposed part 10-1. When the north pole is on this adhering surface, the magnetic yoke 10, which adheres to this north pole, is magnetized to be the north pole, and the north pole appears on the inside of the opposed part 10-2. The magnetic field M is produced in a magnetic gap 18 between this north pole and the south pole of the magnet 8. This magnetic field M is a parallel magnetic field. It is an example to arrange the north pole of the magnet 8 on the opposed part 10-1 in FIG. 1. The south pole may be arranged on the opposed part 10-1.

[0037] The piezoelectric element 12 has piezoelectricity. For example, this piezoelectric element 12 is formed by any of a piezoelectric substance such as crystal and langasite, a pyroelectric substance such as tourmaline, lithium sulfate hydrate and calamine, and a ferroelectric substance such as Rochelle salt, barium titanate and lead zirconate titanate (for example, PZT: the trade name). A pyroelectric substance is an example of a piezoelectric substance, has piezoelectricity, and has pyroelectricity. A ferroelectric substance is an example of a piezoelectric substance and also an example of a pyroelectric substance, has piezoelectricity, and has pyroelectricity. If the magnetic field M applies to such a piezoelectric element 12 at temperature within a certain range, the piezoelectric element 12 exerts the function of one or both of piezoelectricity and pyroelectricity, and generates electromagnetic waves E including far infrared radiation. The piezoelectric element 12 may have other characteristics as long as such a function of piezoelectricity is obtained therefrom.

[0038] As depicted in FIG. 2, the piezoelectric element 12 is formed cylindrically as an example. The height of the piezoelectric element 12, H2 is set less than the diameter of the piezoelectric element 12, Φ2 (H2 < Φ2). The piezoelectric element 12 may be a shape other than a cylindrical shape.

[0039] This piezoelectric element 12 is installed in the magnetic gap 18 between the opposed part 10-2 of the magnetic yoke 10 and the magnet 8. Thereby, the magnetic field M passes through the piezoelectric element 12. As to a relationship between the piezoelectric element 12 and the magnet 8 concerning their arrangement, the magnet 8 may either adhere to the piezoelectric element 12, or be opposed to the piezoelectric element 12 with the magnetic gap 18 therebetween. That is, there may be any relationship between the piezoelectric element 12 and the magnet 8 as long as the magnetic field M, which is parallel and formed by the magnet 8 and the magnetic yoke 10, passes through the piezoelectric element 12. Or, there may be any relationship between the piezoelectric element 12 and the magnet 8 as long as the magnetic field M, which is produced from the magnet 8 and converges on the magnetic yoke 10, passes through the piezoelectric element 12.

[0040] In this embodiment, the diameter of the piezoelectric element 12, Φ2 is set more than the diameter of the magnet 8, Φ1. The diameter of the magnet 8, Φ1 may be the same as the diameter of the piezoelectric element 12, Φ2. The diameter of the magnet 8, Φ1 may be more than the diameter of the piezoelectric element 12, Φ2.

[0041] The temperature control unit 14 detects temperature of the piezoelectric element 12, heats or cools the piezoelectric element 12, and controls the temperature of the piezoelectric element 12 so as to be within a certain temperature range.

[0042] The external member 16 is an example of a casing that surrounds and covers the magnet 8, the magnetic yoke 10, the piezoelectric element 12 and the temperature control unit 14. A space 20 is formed inside this external member 16. Temperature of this space 20 is controlled by the temperature control unit 14 so as to be within a certain range. In short, the external member 16 suppresses heat radiation from the space 20 and heat application from the outside.

[0043] For example, a material that blocks heat passing, such as a thermal insulating member, may be used as this external member 16. For example, a heat-resistant thermal insulating material such as glass wool, rock wool and silicone foam may be used for the material. Providing such an external member 16 can prevent heat radiation from the space 20 and heat application from the outside, and enables the inside of the space 20 to be kept within a certain temperature. That is, the external member 16 is also a thermostat member. Installing such an external member 16 controls temperature inside the space 20 so that the temperature is within a certain range, can reduce the loss of heating energy, can block heat from the outside such as heat generated from the combustion chamber 6, and does not cause the piezoelectric element 12 to overheat. The piezoelectric element 12 can be prevented from being a high temperature.

<Function of Accelerating Combustion>

[0044] Concerning this combustion apparatus 2-1, a function of accelerating combustion of the apparatus for accelerating combustion 4 will be described.

[0045] The magnet 8 magnetizes the magnetic yoke 10. Magnetic flux passes through the magnetic yoke 10 from the magnet 8. Magnetic flux from one flat surface of the cylinder of the magnet 8 passes through the magnetic yoke 10, converges on a magnetic circuit of this magnetic yoke 10, and returns to the other flat surface of the cylinder of the magnet 8. The magnetic field M, which is parallel, is produced between the magnet 8 and the opposed part 10-2 of the magnetic yoke 10. Magnetic flux passes through the piezoelectric element 12, which is put in this magnetic field M. The temperature of this piezoelectric element 12 is controlled by the temperature control unit 14 so as to be within a certain range because the piezoelectric element 12 is installed in the space 20 in the external member 16.

[0046] If the magnetic field M applies to the piezoelectric element 12, the temperature of which is controlled so as to be within a certain range as the above, the electromagnetic waves E including far infrared radiation are generated from the piezoelectric element 12 by its function of piezoelectricity, and are radiated. The electromagnetic waves E, which have passed through the external member 16, are radiated over the fuel F and the air BA in the combustion chamber 6.

[0047] Molecules and particles of the fuel F, which is irradiated by these electromagnetic waves E, are activated by the effect of the electromagnetic waves E thereon. As described above, certain wave lengths of the electromagnetic waves E in the regime of far infrared radiation, which are radiated from the piezoelectric element 12, cause a resonance phenomenon for chemical species of combustion activity in the fuel F. Such a resonance phenomenon accelerates combustion of the fuel F. This is also disclosed in the above Non Patent Literature 1.

[0048] Every piezoelectric substance, pyroelectric substance and ferroelectric substance as an example of the piezoelectric element 12 has a characteristic of generating the electromagnetic waves E including far infrared radiation. Both pyroelectric substance and ferroelectric substance have a characteristic of changing their polarization according to a change in temperature. Every piezoelectric substance, pyroelectric substance and ferroelectric substance generates the electromagnetic waves E including far infrared radiation when a magnetic field applies thereto.

[0049] As an example, flux density B of magnetic flux that the magnet 8 produces may be approximately over 50 mT (millitesla). When the flux density B is within this limit, the effect of accelerating combustion of the electromagnetic waves E on the fuel F is obtained. The flux density B of the range from 50 mT to 300 mT can be easily obtained from the above described magnetic materials. If the obtained flux density B is approximately 100 mT or over 100 mT, the flux density B is sufficient, and the proportion of a margin to the flux density B rises. Thus, it is preferable that the flux density B is within the range from 50 mT to 300 mT, and it is desirable that the flux density B is within the range from 100 mT to 300 mT.

[0050] As an example, it is preferable that temperature T1 of the piezoelectric element 12 is within the range from 40°C to 150°C. The effect of accelerating combustion of the electromagnetic waves E on the fuel F is remarkable at the temperature T1, which is within this range. Thus, it is desirable that the temperature T1 is within the range from 60°C to 110°C. The effect of accelerating combustion of the electromagnetic waves E on the fuel F is improved at the temperature T1. The fuel F combusts efficiently because of this acceleration of combustion. This acceleration of combustion contributes to reduction of the consumption of the fuel F. For example, if the flux density B is within the range from 50 mT to 300 mT and the temperature T1 of the piezoelectric element 12 is within the range from 40°C to 150°C, the above described generation of the electromagnetic waves E is remarkable. Thereby, acceleration of combusting the fuel F is achieved and promoted.

<Temperature Control Unit 14>

[0051] A of FIG. 3 depicts an example of the temperature control unit 14. The temperature control unit 14 includes a PTC (Positive Temperature Coefficient) thermistor 22 and a heating part 24. In this embodiment, the heating part 24 is connected to a power supply 26 via the PTC thermistor 22. The power supply 26 may be either alternating current one or direct current one.

[0052] The PTC thermistor 22 is an example of a thermosensitive control element. Thermosensitivity of this PTC thermistor 22 controls current flowing from the power supply 26 to the heating part 24. Reference temperature Tc is a threshold for the change in the resistance of the PTC thermistor 22. This resistance of the PTC thermistor 22 presents reversibility; that is, when detecting temperature is over the reference temperature Tc, the resistance sharply increases and when detecting temperature is below the reference temperature Tc, the resistance sharply reduces.

[0053] The heating part 24 generates heat from electricity supplied by the power supply 26, which is connected thereto via the PTC thermistor 22. For example, a heater or an electric heating instrument is used as this heating part 24. The piezoelectric element 12 is heated to a temperature within a certain range.

[0054] According to such a temperature control unit 14, temperature is detected by the PTC thermistor 22, and current supplied to the heating part 24 is controlled by the resistance corresponding to the detected temperature. Thereby, a temperature to which the heating part 24 heats can be controlled so as to be within a certain range.

[0055] The piezoelectric element 12 is equipped with the PTC thermistor 22 via the opposed part 10-2 of the magnetic yoke 10. The PTC thermistor 22, which is installed near the piezoelectric element 12 as the above, presents internal resistance corresponding to the detected temperature of the piezoelectric element 12 etc. If the detected temperature is below the predetermined temperature Tc, the heating part 24 is started to heat. If the detected temperature is over the temperature Tc, the resistance of the PTC thermistor 22 increases, current flowing through the heating part 24 is reduced, and heating of the heating part 24 is suppressed.

[0056] B of FIG. 3 depicts a variation of the temperature control unit 14. When the piezoelectric element 12 can be beyond a predetermined temperature range, the temperature control unit 14 may include a cooling part 28 instead of, or along with the above described heating part 24 as depicted in B of FIG. 3. It may be possible that the operation of this cooling part 28 is controlled by a thermosensitive control part 30, and as a result, the space 20 in the exterior member 16 and the piezoelectric element 12 are cooled and adjusted so that the temperature thereof is within a predetermined range.

<Effects of First Embodiment>

[0057] According to the first embodiment, the following effects are obtained.

(1) The magnetic field M is applied to the piezoelectric element 12 from the magnet 8. The electromagnetic waves E including far infrared radiation are generated from the piezoelectric element 12 by its function of piezoelectricity. The piezoelectric element 12 is heated or cooled by the temperature control unit 14, and thereby, kept at a temperature within a certain range. The electromagnetic waves E including far infrared radiation, which are generated from the piezoelectric element 12 by applying of the magnetic field M, are radiated over the fuel F and the air BA in the combustion chamber 6. Thereby, the fuel F combusted by the combustion chamber 6 is activated, and the combustion is accelerated.

(2) Such acceleration of combustion improves combustion of the fuel F and a state of the combustion. The combustion speed and heat of the combustion are increased.

(3) This acceleration of combustion improves the combustion efficiency, and can contribute to reduction of the fuel consumption.

Second Embodiment

[0058] FIG. 4 depicts an example of a heat engine according to the second embodiment. In FIG. 4, the same portions as FIG. 1 are denoted by the same reference numerals.

[0059] This heat engine 2-2 is an example of the above described combustion apparatus. This heat engine 2-2 has a structure of providing the existing heat engine unit with the above described apparatus for accelerating combustion 4. For example, this heat engine 2-2 is a diesel engine, and produces kinetic energy by combusting the fuel F.

[0060] This heat engine 2-2 includes a cylinder block unit 32, a cylinder head unit 34 and a crankcase 36.

[0061] A cylinder 38 is installed in the cylinder block unit 32. This cylinder 38 corresponds to the above described combustion chamber 6 (FIG. 1). A piston 40 is slidably installed in this cylinder 38.

[0062] The cylinder head unit 34 is installed on the top of the piston 40 in the cylinder 38. A fuel injection part 44, an intake part 46 and an exhaust part 48 are provided for this cylinder head unit 34 and connected to the cylinder 38. The fuel injection part 44 is arranged on the center of the cylinder 38. The fuel injection part 44 is between the intake part 46 and the exhaust part 48, which are arranged on the left and right of the fuel injection part 44, respectively.

[0063] A fuel valve 50 is installed in the fuel injection part 44. An intake valve 52 is installed in the intake part 46. An exhaust valve 54 is installed in the exhaust part 48. If the fuel valve 50 is opened, the fuel F is injected into the cylinder 38. If the intake valve 52 is opened, the air BA is supplied to the cylinder 38. If the exhaust valve 54 is opened, combustion exhaust gas FG is pushed out from the cylinder 38 by the piston 40.

[0064] A water jacket 56 is installed on the outside of this cylinder 38. This water jacket 56 is an example of a cooling part. A water passage part 58 is formed in this water jacket 56. Cooling water is passed through this water passage part 58. Thereby, heat exchange is carried out between the cylinder 38 and cooling water, the cylinder 38 is cooled, and the cylinder 38 is prevented from overheating.

[0065] A crankshaft 60 is installed in the crankcase 36. The piston 40 is coupled to the crankshaft 60 via a connecting rod 62. Up and down motion of the piston 40 is transmitted to the crankshaft 60 via the connecting rod 62, and converted into rotary motion.

[0066] This heat engine 2-2 outputs mechanical energy through an intake step, a compression step, a combustion step and an exhaust step.

(1) Intake Step

[0067] In this intake step, the intake valve 52 is opened for the inflow of the air BA, and the air BA is allowed to flow from the intake part 46 into the cylinder 38 and is trapped in the cylinder 38. The intake valve 52 is in an open state while the piston 40 is falling from the top to the bottom of a stroke S, and closes when the piston 40 reaches the bottom of the stroke S.

(2) Compression Step

[0068] In the compression step, the fuel valve 50, the intake valve 52 and the exhaust valve 54 close. If the piston 40 rises under this condition, the air BA in the cylinder 38 is compressed, and the temperature of the air BA rises. This temperature reaches several hundred degrees, for example.

(3) Combustion Step

[0069] When the piston 40 reaches the top dead center of the stroke S, the fuel valve 50 opens, and the fuel F, which is compressed with high pressure, is injected into the cylinder 38. The fuel F reacts with the air BA, which is compressed in the cylinder 38 and reaches several hundred degrees, and combustion is executed. This combustion is explosion. The electromagnetic waves E including far infrared radiation are radiated over the fuel F, which is injected into the cylinder 38, from the apparatus for accelerating combustion 4, and as described above, the combustion is accelerated by the electromagnetic waves E. The combustion of composite fuel including the fuel F and the air BA is accelerated, and this combustion is in an exploding state. In addition, the function of accelerating combustion by the electromagnetic waves E is applied, and explosive power increases. This combustion produces the combustion exhaust gas FG. The combustion gas in the cylinder 38 is in an expanding state, and the piston 40 is pushed down to the bottom dead center of the stroke S. That is, explosive combustion is executed concerning the fuel F, and energy of this combustion moves the piston 40 and is converted into kinetic energy.

(4) Exhaust Step

[0070] When pushed down to the bottom of the stroke S, the piston 40 turns its motion upward by inertial motion of the crankshaft 60. In so doing, the exhaust valve 54 opens, and the combustion exhaust gas FG in the cylinder 38 is released to the outside.

[0071] In such an intake step and a combustion step of the heat engine 2-2, the apparatus for accelerating combustion 4 radiates the electromagnetic waves E including far infrared radiation over the fuel F and the air BA in the cylinder 38. Thereby, the fuel F and the air BA are activated, and the combustion of the fuel F is accelerated.

[0072] A flat surface of the cylindrical piezoelectric element 12 covers an area of $(\pi \times \Phi 2 \times \Phi 2) / 4$ in this heat engine 2-2. This flat surface of the piezoelectric element 12 radiates the above described electromagnetic waves E over the fuel F and the air BA in a space for combustion in the cylinder 38.

<Features and Effects of Second Embodiment>

[0073] Features, advantages, variations, etc. of this second embodiment will be listed as follows.

(1) The piezoelectric element 12 irradiates the fuel F and the air BA, which combust in the cylinder 38, with the electromagnetic waves E including far infrared radiation. Thus, the combustion of the fuel F can be improved and accelerated.

(2) The temperature of the piezoelectric element 12 is controlled by the temperature control unit 14 so as to be within a certain range. In addition, the magnetic field M is applied to the piezoelectric element 12, using the magnet 8 and the magnetic yoke 10. Thus, the electromagnetic waves E including far infrared radiation can be obtained.

(3) Combustion of the fuel F is improved, the fuel F in the cylinder 38 is activated, combustion of the fuel F is promoted in the combustion process of the heat engine 2-2, and the combustion efficiency increases. As a result, the fuel consumption in the heat engine 2-2 is reduced, or a workload per unit fuel can be increased. That is, if the fuel consumption is not different between the heat engine 2-2 with and without the apparatus for accelerating combustion 4, the workload, in other words, kinetic energy of the heat engine 2-2 with the apparatus for accelerating combustion 4 increases.

(4) For example, a permanent magnet, a piezoelectric material, a magnetic yoke 10 and a heater can constitute the apparatus for accelerating combustion 4. The apparatus for accelerating combustion 4 can be realized by comparably cheap materials. That is, the apparatus for accelerating combustion 4 can be obtained and the heat engine 2-2 of high efficiency can be realized with a low production cost.

(5) The apparatus for accelerating combustion 4 can be installed outside the heat engine 2-2. The structure of the heat engine 2-2 is not necessary to be changed. Thus, the installation is easy and equipment is not complicated.

Third Embodiment

[0074] FIG. 5 depicts a fuel injection device according to the third embodiment. In FIG. 5, the same portions as FIG. 1 are denoted by the same reference numerals.

[0075] This fuel injection device 64 is an example of an apparatus for accelerating combustion. The fuel injection device 64 has the function of accelerating combustion and a function of injecting fuel. This fuel injection device 64 includes the above described apparatus for accelerating combustion 4. The same portions as the above described embodiments are denoted by the same reference numerals.

[0076] This fuel injection device 64 includes a housing 66. The apparatus for accelerating combustion 4 is installed in this housing 66. The apparatus for accelerating combustion 4 includes the magnet 8, the magnetic yoke 10, the piezoelectric element 12 and the temperature control unit 14 as described above. The above described exterior member 16 serves as the housing 66.

[0077] In this fuel injection device 64, the piezoelectric element 12 included in the apparatus for accelerating combustion 4 functions as a piezoelectric actuator. In this embodiment, the piezoelectric element 12 has a multilayer structure consisting of multilayer piezoelectric members. The piezoelectric element 12 of such a multilayer structure produces mechanical displacement larger than that produced by a piezoelectric element consisting of a single layer piezoelectric member.

[0078] A fuel supply pipe 68 and an injection nozzle part 70 are formed in the housing 66. The fuel supply pipe 68 is a passage that passes the side of the fuel injection device 64, and guides the fuel F toward the injection nozzle part 70. The injection nozzle part 70 is formed in a tip side of the housing 66, and includes a fuel injection hole 72. An injection valve 74 that opens and closes the fuel injection hole 72 is installed inside this injection nozzle part 70. A valve control part 76 is installed between this injection valve 74 and the piezoelectric element 12, which constitutes a piezoelectric actuator. The piezoelectric element 12 generates mechanical displacement as a piezoelectric actuator. This mechanical displacement is transmitted to the injection valve 74 via the valve control part 76. That is, mechanical displacement of the piezoelectric element 12 operates the injection valve 74. Thereby, injection of fuel F and suspension of the injection are controlled.

[0079] The piezoelectric element 12 is connected to a power supplying part 80 via electric wiring 78. For example, the power supplying part 80 is an electric connector. A drive circuit is connected to the power supplying part 80. If the electric wiring 78 is charged with electricity via the drive circuit, mechanical displacement appears in the piezoelectric element 12 due to a piezoelectric effect. For example, this mechanical displacement is contraction. This contraction of the piezoelectric element 12 pulls and moves the valve control part 76. The injection valve 74 is separated from a valve seat in the fuel injection hole 72 at this time. That is, the fuel injection hole 72 is opened, and the fuel F is injected.

[0080] If the electric wiring 78 is discharged via the drive circuit, the piezoelectric element 12 produces mechanical displacement. That is, the above described contraction is released, and the piezoelectric element 12 is returned to an original state (extending state). If the valve control part 76 is restored to an original position by receiving this mechanical displacement of the piezoelectric element 12, the injection valve 74 adheres to the valve seat. That is, the fuel injection hole 72 is closed, and the injection of the fuel F is canceled (suspended).

<Effects of Third Embodiment>

[0081]

(1) In this fuel injection device 64, the piezoelectric element 12 not only controls the injection of fuel but also generates the electromagnetic waves E including far infrared radiation. The fuel F is irradiated with this electromagnetic waves E while passing through the fuel supply pipe 68. Thus, particles and molecules of the fuel F can be activated.

(2) A heat engine where this fuel injection device 64 is installed can irradiate the fuel F with the electromagnetic waves E, and can activate combustion of the fuel F.

Fourth Embodiment

[0082] FIG. 6 depicts a heat engine 2-3 according to the fourth embodiment. In FIG. 6, the same portions as FIG. 4 are denoted by the same reference numerals.

[0083] This heat engine 2-3 includes the fuel injection device 64 instead of the apparatus for accelerating combustion 4 and the fuel valve 50, which are installed in the above described heat engine 2-2 (FIG. 4). That is, the fuel injection device 64, which has the function of injecting fuel and the function of accelerating combustion, is installed.

[0084] The fuel F is injected from such a fuel injection device 64 into the cylinder 38. The fuel injection device 64 radiates the electromagnetic waves E including far infrared radiation over the fuel F and the air BA in the cylinder 38. In such a structure, the fuel F passing through the fuel injection device 64 is irradiated with the electromagnetic waves E in the fuel injection device 64. The fuel F and the air BA in the cylinder 38 are also irradiated with the electromagnetic waves E, which are radiated from the fuel injection device 64. Thereby, the combustion of the fuel F is accelerated, and the explosive power is increased.

<Effects of Fourth Embodiment>

[0085]

(1) In addition to the above described effects, the apparatus for accelerating combustion 4 can be compactified because the apparatus for accelerating combustion 4 is incorporated into the fuel injection device 64.

(2) Such a fuel injection device 64 not only has the function of injecting the fuel F but also can irradiated the fuel F, which is passing through the fuel injection device 64, with the electromagnetic waves E. The fuel F before the injection can be activated.

(3) The electromagnetic waves E including far infrared radiation can be radiated over the fuel F in the cylinder 38 from the fuel injection device 64, which is installed in the head of the cylinder 38. The fuel can be activated and the combustion can be accelerated.

(4) In this embodiment, multiple irradiation can be obtained from irradiation of the fuel F before the injection with the electromagnetic waves E and irradiation of the fuel F injected into the cylinder 38 with the electromagnetic waves E. The fuel F can be activated, and acceleration of the combustion can be improved.

(5) The fuel injection device 64 has the built-in apparatus for accelerating combustion 4. Thus, the function of accelerating combustion can be obtained without any change in a mechanical structure of the existing cylinder 38 in the heat engine 2-3, and operating costs for the heat engine 2-3 can be reduced.

Fifth Embodiment

[0086] FIG. 7 depicts an example of a method for manufacturing the apparatus for accelerating combustion 4. In this embodiment, the temperature control unit 14 is installed in the side of the magnet 8.

[0087] A process of this manufacture includes a forming step for the magnetic yoke 10, an installing step for the magnet 8 and the piezoelectric element 12 in the magnetic yoke 10, a mounting step for the temperature control part 14, and a mounting step for the exterior member 16.

[0088] In the forming step for the magnetic yoke 10, as depicted in A of FIG. 7, a plate of soft iron is formed into the U-shaped magnetic yoke 10, for example.

[0089] In the installing step for the magnet 8 and the piezoelectric element 12, as depicted in A of FIG. 7, the magnet 8 is installed on the inside of the opposed part 10-1 of the magnetic yoke 10, and the piezoelectric element 12 is installed on the top surface of the opposed part 10-2. Thereby, the magnetic field M is passed through the piezoelectric element 12.

[0090] In the mounting step for the temperature control part 14, as depicted in B of FIG. 7, the temperature control part 14 is mounted on the top surface of the opposed part 10-1 of the magnetic yoke 10, for example. The temperature control part 14 has been formed in advance. In this temperature control part 14, a thermosensitive control element 220 is connected to a heater 240 in series via electric wiring 82. The heater 240 is an example of the heating part 24, and is an electric heater.

[0091] In the mounting step for the exterior member 16, as depicted in C of FIG. 7, the magnetic yoke 10, the magnet 8, the piezoelectric element 12 and the temperature control part 14 are covered by the exterior member 16. For example, a heat insulating sheet constitutes the exterior member 16. The magnetic yoke 10 and the temperature control part 14 are wrapped by this exterior member 16. This exterior member 16 is tied by a tie 84. Thereby, the apparatus for accelerating combustion 4 is kept in a covered state.

[0092] For example, the following specifications or components may be used for the magnet 8, the magnetic yoke 10, the piezoelectric element 12, the thermosensitive control element 220, the heater 240 and the exterior member 16.

[Magnet 8]

[0093]

Material: ferrite magnet
Form: disc; Diameter (Φ) = 30 mm; Height (H) = 6 mm
Flux Density (B) = approximately 100 mT

[Magnetic Yoke 10]

[0094]

Material: soft iron
Thickness (t): 2 mm

[Piezoelectric Element 12]

[0095]

Material: PZT (lead zirconate titanate) manufactured by Morgan Crucible Company plc
Form: annularity; Outside Diameter (Φ) = 40 mm; Inside Diameter = 14 mm; Height (H) = 7 mm

[Thermosensitive Control Element 220]

[0096]

Polyswitch manufactured by Raychem Corporation

[0097] The polyswitch is an example of the above described PTC thermistor. Electric power supplied to the heater 240 is controlled through the property (reversibility) of sharp increase and reduction of the resistance using the reference temperature Tc as a threshold as described above. When the polyswitch detects a temperature below the reference temperature Tc, electric power applied to the heater 240 increases. On the contrary, when the polyswitch detects increase of temperature to the reference temperature Tc, the resistance increases, and electric power applied to the heater 240 is limited. Such operation of the polyswitch controls the piezoelectric element 12 so as to be 90 °C, for example.

[Heater 240]

[0098]

Power: 5 W

[Exterior Member 16]

[0099]

Material: glass wool

[0100] The above structure and specifications are examples. Such structure or specification does not limit the present invention.

Sixth Embodiment

[0101] FIG. 8 depicts an example of an engine generator 2-4 according to the sixth embodiment. The above described apparatus for accelerating combustion 4 (FIG. 1) is installed in this engine generator 2-4.

[0102] The engine generator 2-4 is an example of the heat engine 2-2. This engine generator 2-4 includes an engine unit 86, an electricity generation part 88 and a battery 90. The engine unit 86 includes at least an engine portion having the above described cylinder block unit 32, cylinder head unit 34 and crankcase 36 of the heat engine 2-2. The above described apparatus for accelerating combustion 4 is installed on the side of this engine unit 86. Approximately 3 cm is set for the distance between the upper side surface of the engine unit 86 and the piezoelectric element 12, for example. The engine unit 86 produces torque from the combustion of the fuel F as kinetic energy. The electricity generation part 88 generates electricity from this torque. The battery 90 is charged with generated electric power. The power from the battery 90 is added to the temperature control part 14 via the electric wiring 82.

[0103] The apparatus for accelerating combustion 4 irradiates the engine unit 86 with the electromagnetic waves E including far infrared radiation. The combustion of the fuel F in the engine unit 86 can be accelerated.

[0104] For example, an engine generator of the following specifications or structure is used as the engine generator 2-4. The following specifications and structure are examples.

[Engine Generator 2-4]

[0105]

Manufacturer: Haige Sangyou Corp.
Model: HG6500CE diesel generator
Engine: 4 Strokes, single cylinder, air-cooled engine
Engine Power: 9.9 HP (horse power) (= 7.4 kW)
Engine Speed: 3600 rpm
Engine Displacements: 406 cc

[Experiment]

[0106] In this experiment, the fuel consumption of the engine generator 2-4 was measured. A load of 1.2 kW at pure resistance was connected to the power unit of the engine generator 2-4, and the engine generator 2-4 was driven under such loaded state. Time it took to consume 10 cc of diesel fuel was compared between the engine generator 2-4 with and without the apparatus for accelerating combustion 4.

[0107] This measurement was started after the engine unit 86 was stabilized by a warm-up for several minutes. The fuel consumption was measured several times, and the mean of the obtained fuel consumption was calculated.

[0108] It took 41 seconds to consume 10 cc of diesel fuel when the apparatus for accelerating combustion 4 was not installed.

[0109] On the contrary, it took 57 seconds to consume 10 cc of diesel fuel when the apparatus for accelerating combustion 4 was installed. It took the engine generator 2-4 operating time 16 seconds longer than that without the apparatus for accelerating combustion 4.

[0110] The combustion efficiency was calculated by dividing the time it took the engine unit 86 with the apparatus for accelerating combustion 4 to consume diesel fuel by the time it took the engine unit 86 without the apparatus for accelerating combustion 4, to consume diesel fuel. In the above described experiment, the combustion efficiency was approximately 1.39. It was confirmed that the efficiency was improved by 39%.

[0111] In this experiment, while the flux density of the magnet 8 (B) was approximately 100 mT; that is, the flux density B was 100 mT, or was a little above or below 100 mT, it was also confirmed that the combustion efficiency was obtained as well as the above described experiment even if the flux density B was within the range from 100 mT to 300 mT, for example.

[Result of Experiment]

[0112] FIG. 9 depicts a characteristic curve that was obtained from the experiment. In FIG. 9, the horizontal axis depicts temperature of the piezoelectric element 12 (°C), and the vertical axis depicts the combustion efficiency. In the experiment, the relationship between the temperature of the piezoelectric element 12 and the combustion efficiency of the engine generator 2-4 was verified in order to verify the function of accelerating combustion of the apparatus for accelerating combustion 4. That is, the combustion efficiency increased and decreased according to the change in temperature of the piezoelectric element 12 in the apparatus for accelerating combustion 4, which was installed outside the engine unit 86. It would be understood that the combustion was accelerated most and the combustion efficiency was improved most at temperature of the piezoelectric element 12 between 60°C and 110°C in the range from 40°C to 150°C. As is apparent from this result of the experiment, the combustion efficiency of the engine generator 2-4, which was irradiated with the electromagnetic waves E radiated from the piezoelectric element 12, changed according to the temperature. Irradiation with the electromagnetic waves E affected the combustion efficiency, and high efficiency was achieved.

[0113] As depicted by the characteristic curve depicted in FIG. 9, the combustion efficiency was increasing as the temperature of the piezoelectric element 12 was rising from 40°C to 86°C. At 86°C, the combustion efficiency was e3 = 1.39, which was the best combustion efficiency. Over 86°C, the combustion efficiency was decreasing as the temperature was rising. When the piezoelectric element was at 60°C, the combustion efficiency was e1. Over 60°C, the rate of increase of the combustion efficiency was elevated. When the piezoelectric element 12 was at 70°C, the combustion efficiency was e2. Over 70°C, the rate of increase of the combustion efficiency was further elevated.

[0114] The combustion efficiency was e1 or was more than e1 in the range from 60°C to 110°C, and good combustion efficiency was obtained. The combustion efficiency was e2 or was more than e2 in the range from 70°C to 105°C, and better combustion efficiency was obtained. As is apparent from this result of the experiment, the fuel consumption of a heat engine was reduced if the apparatus for accelerating combustion 4 was installed.

[0115] In the above described experiment, approximately 3 cm was set for the distance between the upper side face of the engine and the piezoelectric element 12. The effect of reducing the fuel consumption could be expected although the distance is approximately 10 cm.

[0116] In the above described example, 7 mm of PZT in height (H) was used. The same effect was obtained when the experiment was conducted while this PZT was replaced with PZT that was used for a fuel injection device using a piezoelectric material, that is, PZT of a multilayer structure.

Other Embodiments

[0117] Variations or the like will be listed as to the above described embodiments or example.

(1) In the above described embodiments, the temperature control unit 14 is installed as a heating means. The piezoelectric element 12 may be heated by heat produced from a heat engine. The piezoelectric element 12 can be heated and the fuel F can be irradiated with the electromagnetic waves E even if a heat engine is used as a heating means.

(2) In the above described embodiments, the magnetic yoke 10 is installed in order to pass a parallel magnetic field through the piezoelectric element 12 using the magnet 8, which is single. A parallel magnetic field may be passed through the piezoelectric element 12 using two magnets, instead of the magnetic yoke 10.

(3) In the third embodiment, the housing 66 may constitute the magnetic yoke 10. In such a structure, the weights of the apparatus for accelerating combustion 4 and the fuel injection device 64 can be reduced. If the apparatus for accelerating combustion 4 is applied to a heat engine of any means of transport such as vehicles, trains and ships, the weight of means for transport where the apparatus for accelerating combustion 4 is installed can be reduced by reducing the weight of the apparatus for accelerating combustion 4. And, energy for moving the means for transport can be reduced, and the amount of fuel can be reduced.

(4) In the above described embodiments, an example of a diesel engine is depicted as the heat engine 2-2. Any other heat engine may be applied: for example, a gasoline engine, a jet engine and a rocket engine. Any two-cycle engine, four-cycle engine and rotary engine may be used as an engine.

(5) A place where the apparatus for accelerating combustion 4 is installed is not limited to right above the cylinder head unit 34. The apparatus for accelerating combustion 4 may be installed in the vicinity of the cylinder 38. For example, the apparatus for accelerating combustion 4 may be installed on a side of the cylinder 38. That is, the apparatus for accelerating combustion 4 may be installed anywhere the apparatus for accelerating combustion 4 can irradiate the fuel F with the electromagnetic waves E.

(6) The magnetic yoke 10 is described as a U-shaped form. The magnetic yoke 10 may be an annular form. A form of the magnetic yoke 10 is not limited to a C-shaped form as long as the piezoelectric element 12 is installed in the magnetic gap 18.

(7) In the above described embodiments, the magnet 8 and the piezoelectric element 12 are installed inside the exterior member 16. The exterior member 16 may be made of any material through which the electromagnetic waves E, which are radiated from

the piezoelectric element 12, passes.

[0118] While the preferred embodiments of the present invention have been described as the above, the present invention is not limited to the above descriptions, and it is a matter of course that various variations and modifications can be made by those skilled in the art based on the spirit of the invention recited in Claims or disclosed in Description, and needless to say, such variations and modifications are also encompassed in the scope of the present invention.

Reference Signs List

[0119]

2-1	combustion apparatus
2-2, 2-3	heat engine
2-4	engine generator
4	apparatus for accelerating combustion
6	combustion chamber
F	fuel
BA	air
FG	exhaust gas
8	magnet
10	magnet yoke
10-1, 10-2	opposed part
10-3	curved part
12	piezoelectric element
14	temperature control unit
16	exterior member
18	magnetic gap
20	space
22	PTC thermistor
24	heating part
26	power supply
28	cooling part
30	thermosensitive control part
32	cylinder block unit
34	a cylinder head unit
36	crankcase
38	cylinder
40	piston
44	fuel injection part
46	intake part
48	exhaust part
50	fuel valve
52	intake valve
54	exhaust valve
56	water jacket
58	water passage part
60	crankshaft
62	connected rod
64	fuel injection device
66	housing
68	fuel supply pipe
70	injection nozzle part
72	fuel injection hole
74	injection valve
76	valve control part
78	electric wiring
80	power supplying part
82	electric wiring
84	tie
86	engine unit
88	electricity generation part
90	battery
220	thermosensitive control element
240	heater

Claims

1. A method for accelerating combustion, the method comprising:

installing a piezoelectric element in the vicinity of a combustion chamber that combusts fuel;
applying a magnetic field to the piezoelectric element; and
radiating electromagnetic waves that are produced by the piezoelectric element over at least the fuel in the combustion chamber, the electromagnetic waves including far-infrared radiation.

2. The method of claim 1, further comprising:

heating or cooling the piezoelectric element to control temperature of the piezoelectric element.

3. The method of claim 1 or 2, wherein temperature of the piezoelectric element is controlled so as to be within a range from 40°C to 150°C.

4. The method of any of claims 1 to 3, wherein the magnetic field is either a direct current magnetic field or an alternating magnetic field.

5. The method of any of claims 1 to 4, wherein flux density of the magnetic filed, which is applied to the piezoelectric element, is within a range from 50 mT to 300 mT.

6. An apparatus for accelerating combustion, the apparatus being installed next to a combustion chamber that combusts fuel, the apparatus comprising:

a piezoelectric element that produces electromagnetic waves including far-infrared radiation by effect of a magnetic field, and radiates the electromagnetic waves over at least the fuel; and
a magnet that applies the magnetic field to the piezoelectric element.

7. The apparatus of claim 6, further comprising; a temperature control unit that heats or cools the piezoelectric element, and controls temperature of the piezoelectric element so that the temperature is within a predetermined range.

8. The apparatus of claim 6 or 7, wherein the magnet is either an electromagnet or a permanent magnet.

9. The apparatus of any of claims 6 to 8, further comprising:

a magnetic circuit that includes the magnet, wherein the piezoelectric element is provided in a gap in the magnet circuit.

10. A heat engine that converts combustion of fuel into kinetic energy, the heat engine comprising:

a combustion chamber that combusts the fuel;
a piezoelectric element that produces electromagnetic waves including far-infrared radiation by effect of a magnetic field, and radiates the electromagnetic waves over at least the fuel; and
a magnet that applies the magnetic field to the piezoelectric element.

11. The heat engine of claim 10, further comprising; a temperature control unit that heats or cools the piezoelectric element to control temperature of the piezoelectric element so that the temperature is within a predetermined range.

12. The heat engine of claim 10 or 11, wherein the magnet is either an electromagnet or a permanent magnet.

FIG.1

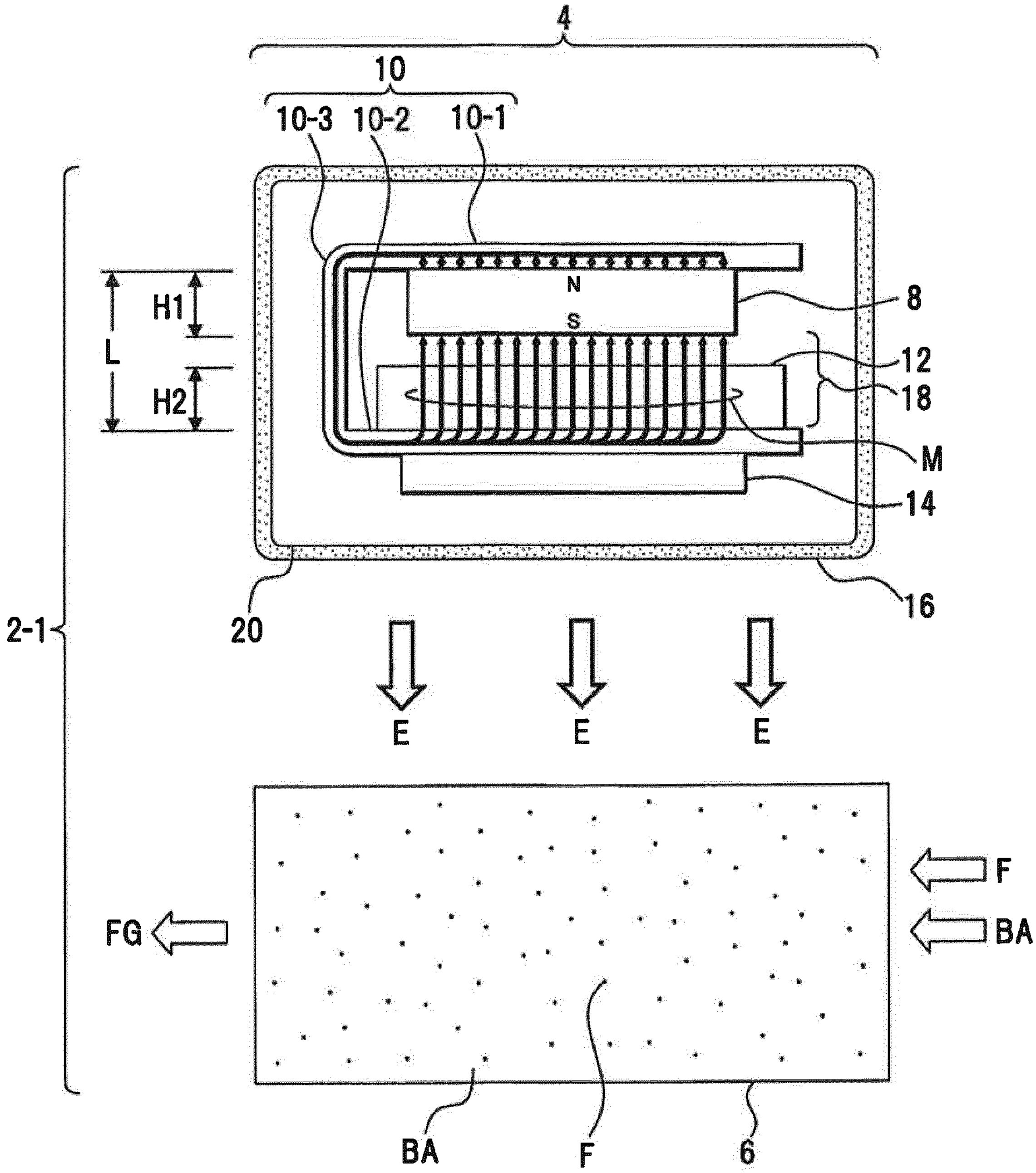


FIG.2

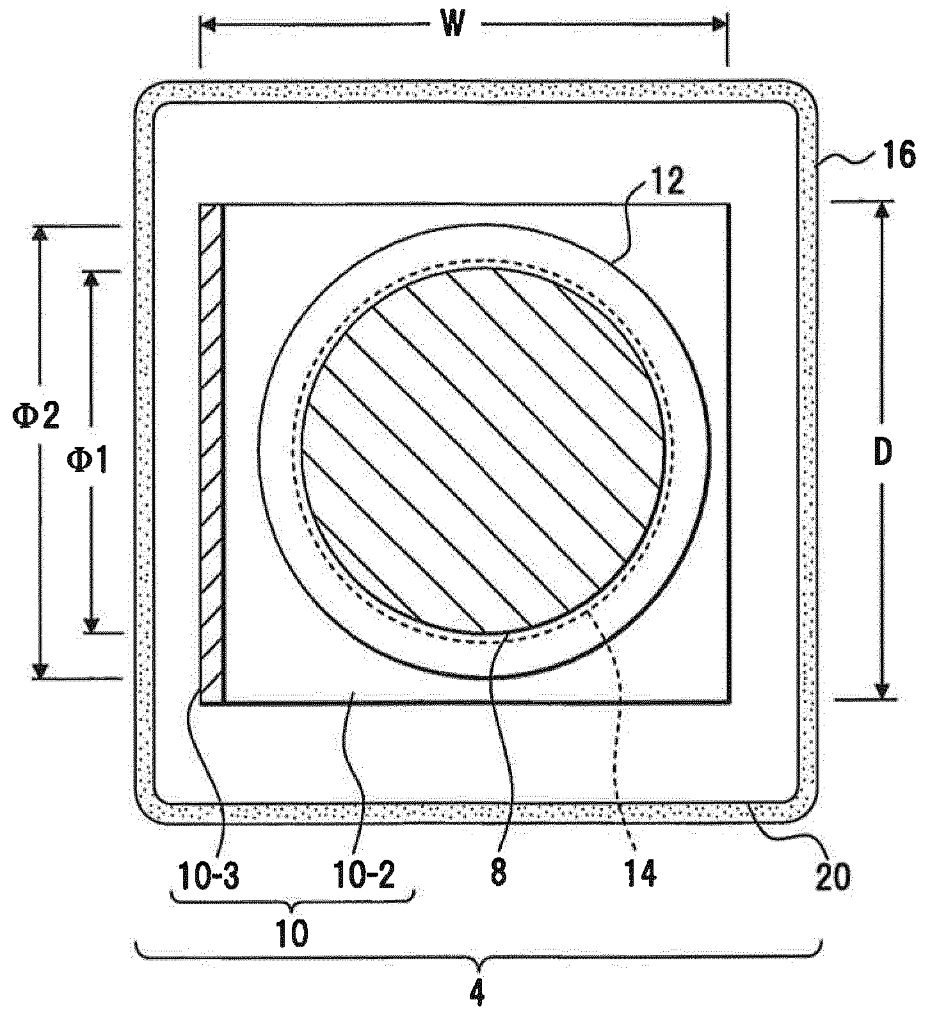


FIG.3A

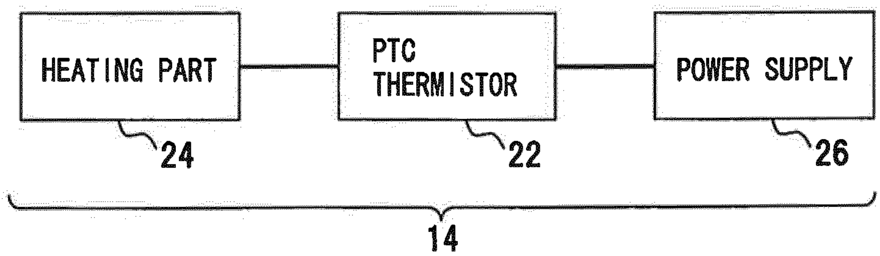

HEATING PART
PTC THERMISTOR
POWER SUPPLY
24
22
26
14

FIG.3B

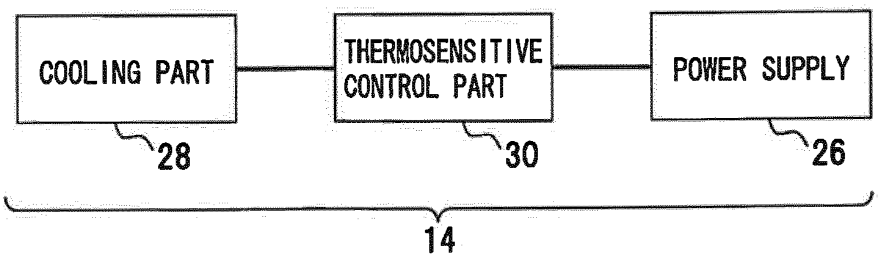

COOLING PART
THERMOSENSITIVE CONTROL PART
POWER SUPPLY
28
30
26
14

FIG.4

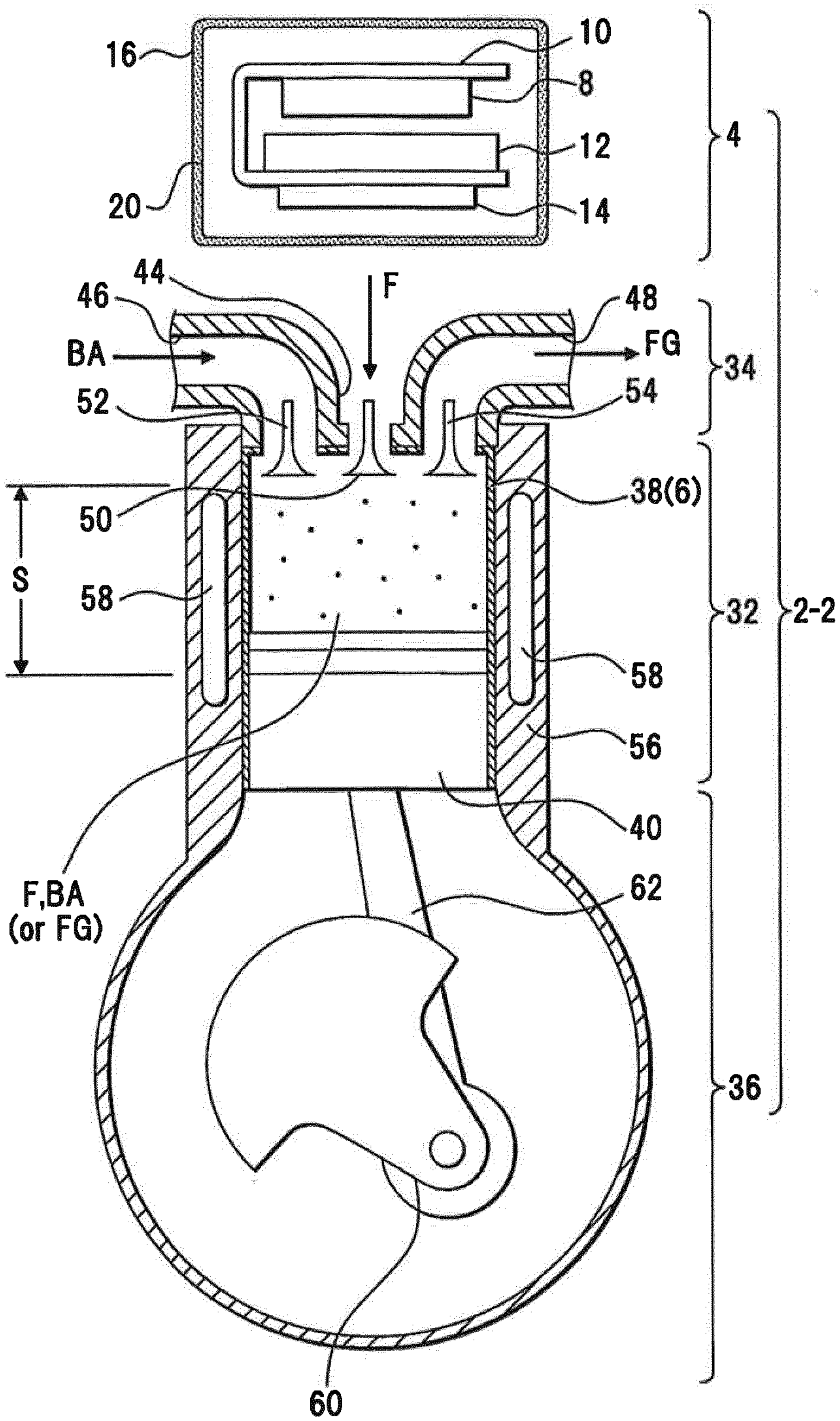

16
10
8
12
4
20
14
44
F
46
48
BA
FG
34
52
54
50
38(6)
S
58
32
2-2
58
56
F,BA
(or FG)
40
62
36
60

FIG.5

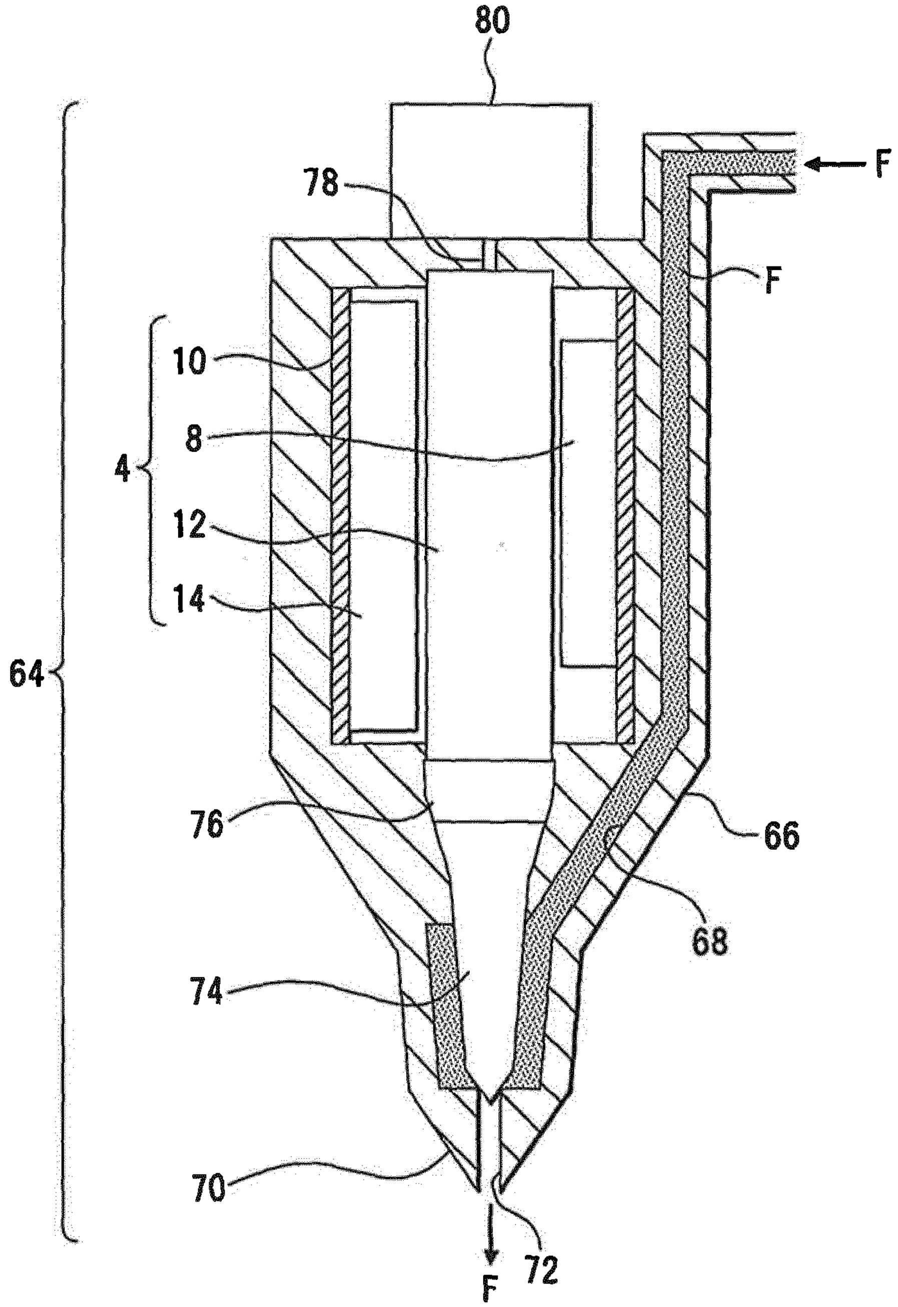


FIG.6

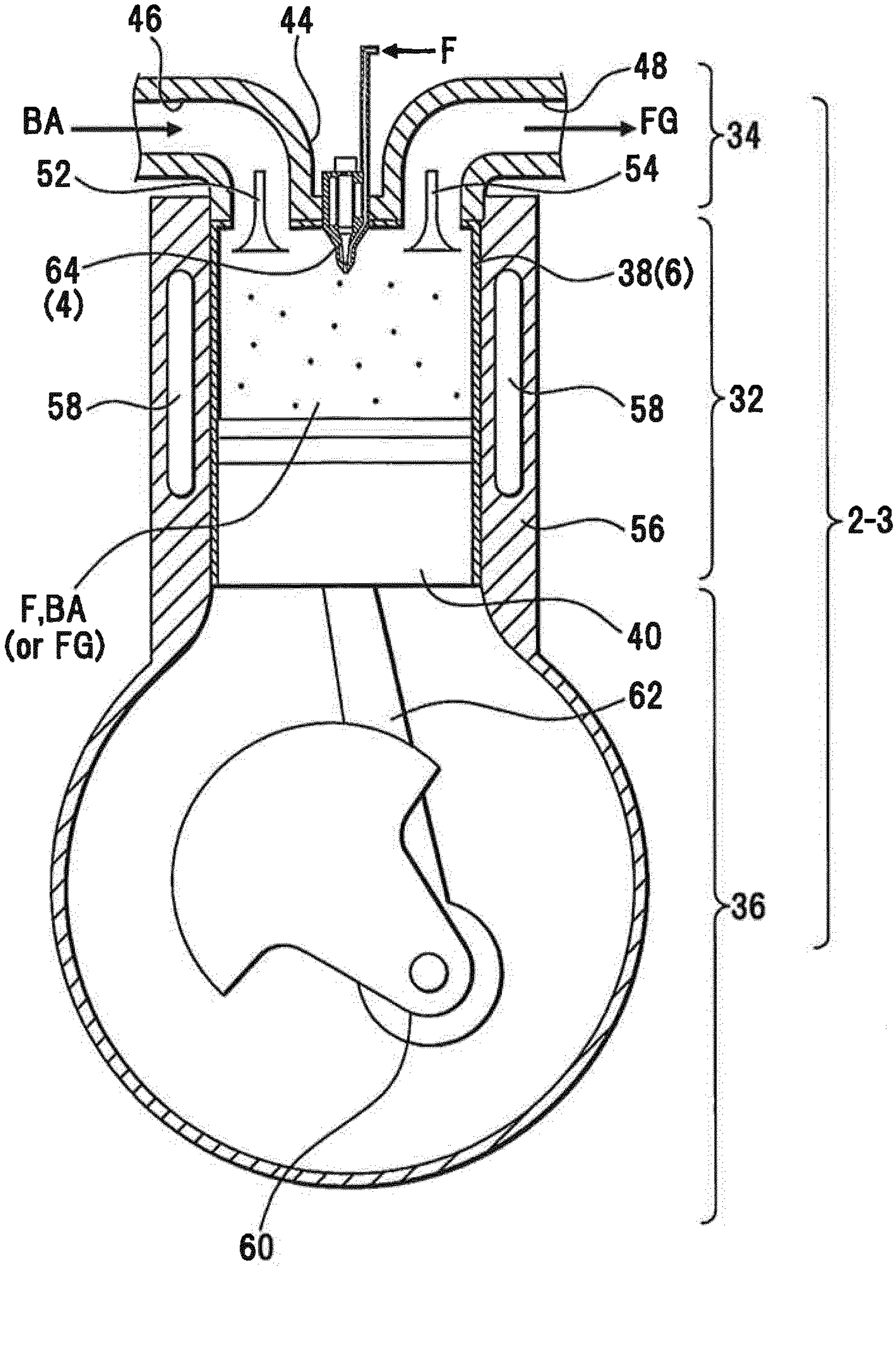


FIG.7A

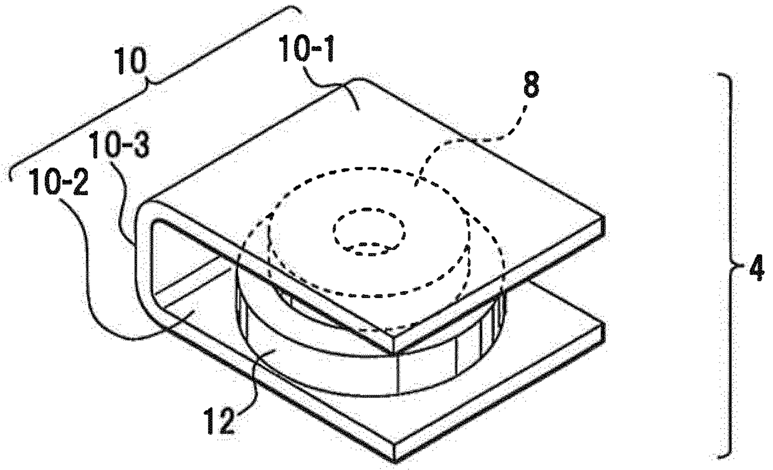


FIG.7B

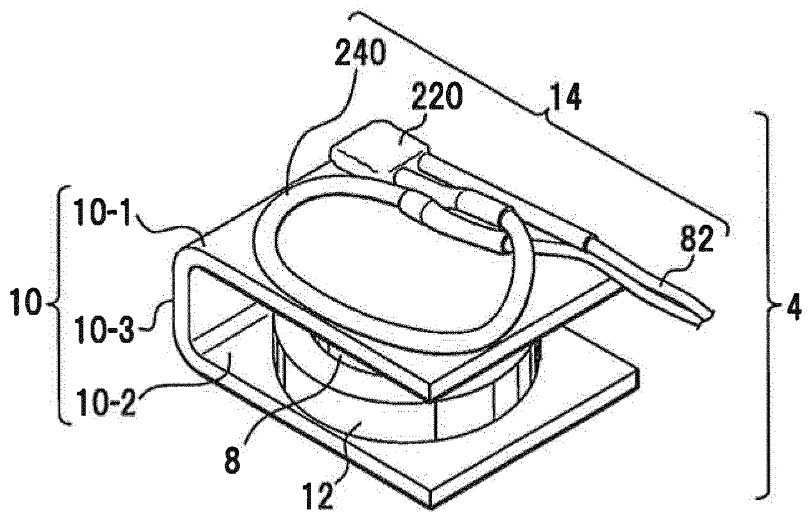


FIG.7C

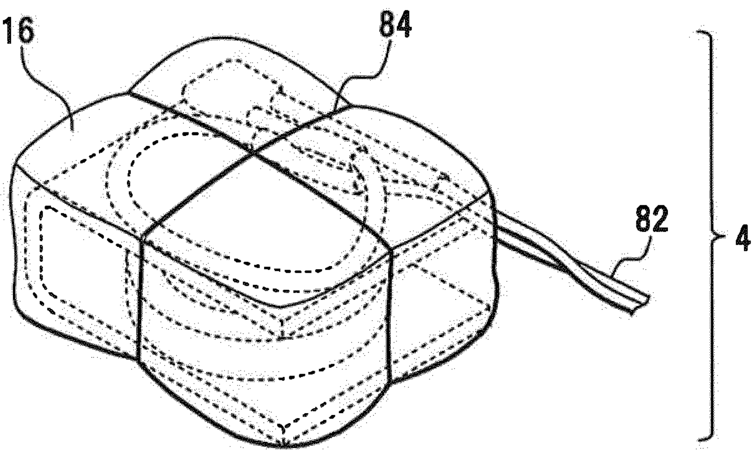


FIG.8

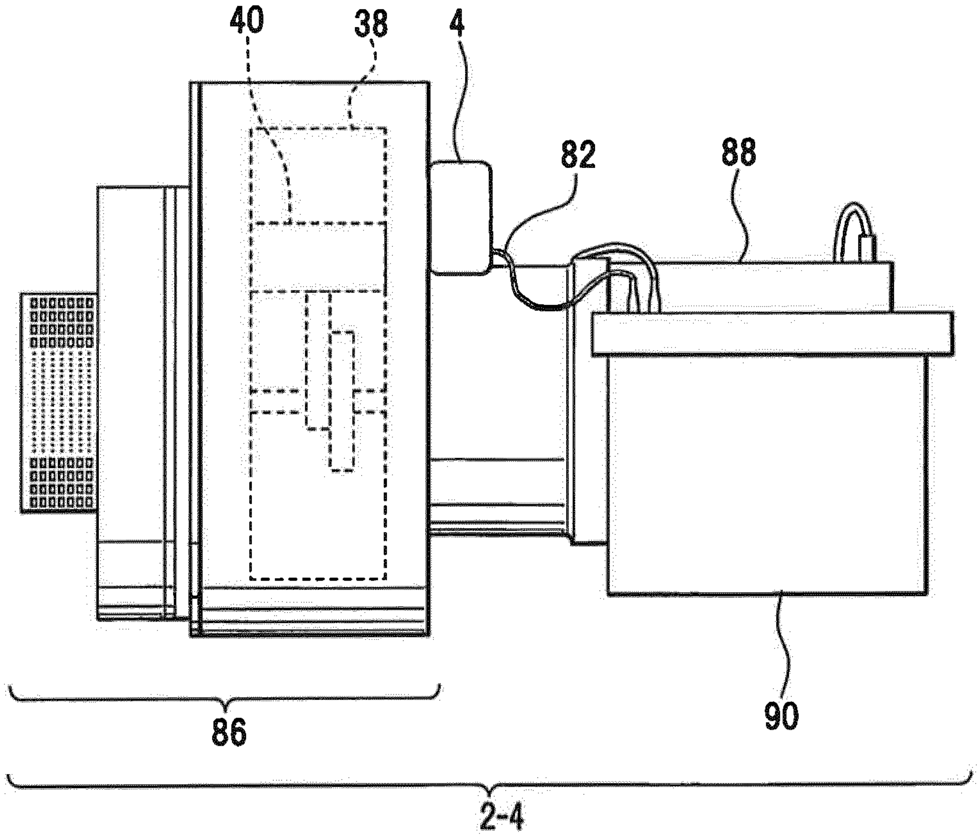
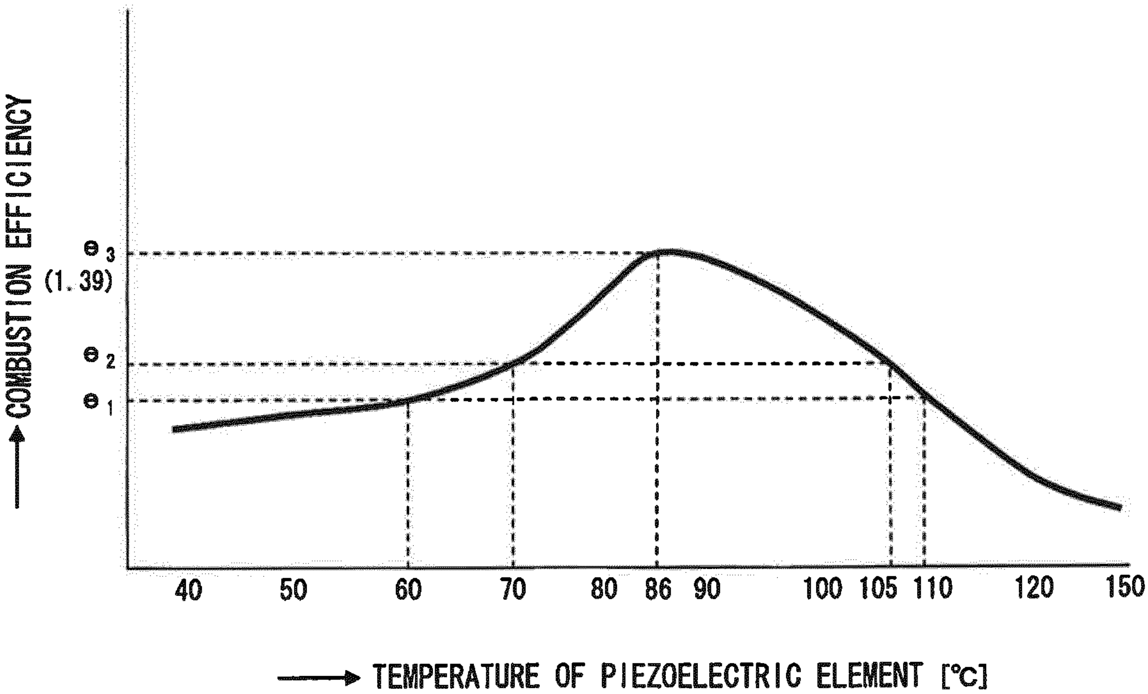


FIG.9


COMBUSTION EFFICIENCY
θ 3
(1.39)
θ 2
θ 1
40
50
60
70
80
86
90
100
105
110
120
150
TEMPERATURE OF PIEZOELECTRIC ELEMENT [°C]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/000617

A. CLASSIFICATION OF SUBJECT MATTER
F02M27/04(2006.01)i, *F02B51/04*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M27/04, F02B51/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2009-221943 A (Imagineering, Inc.), 01 October 2009 (01.10.2009), paragraphs [0021] to [0028], [0034]; fig. 1 & US 2011/0001294 A1 & EP 2264304 A1 & WO 2009/113688 A1 & CN 101970842 A	1,4-6,8-10, 12 2,3,7,11
Y A	JP 2002-161817 A (Toyota Motor Corp.), 07 June 2002 (07.06.2002), paragraph [0013] (Family: none)	1,4-6,8-10, 12 2,3,7,11
Y A	JP 3177513 U (Yasutane TAKAFUJI), 09 August 2012 (09.08.2012), paragraphs [0019] to [0024] (Family:none)	1,4-6,8-10, 12 2,3,7,11

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 April, 2013 (22.04.13)	07 May, 2013 (07.05.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/000617

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 10-223150 A (Hitachi, Ltd.), 21 August 1998 (21.08.1998), paragraphs [0003], [0010]; fig. 3 (Family: none)	4,5,8,9,12 1-3,6,7,10, 11
Y A	JP 2009-245760 A (Panasonic Corp.), 22 October 2009 (22.10.2009), paragraph [0019]; fig. 4 & US 2009/0218949 A1 & EP 2096660 A2	5 1-4,6-12

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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- JP 2002161817 A **[0005]**
- JP 2002242769 A **[0005]**

Non-patent literature cited in the description

- Application and Development of Combustion Promotion Technique by a Certain Wave Length in the Regime of Far Infrared Ray: The Challenge to Energy Saving and Reduction of CO_2 Emission using Electro-Magnetic Combustion Technique. *Eizo jyoho media gakkai gijyutu hokoku,* vol. 33 (7), 1-8 **[0006]**