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(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**
Osaka-shi, Osaka 540-6207 (JP)

(72) Inventors:
• **KUROSE, Yoichi**
Osaka-shi
Osaka 540-6207 (JP)

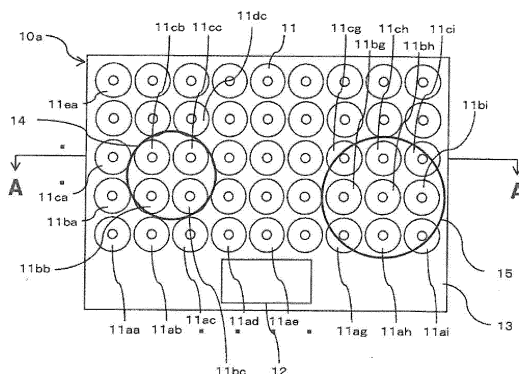
- **KITAIZUMI, Takeshi**
Osaka-shi
Osaka 540-6207 (JP)
- **FUJINAMI, Tomoya**
Osaka-shi
Osaka 540-6207 (JP)
- **MINATODANI, Junichi**
Osaka-shi
Osaka 540-6207 (JP)
- **NIIYAMA, Kohji**
Osaka-shi
Osaka 540-6207 (JP)

(74) Representative: **Eisenführ Speiser
Patentanwälte Rechtsanwälte PartGmbH
Postfach 31 02 60
80102 München (DE)**

(54) **INDUCTION HEATING DEVICE**

(57) An induction heating device includes a top plate on which an object to be heated is placed, a plurality of heating coils which are disposed below the top plate, an inverter which supplies a high frequency current to the plurality of heating coils, a control unit which controls an output of the inverter, an operation display unit which outputs an operation command to the control unit, and a detection unit for the object to be heated which detects whether the object to be heated is present on the top plate. The control unit controls the inverter to supply a detection current for detecting presence of the object to be heated to the plurality of heating coils prior to receiving an operation command signal for indicating a start of a heating operation from the operation display unit. The detection unit for the object to be heated detects the presence of the object to be heated from an input current and/or an output voltage in an electrically conductive path for electric power transmission from a power source to the heating coils, during a detection time period which the detection current is supplied to the heating coils.

Fig. 1



Description

Technical Field

[0001] The present disclosure relates to an induction heating device. The present disclosure relates particularly to an induction heating device which executes an induction heating to an object to be heated such as a metal cooking pan placed on a top plate.

Background Art

[0002] An induction heating cooking device generally used as an induction heating device is configured to have, for example, one or two heating coil(s) disposed immediately below a top plate, and execute an induction heating to an object to be heated, such as a metal cooking pan, etc., placed on the top plate using the heating coil(s).

[0003] For the induction heating cooking device, a multi-coil configuration has been proposed that has many heating coils arranged immediately below the top plate (see, e.g., Patent Literature 1).

[0004] The heating cooking device of Patent Literature 1 is configured to have many heating coils disposed each adjacent to each other densely arranged below the top plate, and be able to execute an induction heating to an object to be heated such as a cooking pan when the object to be heated is placed at any position on the top plate.

[0005] The multi-coil configuration is described in, for example, Patent Literature 2, that heats a cooking pan which is an object to be heated by the many coils. The heating cooking device described in Patent Literature 2 is configured to supply an AC signal in a radio frequency band to each heating cell, and detect an induction signal in a conductive loop positioned between the object to be heated and the heating cell. The induction signal is varied by the presence of the object to be heated, and the position of the object to be heated placed on the top plate can therefore be detected.

Citation List

Patent Literature

[0006]

PLT 1: DE 102010028549 A1

PLT 2: EP 1206164 B1

Summary of Invention

Technical Problem

[0007] As above, the heating cooking device described in Patent Literature 2 includes the inductive loop to detect the position of the object to be heated and/or an AC signal

source in the radio frequency band and a problem therefore arises that the components of the heating cooking device are increased to increase the cost.

[0008] When the number of components is great, the time necessary for assembling a product becomes long and a problem therefore arises that the manufacture cost is increased.

[0009] Especially, for the induction heating device having the multi-coil configuration, the increase of the cost is significantly increased because it is necessary to have a configuration of the conductive loop which corresponds to the number of heating coils.

[0010] A scheme of detecting a current flowing through the heating coil and/or the voltage generated therein is present as a scheme generally used as a detecting means of the object to be heated on the top plate. According to this scheme, an inverter to supply electric power to the heating coil is operated, thereby, the current flowing from the power source to the inverter, and the current flowing through the heating coil and/or the voltage generated therein are detected, and, thereby, the object to be heated is detected based on the mutual relation among the detected values.

[0011] According to this scheme, however, in general, a control unit drives the inverter after receiving an operation command signal for indicating a start of the heating operation and, when the object to be heated is detected, the operation advances to the heating operation. The traditional induction heating cooking device cannot detect the object to be heated using the inverter prior to the reception by the control unit of the operation command signal indicating that the heating operation is to commence.

[0012] When the object to be heated is detected using the operation of the inverter, the inverter is used that supplies electric power as much as about several hundred W(watt) during the heating with its rated electric power. For the traditional induction heating cooking device, any significant reduction of its power consumption to a level of several W is difficult even when the inverter is caused to operate to reduce the electric power to be minimal that is supplied from the inverter to the object to be heated during the detection of the object to be heated.

[0013] With the traditional induction heating cooking device, the electric power necessary for detecting the object to be heated is therefore significant when the detection is executed for the object to be heated concurrently by the many heating coils and, only the electric power used by the detection operation for the object to be heated may exceed the rated electric power. A problem therefore arises that the object to be heated such as a pan cannot easily be detected.

[0014] When the heating is executed using a portion of the area, the electric power usable for detecting the object to be heated is smaller than the rated electric power of the device and the detection of the object to be heated is therefore more difficult.

[0015] When the object to be heated is detected con-

currently using the many heating coils, a leakage magnetic field generated from the induction heating device is significant because the magnetic field propagates in the form of integration of the magnetic fields generated from the heating coils. A problem therefore arises that this leakage magnetic field may adversely influence the peripheral devices causing their malfunctions, etc.

[0016] The induction heating device of the multi-coil configuration has the many heating coils disposed each adjacent to each other. In the traditional induction heating cooking device, therefore, the magnetic fields generated from the adjacent heating coils mutually interfere with each other to increase or reduce the detected values from the heating coils. A problem therefore arises that the object to be heated on the top plate cannot highly precisely be detected.

[0017] An object of the present disclosure is to provide an induction heating device of the multi-coil configuration having many heating coils disposed below the top plate, that can highly precisely detect whether an object to be heated is placed on the top plate and that can reduce its manufacture cost.

Solution to Problem

[0018] In order to solve the above problems, an induction heating device of one aspect according to the present disclosure includes:

a top plate on which an object to be heated is placed;
a plurality of heating coils which are disposed below the top plate;
an inverter which supplies a high frequency current to the plurality of heating coils;
a control unit which controls an output of the inverter;
an operation display unit which outputs an operation command to the control unit; and
a detection unit for the object to be heated which detects whether the object to be heated is present on the top plate,
wherein the control unit controls the inverter to supply a detection current for detecting presence of the object to be heated to the plurality of heating coils prior to receiving an operation command signal for indicating a start of a heating operation from the operation display unit, and
wherein the detection unit for the object to be heated detects the presence of the object to be heated from an input current and/or an output voltage in an electrically conductive path for electric power transmission from a power source to the heating coils, during a detection time period which the detection current is supplied to the heating coils.

Advantageous Effects of Invention

[0019] According to the induction heating device according to the present disclosure, the current is caused

to flow to detect the presence of the object to be heated through the heating coils by the operation of the inverter prior to the start of the heating of the object to be heated and, thereby, can detect the object to be heated without adding any new component only to detect the object to be heated.

Brief Description of Drawings

[0020]

Fig. 1 is a schematic plan diagram of an induction heating device of a first embodiment according to the present disclosure.

Fig. 2 is a vertical cross-sectional diagram of the induction heating device cut off along an A-A line in Fig. 1.

Fig. 3 is a block diagram of a configuration of the induction heating device of the first embodiment according to the present disclosure.

Fig. 4 is a diagram of a circuit configuration of the induction heating device of the first embodiment according to the present disclosure.

Fig. 5 is an explanatory diagram of a relation between a current from a power source and a voltage generated in an inverter of the induction heating device of the first embodiment according to the present disclosure.

Fig. 6 is a time chart of a detection operation for an object to be heated of the induction heating device of the first embodiment according to the present disclosure.

Fig. 7 is a time chart of the detection operation for the object to be heated of the induction heating device of the first embodiment according to the present disclosure.

Fig. 8 is a time chart of the detection operation for the object to be heated of an induction heating device of a second embodiment according to the present disclosure.

Fig. 9 is a time chart of the detection operation and a heating operation for the object to be heated of an induction heating device of a third embodiment according to the present disclosure.

Fig. 10 is a time chart of a detection operation and a heating operation for the object to be heated of an induction heating device of a fourth embodiment according to the present disclosure.

Fig. 11 is a schematic plan diagram of an induction heating device of a fifth embodiment according to the present disclosure.

Fig. 12 is a time chart of a detection operation for the object to be heated of the induction heating device of the fifth embodiment according to the present disclosure.

Fig. 13 is a time chart of a detection operation for the object to be heated of an induction heating device of a sixth embodiment according to the present disclosure.

closure.

Fig. 14 is a time chart of a detection operation for the object to be heated of an induction heating device of a seventh embodiment according to the present disclosure.

Fig. 15 is an explanatory diagram of a relation between an input current from a power source and an output voltage generated in an inverter of an induction heating device of an eighth embodiment according to the present disclosure.

Fig. 16 is an explanatory diagram of a relation between an input current from a power source and an output voltage generated in an inverter of an induction heating device of a ninth embodiment according to the present disclosure.

Fig. 17 is an explanatory diagram of directions of currents of heating coils in an induction heating device of a tenth embodiment according to the present disclosure.

Description of Embodiments

[0021] An induction heating device according to a first aspect of the present disclosure includes:

a top plate on which an object to be heated is placed;
a plurality of heating coils which are disposed below the top plate;
an inverter which supplies a high frequency current to the plurality of heating coils;
a control unit which controls an output of the inverter;
an operation display unit which outputs an operation command to the control unit; and
a detection unit for the object to be heated which detects whether the object to be heated is present on the top plate,
wherein the control unit controls the inverter to supply a detection current for detecting presence of the object to be heated to the plurality of heating coils prior to receiving an operation command signal for indicating a start of a heating operation from the operation display unit, and
wherein the detection unit for the object to be heated detects the presence of the object to be heated from an input current and/or an output voltage in an electrically conductive path for electric power transmission from a power source to the heating coils, during a detection time period which the detection current is supplied to the heating coils.

[0022] With this configuration, the object to be heated can be detected without adding any new component only to detect the object to be heated.

[0023] In an induction heating device according to a second aspect of the present disclosure, the control unit according to the first aspect controls the inverter so as to sequentially supply the detection current to the plurality of heating coils and so as not to concurrently supply the

detection current to heating coils adjacent to the plurality of heating coils to which the detection current is supplied.

[0024] The control unit controls the inverter such that the current value of the detection current supplied to the heating coils is smaller than the current value of the heating current supplied to the heating coils to heat the object to be heated.

[0025] In an induction heating device according to a third aspect of the present disclosure, a current value of the detection current supplied to the heating coils according to the first or second aspect is smaller than a current value of a heating current supplied to the heating coils to execute a heating operation for the object to be heated.

[0026] When the detection current is supplied to the plurality of the heating coils prior to receiving the operation command signal for indicating a start of the heating operation from the operation display unit, the control unit controls the inverter to switch in a specific time period between the case where the detection current is supplied to the plurality of heating coils and the case where the detection current is not supplied thereto, and cyclically execute this operation.

[0027] In an induction heating device according to a fourth aspect of the present disclosure, the control unit according to any one of the first to third aspects controls the inverter so as not to supply the detection current to heating coils adjacent to heating coils which execute a heating operation.

[0028] When the detection current is supplied to the plurality of heating coils prior to receiving the operation command signal for indicating the start of the heating operation from the operation display unit, the control unit controls the inverter such that the timing of supplying the detection current is shifted among the plurality of the heating coils by sequentially changing the heating coil to be supplied with the detection current.

[0029] In an induction heating device according to a fifth aspect of the present disclosure, the control unit according to any one of the first to fourth aspects controls the inverter such that the detection current is also supplied to the heating coils that the object to be heated is detected after the detection unit for the object to be heated detects the object to be heated, and the control unit continues the detection operation using the detection unit for the object to be heated.

[0030] In an induction heating device according to a sixth aspect of the present disclosure, the plurality of heating coils according to any one of the first to fifth aspects include heating coil groups each including at least two of the heating coils, and wherein the control unit controls the inverter so as to concurrently supply the detection current to all the heating coils in the heating coil group.

[0031] In an induction heating device according to a seventh aspect of the present disclosure, the control unit according to the first to sixth aspects controls inverter so as to continuously supply the detection current to the heating coils that the object to be heated is detected after

the detection unit for the object to be heated detects the object to be heated until the detection unit for the object to be heated does not detect the object to be heated.

[0032] In an induction heating device according to an eighth aspect of the present disclosure, the control unit according to the first to seventh aspects controls the inverter such that number of sessions to supply the detection current to the heating coils which are detecting the object to be heated is set to be small compared to that of the heating coils which are not detecting the object to be heated, after the detection unit for the object to be heated detects the object to be heated until the detection unit for the object to be heated does not detect the object to be heated.

[0033] In an induction heating device according to a ninth aspect of the present disclosure, the detection unit for the object to be heated according to any one of the first, third, and fifth to eighth aspects sets a first threshold value used in detecting the presence of the object to be heated when no current is supplied to adjacent heating coils and a second threshold value used in detecting the presence of the object to be heated by concurrently supplying a current to the adjacent heating coils, and the detection unit for the object to be heated detects the presence of the object to be heated using the first threshold value or the second threshold value.

[0034] In an induction heating device according to a tenth aspect of the present disclosure, the detection unit for the object to be heated according to any one of the first, third, and fifth to ninth aspects sets the first threshold value used in detecting the presence of the object to be heated when no current is supplied to adjacent heating coils, a third threshold value used in detecting the presence of the object to be heated when the adjacent heating coils execute the heating operation with minimal electric power, and a fourth threshold value used in detecting the presence of the object to be heated when the adjacent heating coils execute the heating operation with rated electric power, and the detection unit for the object to be heated detects the presence of the object to be heated using any one of the first threshold value, the third threshold value, and the fourth threshold value.

[0035] In an induction heating device according to an eleventh aspect of the present disclosure, the control unit according to any one of the first, and fifth to tenth aspects controls the inverter such that the detection current supplied to each of the heating coils has a direction that is opposite to each other among the heating coils longitudinally and laterally adjacent to each other.

[0036] Embodiments of the present disclosure are described with reference to the drawings. The embodiments do not limit the present disclosure. In all the drawings below, the same or the corresponding parts are given the same reference numerals and are not described again.

(First Embodiment)

[Overall Configuration]

[0037] Fig. 1 is a schematic plan diagram of an induction heating device 10a of the first embodiment according to the present disclosure, and schematically shows the main elements in the first embodiment. Fig. 2 is a vertical cross-sectional diagram of the induction heating device 10a cut off along an A-A line in the schematic plan diagram of the induction heating device 10a shown in Fig. 1. Fig. 3 is a block diagram of a configuration of the induction heating device 10a of the first embodiment.

[0038] As shown in Figs. 1 to 3, the induction heating device 10a of the first embodiment includes a top plate 13, a plurality of heating coils 11 arranged and disposed below the top plate 13, an inverter that supplies a high frequency current to the heating coils 11, and a control unit 17 which controls the output of the inverter 16. The induction heating device 10a of the first embodiment further includes an operation display unit 12 that outputs an operation command to the control unit 17, and also includes a detection unit 18 for object to be heated that detects the state of the object to be heated (presence of the object to be heated) from the detected value(s) of an input current and/or an output voltage in an electrically conductive path for the electric power transmission from the power source to each of the heating coils 11.

[0039] Elements included in the induction heating device 10a of the first embodiment are described in detail.

[Top Plate]

[0040] The induction heating device 10a of the first embodiment includes the flat-board top plate 13 in the upper portion thereof. An object to be heated such as a cooking pan is placed on the top plate 13. For example, as shown in Figs. 1 and 2, a first object 14 to be heated and/or a second object 15 to be heated larger than the first object 14 to be heated is/are placed. The top plate 13 is made of an electric insulator such as glass or ceramic.

[Heating Coils]

[0041] The heating coils 11 are in a multi-coil configuration including a plurality of heating coils. The plurality of heating coils 11 is disposed in a matrix at predetermined intervals immediately below the top plate 13. For example, as shown in Fig. 1, the induction heating device 10a of the first embodiment may be configured to have the plurality of heating coils 11 disposed therein having each five thereof longitudinally arranged and each nine thereof laterally arranged. In the first embodiment, rows of the heating coils 11 are referred to as "a" to "e" rows sequentially from the row of the heating coils 11 close to the operation display unit 12 in Fig. 1, and columns are referred to as "a" to "i" columns sequentially from the column on the left in the induction heating device 10a of

Fig. 1. In the first embodiment, therefore, the plurality of heating coils 11 are denoted by reference letters of the heating coils 11aa to 11ei. Similar reference letters are attached to the heating coils 11 in the following description.

[0042] All the heating coils 11 have the substantially same shape and the substantially same configuration. In the induction heating device 10a of the first embodiment, the heating coils 11 execute the induction heating operation.

[Inverter]

[0043] The inverter 16 is connected to the plurality of heating coils 11. The inverter 16 supplies a high frequency current to each of the plurality of heating coils 11. The induction heating device 10a of the first embodiment may be configured to include a plurality of inverters 16 each corresponding to and connected to any one of the plurality of heating coils 11. For example, as shown in Fig. 2, the induction heating device 10a of the first embodiment may include inverters 16aa to 16ei connected respectively to the heating coils 11aa to 11ei. Otherwise, a configuration is present to connect only the heating coils 11 needing supply of the electric power are connected to the inverter 16 in addition to configurations such as that to collectively connect some heating coils 11 to the inverter 16.

[Control Unit]

[0044] The control unit 17 is connected to the inverter 16, the operation display unit 12, and the detection unit 18 for object to be heated. For example, the control unit 17 receives an instruction by an operation command from the operation display unit 12 and controls the output of the inverter 16. The control unit 17 receives a detection result from the detection unit 18 for object to be heated and controls the output of the inverter 16.

[Operation Display Unit]

[0045] The operation display unit 12 is disposed at the center on the user side (the lower side in Fig. 1) on the top plate 13, and is configured to be usable for the user. The position of the operation display unit 12 is not limited to the position shown in Fig. 1, and the operation display unit 12 may be disposed at an arbitrary position only when the operation display unit 12 is configured to be usable.

[0046] The operation display unit 12 is connected to the control unit 17. The operation display unit 12 outputs to the control unit 17 operation command signals for indicating the start or discontinuation of the supply of the electric power, electric power adjustment, etc.

[0047] For example, when the first object 14 to be heated such as a cooking pan is placed on the top plate 13, the operation display unit 12 outputs an operation command signal indicating that the heating operation is to

commence, to the control unit 17.

[Detection Unit for Object to Be Heated]

[0048] The detection unit 18 for object to be heated is connected to the inverter 16 and the control unit 17. The detection unit 18 for object to be heated detects the heating coils 11 corresponding to the position at which the object to be heated is placed, based on, for example, the detected value(s) of an input current into and/or an output voltage generated in an electrically conductive path for the electric power transmission from the power source to each of the heating coils 11. The detection unit 18 for object to be heated determines, for example, the state of the object to be heated magnetically coupled with the heating coils 11 (the presence of the object to be heated) such as whether the first object 14 to be heated such as a cooking pan is placed above the heating coils 11 currently energized.

[0049] The detection unit 18 for object to be heated outputs, for example, a detection result of the state of the first object 14 to be heated, as a signal to the control unit 17.

[0050] As above, when the first object 14 to be heated or the second object 15 to be heated is placed on the top plate 13 as shown in Fig. 1, the induction heating device 10a of the first embodiment detects the heating coils 11 corresponding to the area in which the object to be heated is placed and executes the heating operation. The induction heating device 10a of the first embodiment detects the heating coils 11 present immediately below the object to be heated placed on the top plate 13 and executes the heating operation.

[0051] For example, when the first object 14 to be heated is placed on the top plate 13 as shown in Fig. 1, the induction heating device 10a of the first embodiment supplies the high frequency current to the heating coils 11bb, 11bc, 11cb, and 11cc which are disposed below the first object 14 to be heated, and executes the proper induction heating operation for the first object 14 to be heated.

[0052] On the other hand, when the second object 15 to be heated is placed on the top plate 13 as shown in Fig. 1, the induction heating device 10a of the first embodiment supplies the high frequency current to the heating coils 11ag, 11ah, 11ai, 11bg 11bh, 11bi, 11cg, 11ch, and 11ci present immediately below the second object 15 to be heated, and executes the proper induction heating operation for the second object 15 to be heated.

[Detection Operation for Object to Be Heated]

[0053] The detection operation for the first object 14 to be heated is described that is executed when the first object 14 to be heated such as a cooking pan is placed on the induction heating device 10a of the first embodiment.

[0054] Fig. 4 shows an example of the circuit configuration of the induction heating device 10a of the first em-

bodiment according to the present disclosure. Fig. 5 is an explanatory diagram of a relation between an input current from the power source 40 and an output voltage generated in the inverter 16 in the induction heating device 10a of the first embodiment according to the present disclosure. Fig. 5 shows the relation between the input current and the output voltage for the detection unit 18 to detect the presence of the object to be heated in the circuit configuration shown in Fig. 4.

[0055] Fig. 4 shows the circuit of the induction heating device 10a constituted by the heating coils 11, the inverter 16, the control unit 17, the detection unit 18 for object to be heated, the AC power source 40, a current detecting unit 48, and a voltage detecting unit 49. The inverter 16 includes a diode bridge 41, a choke coil 42, a smoothing capacitor 43, a first switching element 44, a second switching element 45, a resonance capacitor 46, and a snubber capacitor 47.

[0056] In the circuit configuration shown in Fig. 4, to convert an AC into a DC to be smoothed, the power source 40 is connected to the diode bridge 41, the choke coil 42, and the smoothing capacitor 43. The first switching element 44 including a reverse conductive diode and the second switching element 45 similarly including a reverse conductive diode are connected in series to both ends of the smoothing capacitor 43 to supply the high frequency current to the heating coils 11.

[0057] The second switching element 45 is connected in parallel to the resonance capacitor 46 to cause current resonance with the heating coils 11, and the snubber capacitor 47 to reduce the switching loss generated when the first switching element 44 and the second switching element 45 are each turned off.

[0058] The circuit configuration shown in Fig. 4 further includes the current detecting unit 48 to detect the input current i_{in} supplied from the power source 40 to the inverter 16, and the voltage detecting unit 49 to detect the output voltage V_c that is the voltage between both ends of the resonance capacitor 46 in the inverter 16. The detected values of the current detecting unit 48 and the voltage detecting unit 49 are output to the detection unit 18 for object to be heated.

[0059] As shown in Fig. 5, the detected values can be plotted of the input current i_{in} and the output voltage V_c on a coordinate plane whose axis of abscissa represents the input current i_{in} and whose axis of ordinate represents the output voltage V_c based on the detected values of the input current i_{in} detected by the current detecting unit 48 and the output voltage V_c detected by the voltage detecting unit 49.

[0060] For example, the induction heating device 10a of the first embodiment can set conditions for maintaining the input voltage of the power source 40 in the circuit configuration shown in Fig. 4 to be constant, and for the detection unit 18 for object to be heated to detect the presence of the object to be heated when the object to be heated is placed in an area that is equal to or larger than 50% of a heating area (the heating area of the upper

face of the heating coil 11) of a surface facing the top plate 13 of one of the heating coils 11. For the induction heating device 10a of the first embodiment, in the case where the driving variables such as the operation frequency or the duty of each of the first switching element 44 and the second switching element 45 are varied under this condition, when the detected values of the input current i_{in} and the output voltage V_c (the voltage between both ends of the resonance capacitor 46) have a correlation to mutually influence each other, a threshold value curved line L shown in Fig. 5 can be shown by connecting the detected values. The induction heating device 10a of the first embodiment may set the condition such that the presence of the object to be heated is detected, for example, when the object to be heated is placed in an area that is equal to or larger than 40% of the heating area of the upper surface of the heating coil 11. The induction heating device 10a of the first embodiment can arbitrarily set the condition for detecting the presence of the object to be heated.

[0061] The threshold value curved line L represents a boundary between the state where the heating coil 11 can heat the object to be heated (the state where the object to be heated is present above the heating coil 11) and the state where the heating coil 11 cannot heat the object to be heated (the state where no object to be heated is present above the heating coil 11). On the coordinate plane shown in Fig. 5, an "AREA 1" (an area shown on the right of the threshold value curved line L) represents the state where the heating coil 11 can heat the object to be heated, and an "AREA 2" (an area shown on the left of the threshold value curved line L) represents the state where the heating coil 11 cannot heat the object to be heated.

[0062] For example, when no object to be heated is placed above the heating coil 11, the output voltage V_c is increased relatively to the input current i_{in} .

[0063] The threshold value curved line L is therefore drawn on the boundary between the state where the heating coil 11 can heat the object to be heated and the state where the heating coil 11 cannot heat the object to be heated and, based on the threshold value curved line L, it can be determined that the heating can be executed (the object to be heated is present) when the detected values of the input current i_{in} and the output voltage V_c are in the "AREA 1" in Fig. 5, and it can be determined that the heating cannot be executed (the object to be heated is absent) when the detected values are in the "AREA 2". In this manner, the detection unit 18 for object to be heated can detect whether the object to be heated is placed on the heating coil 11, based on the detected value(s) of the input current into and/or the output voltage generated in the electrically conductive path for electric power transmission from the power source 40 to the heating coil 11.

[0064] Fig. 6 is a time chart of a detection operation for the object to be heated of the induction heating device 10a of the first embodiment according to the present dis-

closure. Fig. 6 shows an example of a time chart of the case where the detection current to detect the presence of the object to be heated is supplied to each of the plurality of heating coils 11 disposed in the arrangement, to detect the placement of the object to be heated (the presence of the object to be heated).

[0065] As shown in Fig. 6, the induction heating device 10a of the first embodiment executes the detection operation (energizing) for only a detection time period T_d first for the heating coil 11aa in a detection cycle T_{c1} for the object to be heated. The induction heating device 10a of the first embodiment supplies the detection current to detect the presence of the object to be heated to the heating coil 11aa only for the detection time period T_d . The induction heating device 10a of the first embodiment detects whether the object to be heated is placed above the heating coil 11aa in the detection time period T_d . The induction heating device 10a determines the presence of the object to be heated based on, for example, whether the detected values of the input current I_{in} and the output voltage V_c of the heating coil 11aa belong to the "AREA 1" or the "AREA 2" in Fig. 5.

[0066] When the detection time period T_d for the heating coil 11aa elapses, the induction heating device 10a of the first embodiment discontinues the detection operation for the heating coil 11aa, starts the detection operation for the heating coil 11ba, and detects whether the object to be heated is placed above the heating coil 11ba, similarly to the case of the heating coil 11aa.

[0067] The detection operation to detect the presence of the object to be heated can be executed prior to receiving by the control unit 17 of the operation command (a heating operation start command) signal for indicating a start of the heating operation from the operation display unit 12. For example, the induction heating device 10a of the first embodiment may start the detection operation when the power switch is turned on, or may start the detection operation when a human sensor detects a person in the vicinity of the induction heating device 10a.

[0068] The induction heating device 10a of the first embodiment can display on the operation display unit 12, at the time point of the indication of the heating operation, the state of the placement of the object to be heated such as whether the object to be heated is placed, grasping of the shape of the object to be heated, etc, and information necessary for the user of the induction heating device 10a to select the heating operation for the object to be heated. As a result, the induction heating device 10a usable for the user can be provided.

[0069] By executing the detection operation using all of the plurality of heating coils 11, the state of the object to be heated can be detected by each of the heating coils 11 for each detection time period T_{c1} . The induction heating device 10a of the first embodiment can therefore facilitate the operation of the heating operation for the user by, for example, displaying on the operation display unit 12 the area in which the object to be heated is placed by grasping the placement state of the object to be heated

by the detection unit 18 for object to be heated. By executing the operation for the heating operation on the operation display unit 12, the user can therefore operate such that the electric power is supplied to the heating coils 11 for which the object to be heated is detected, that is, only the heating coils 11 immediately below the object to be heated and the heating operation is executed only for the object to be heated.

[0070] The heating operation is not started for the heating coils 11 above which no object to be heated is placed and, thereby, the risk can be avoided that a cooking pan placed after the operation, is heated from the time point of its placement. In the induction heating device 10a of the first embodiment, the heating coils 11 corresponding to the area in which no object to be heated is placed, that is, the heating coils 11 not present immediately below the object to be heated execute only the detection operation. For example, even when another object to be heated is placed in the area except that of the heating coils 11 executing the heating operation, no heating operation is therefore executed as far as no heating operation is executed for the other object to be heated. In this manner, the induction heating device 10a of the first embodiment is configured not to start the heating for the object to be heated after the heating coils 11 are detected that correspond to the area in which the object to be heated is placed until the user executes the operation for the heating operation.

[0071] During the detection operation, the leakage magnetic field is increased when the high frequency current is continuously supplied for a long time to the heating coils 11 above which no object to be heated is placed. Otherwise, the efficiency is degraded, etc., due to the conduction loss by supplying the detection current to detect the presence of the object to be heated to the heating coils 11. The induction heating device 10a of the first embodiment can, however, prevent the increase of the leakage magnetic field by supplying a small detection current for a short time at constant intervals during the detection operation and can suppress the degradation of the efficiency.

[0072] As shown in Fig. 6, in the first embodiment, the detection operation for the object to be heated is executed avoiding concurrent energizing of the plurality of heating coils 11. In the first embodiment, the detection current to detect the presence of the object to be heated is not concurrently supplied to the plurality of heating coils 11. Thereby, the magnetic field generated by the execution by the other heating coils 11 of the detection operation for the object to be heated does not link to and does not interfere with the heating coil 11 of the magnetic field itself. The induction heating device 10a of the first embodiment can therefore highly precisely detect the object to be heated because the detected values of the input current I_{in} and the output voltage V_c do not fluctuate.

[0073] The induction heating device 10a of the first embodiment sequentially executes the detection operation for the object to be heated using the plurality of heating

coils 11. The induction heating device 10a of the first embodiment can reduce the peak value of the electric power necessary for the detection operation for the object to be heated by sequentially supplying the detection current to the plurality of heating coils 11 so as to detect the presence of the object to be heated. As a result, the induction heating device 10a of the first embodiment can securely detect the cooking pan without causing its power consumption to exceed the rated electric power.

[0074] Fig. 7 is another time chart of the detection operation for the object to be heated of the induction heating device 10a of the first embodiment according to the present disclosure. As shown in Fig. 7, the induction heating device 10a of the first embodiment may have in a detection cycle Tc2 a time period Tcm to execute the detection operation and a time period Tcp for no heating coil 11 to execute the detection operation.

[0075] As above, the induction heating device 10a of the first embodiment can adjust the length of the detection cycle Tc2 by having the time period Tcp during which no detection operation is executed. For example, assuming that the time period Tcm is constant during which the detection operation is executed, the detection time period Tc2 can be set to be long by setting the time period Tcp during which no detection operation is executed to be long. As a result, the induction heating device 10a of the first embodiment can reduce the electric power loss by reducing the average power consumption by reducing the time period during which the detection operation is executed, that is, the time period during which the detection current is supplied to the heating coil 11, relative to the detection cycle Tc2.

[0076] For example, the induction heating device 10a of the first embodiment may insert for a specific time period a time period Tcp during which no detection operation by the heating coil 11 is executed, between the detection operation for the object to be heated executed by the heating coil 11aa and the detection operation for the object to be heated executed by the heating coil 11ba adjacent to the heating coil 11aa. The length of the time period Tcm and the length of the time period Tcp are not limited to the lengths shown in Fig. 7 and may arbitrarily be set.

[0077] As above, the detection for the object to be heated such as a cooking pan can be executed avoiding the mutual interference by the magnetic fields generated by the heating coils 11 by avoiding concurrent execution of the detection operation by the adjacent heating coils 11.

(Second Embodiment)

[0078] An induction heating device 10b of the second embodiment is described with reference to the drawings.

[0079] Only the parts different from the first embodiment are described in the second embodiment and the same parts as those in the first embodiment are not described again.

[0080] Fig. 8 is a time chart of the detection operation

for the object to be heated of the induction heating device 10b of the second embodiment according to the present disclosure, and shows an example of the time chart used when the detection operation is executed by each of the plurality of heating coils 11 disposed being arranged to detect the placement of the object to be heated.

[0081] As shown in Fig. 8, the second embodiment differs from the first embodiment in that the plurality of heating coils concurrently execute the detection operation. In the second embodiment, during the detection time period Td, some heating coils 11 not mutually adjacent to each other of the plurality of heating coils 11 concurrently execute the detection operation for the object to be heated.

[0082] As shown in Fig. 8, for example, during a detection time period Tc3, the heating coils 11 concurrently executing the detection operation in the first detection time period Td are the three heating coils that are the heating coils 11aa, 11ad, and 11ag to be every three heating coils in the "a" row, in the configuration shown in Fig. 1. In this case, of the three heating coils 11aa 11ad, and 11ag, for example, the heating coil 11aa and the heating coil 11ad are noted. As shown in Fig. 1, the two heating coils 11ab and 11ac executing no detection operation are present between the heating coils 11aa and 11ad executing the detection operation.

[0083] A distance twice as long as the diameter of the heating coil 11 is present as the distance between the heating coils 11aa and 11ad that concurrently execute the detection operation (that are energized). The air propagation intensity of a magnetic field is reversely proportional to the n-th power of the distance (n is two or greater) and the interference intensity of the magnetic fields is significantly reduced by increasing the distance.

[0084] According to the experiments executed by the inventors, it has been confirmed that, when at least one heating coil 11 not executing any detection operation (not energized) is present between the two heating coils 11aa and 11ad executing the detection operation (energized), the detection precision for the object to be heated is improved to a level with which no influence by the interference is present.

[0085] The distance between the two heating coils 11aa and 11ad executing the detection operation is varied according to the diameter of the heating coil 11. The electric power capable of being supplied from the heating coil 11 to the object to be heated, that is, the generated magnetic field is, however, reduced as the diameter of the heating coil 11 is reduced, and the detection for the object to be heated can highly precisely be executed only when the adjacent heating coils 11 alone do not concurrently execute the detection operation.

[0086] The detection time period Td is a time period during which the detection current to detect the presence of the object to be heated is supplied (energized) to detect whether the object to be heated is placed above each of the heating coils 11. For example, assuming that the power source 40 is an AC power source at 50 Hz, at least about 10 msec are necessary as the detection time period

Td. In the case where any improvement is attempted of the precision of the detection for the object to be heated, a longer time period is necessary as the detection time period Td, and the detection time period Tc1 is increased when the detection current is sequentially supplied to the plurality of heating coils 11 as in the first embodiment.

[0087] In the case where the detection operation is concurrently executed by the plurality of heating coils 11 as in the second embodiment, when the detection operation is executed by the plurality of heating coils 11 present at a distance with which the precision of the detection for the object to be heated is not degraded due to the interference of the magnetic field generated by the other heating coil 11, the detection cycle Tc3 necessary for concurrently executing the detection operation can be shortened. For example, the detection cycle Tc3 in the second embodiment can be set to be shorter than the detection cycle Tc1 necessary for executing the detection operation by each single heating coil 11 in the first embodiment.

[0088] The induction heating device 10b of the second embodiment can shorten the maximal time period (the detection cycle Tc3) spanning from the placement of the object to be heated to the detection thereof, and can therefore quickly display the state of the object to be heated (for example, the shape and the position of the placement of the object to be heated) on the operation display unit 12. Thereby, the usable induction heating device can be provided with which the user can smoothly start the heating operation without any stress therefrom.

[0089] According to the induction heating device 10b of the second embodiment of the present disclosure, the detection operation for the object to be heated is concurrently executed by the heating coils 11aa, 11ad, and 11ag that are laterally every three heating coils in the "a" row in the configuration shown in Fig. 1. In addition, for example, the detection operation for the object to be heated may be concurrently executed by the heating coils 11aa, 11ac, 11ae, and 11ag that are laterally every two heating coils in the "a" row in the configuration shown in Fig. 1. The detection operation for the object to be heated may also be concurrently executed by the heating coils 11aa and 11ca that are longitudinally every two heating coils in the "a" column in the configuration shown in Fig. 1. In this manner, for the induction heating device 10b of the second embodiment, the order, the number of heating coils, etc., are not limited in executing the detection operation for the object to be heated only when the detection operation for the object to be heated is not concurrently executed by any adjacent heating coils 11.

[0090] The induction heating device 10b of the second embodiment may execute the detection operation for the object to be heated prior to receiving by the control unit 17 of the operation command signal for indicating the start of the heating operation from the operation display unit 12. The current value of the detection current to detect the presence of the object to be heated supplied to the heating coil 11 is smaller than the current value of

the heating current to execute the heating operation supplied to the heating coil 11.

(Third Embodiment)

[0091] An induction heating device 10c of the third embodiment will be described with reference to the drawings.

[0092] Only the parts different from the first embodiment or the second embodiment are described in the third embodiment and the same parts as those in the first embodiment or the second embodiment are not described again.

[0093] Fig. 9 is a time chart of the detection operation and the heating operation for the object to be heated of the induction heating device 10c of the third embodiment according to the present disclosure, and depicts an example of the time chart before and after the start of the heating for the first object 14 to be heated.

[0094] As shown in Fig. 9, the third embodiment differs from the first embodiment or the second embodiment in that the detection operation as to whether the object to be heated is placed on the top plate 13 of the induction heating device 10c is executed before the time Ts at which the heating is started for the first object 14 to be heated. In the third embodiment, the detection operation as to whether the object to be heated is placed on the top plate 13 is same as that of the first embodiment or the second embodiment.

[0095] The case is described where the first object 14 to be heated is placed at the position shown in Fig. 1 at a time point before the time Ts. Based on the detection operation for the object to be heated, the detection unit 18 for object to be heated detects that the object to be heated is placed above the heating coils 11bb, 11cb, 11bc, and 11cc shown in Fig. 1. Even when the object to be heated is detected to be present above the heating coils 11, the induction heating device 10c of the third embodiment is controlled by the control unit 17 such that the detection operation for the object to be heated is continued as far as the operation display unit 12 does not output the signal for indicating the heating operation. This is because the first object 14 to be heated is again detected when the first object 14 to be heated placed on the top plate 13 of the induction heating device 10c is moved.

[0096] When the control unit 17 receives the operation command signal for indicating the start of the heating operation from the operation display unit 12 at the time point of the time Ts, the control unit 17 controls the inverter 16 such that the high frequency current to execute the heating operation is supplied to the heating coils 11bb, 11cb, 11bc, and 11cc. In this manner, when the operation display unit 12 outputs the operation command signal for indicating the start of the heating operation, the heating operation is started by the heating coils 11bb, 11cb, 11bc, and 11cc, and the detection operation is discontinued.

[0097] On the other hand, for example, because the object to be heated is not placed above the heating coil 11dc adjacent to the heating coil 11cc executing the heating operation (because the object to be heated is not detected) and the heating coil 11dc therefore continues the detection operation for the object to be heated. Even when the heating coils 11bb, 11cb, 11bc, and 11cc start the heating operation that are present immediately below the first object 14 to be heated placed on the induction heating device 10c, the heating coils 11 continue the detection operation for the object to be heated except the heating coils 11bb, 11cb, 11bc, and 11cc executing the heating operation. Even when an object to be heated other than the first object 14 to be heated is placed above the heating coil 11dc and the detection unit 18 for object to be heated detects the object to be heated, the heating coil 11dc continues the detection operation for the object to be heated as far as the operation display unit 12 does not output the signal for indicating the heating operation.

[0098] As above, according to the induction heating device 10c of the third embodiment, even when the heating operation is started by the heating coils 11 in an area, this heating operation does not obstruct the detection of the object to be heated by the heating coils 11 in another area. In the third embodiment, therefore, the usable induction heating device can be provided that maintains the detection frequency and the detection precision for the object to be heated.

[0099] When the detection operation is executed for the object to be heated, the detection current to detect the presence of the object to be heated needs to be supplied to the heating coils 11 and a conduction loss is therefore generated by the detection current supplied to the heating coils 11. When the object to be heated is placed above the heating coils 11, even a micro current for the detection operation generates a magnetic field and micro induction heating is therefore executed. Electric power P1 is supplied from the power source 40 and is consumed due to the conduction loss and the induction heating.

[0100] The supply and the consumption of the electric power P1 due to these items are, however, not preferable. Preferably, when the inverter 16 is operated to detect the object to be heated, the electric power to detect the presence of the object to be heated is electric power that is capable of detecting the state of the placement of the object to be heated and that is small as much as possible, to be supplied to the heating coils 11.

[0101] According to the third embodiment, the efficiency of the induction heating device 10c can be increased by suppressing the consumption of the electric power used by the detection operation for the object to be heated, by controlling the inverter 16 such that the electric power P1 supplied for the detection operation for the object to be heated is smaller than the electric power P2 supplied for the heating operation for the object to be heated.

(Fourth Embodiment)

[0102] An induction heating device 10d of the fourth embodiment is described with reference to the drawings.

[0103] Only the parts different from the first to the third embodiments are described in the fourth embodiment and the same parts as those in the first to the third embodiments are not described again.

[0104] Fig. 10 is a time chart of the detection operation and the heating operation for the object to be heated of the induction heating device 10d of the fourth embodiment according to the present disclosure and shows an example of the time chart before and after the start of the heating for the first object 14 to be heated.

[0105] Fig. 10 differs from Fig. 9 in that the heating coil 11dc, that is, the heating coil adjacent to the heating coils executing the heating operation does not execute the detection operation for the object to be heated, after the time Ts at which the heating is started for the first object 14 to be heated placed at the position shown in Fig. 1.

[0106] The operation frequency of the inverter 16 for detecting the presence of the object to be heated is set to be higher than the operation frequency of the inverter 16 for the heating operation for the object to be heated.

[0107] This is because, when the presence of the object to be heated is detected, the electric power supplied from the power source 40 can be reduced by, for example, causing the operation frequency of the inverter 16 to be away from the resonant frequency of the heating coils 11 and the resonance capacitor 26.

[0108] The width between the operation frequency of the inverter 16 for detecting the presence of the object to be heated and the operation frequency of the inverter 16 for heating the presence of the object to be heated is set to be away from each other by a frequency equal to or higher than about 20 kHz that is an audible frequency difference.

[0109] For example, when the first object 14 to be heated is heated at the position shown in Fig. 1, a magnetic field generated from the heating coil 11cc interferes with the heating coil 11dc disposed adjacent to the heating coil 11cc supplied with the high frequency current to heat the first object 14 to be heated.

[0110] As above, the frequency of the heating current of the heating coil 11cc executing the heating operation differs from the frequency of the detection current of the heating coil 11dc executing the detection operation. The influence by the magnetic field interference on the detection precision is therefore small compared to that in the case where the frequencies are equal to each other (the case where both of the heating coils 11cc and 11dc execute the detection operation), and the detection for the object to be heated can be executed.

[0111] For example, when higher precision detection for the object to be heated is necessary in the case such as where a micro displacement of the object to be heated is highly precisely detected, the heating coil adjacent to the heating coils 11bb, 11cb, 11bc, and 11cc executing

the heating operation, for example, the heating coil 11dc does not execute the detection operation for the object to be heated and also cannot execute the heating operation. The heating coil 11dc, etc., difficult to precisely detect the object to be heated do not execute the detection operation for the object to be heated and, thereby, the precision of the detecting operation for the object to be heated as the overall induction heating device 10d can be maintained. When the one heating coil 11dc is present that does not execute the detection operation for the object to be heated, the interference intensity is significantly degraded from the heating coil 11cc to the heating coil 11ec disposed sandwiching the heating coil 11dc therebetween, and the precision can be secured for the detection operation for the object to be heated. The heating coil 11ec can therefore continue the detection operation.

[0112] When the second object 15 to be heated other than the first object 14 to be heated is placed on the top plate 13 in the case where the first object 14 is heated, the second object 15 to be heated does not need to be placed at a position adjacent to the first object 14 to be heated in the induction heating device having the multi-coil configuration whose heating area is large and whose placement area is freely selected, and the usability thereof is not significantly obstructed.

(Fifth Embodiment)

[0113] An induction heating device 10e of the fifth embodiment is described with reference to the drawings.

[0114] Only the parts different from the first to the fourth embodiments are described in the fifth embodiment and the same parts as those in the first to the fourth embodiments are not described again.

[0115] Fig. 11 is a schematic plan diagram of the induction heating device 10e of the fifth embodiment according to the present disclosure, and schematically shows the main elements in the fifth embodiment.

[0116] Fig. 11 differs from Fig. 1 in that heating coil groups are included. In the fifth embodiment, the plurality of heating coils 11 are divided into three heating coil groups G1, G2, and G3 to execute the detection operation for the object to be heated.

[0117] Fig. 12 is a time chart of the detection operation for the object to be heated of the induction heating device 10e executed when the 45 heating coils shown in the schematic plan diagram of Fig. 11 are divided into three heating coil groups G1, G2, and G3 in the fifth embodiment according to the present disclosure. Fig. 12 shows an example of the time chart of the detection operation for the object to be heated.

[0118] Fig. 12 differs from Figs. 6 to 8 in that the detection operation for the object to be heated is concurrently executed by all the heating coils 11 in the same group including adjacent heating coils.

[0119] When the current flows through the adjacent heating coils in the case where the detection operation

for the object to be heated is executed, magnetic fields are generated from the adjacent heating coils and the magnetic fields interfere with the other heating coil that executes the detection operation for the object to be heated. A current originated from the Lenz's law therefore flows through the heating coil that executes the detection operation for the object to be heated, and the detection operation for the object to be heated cannot accurately be executed because an error is generated in each of the current value and the voltage value used to determine the presence of the object to be heated.

[0120] Only for the trouble caused by the interference of the magnetic fields generated from the heating coils incorporated in the same induction heating device, the level can be measured in advance of the error generated when the detection current supplied to the adjacent heating coils and the magnetic fields interfere with each other. Threshold values (threshold values for the current and the voltage) can be set for the determination of the object to be heated that presents no influence even when the interference by the magnetic fields is received from the adjacent heating coil. Thereby, any mistake in determining the object to be heated due to the magnetic field interference can be avoided, and any adjacent heating coils 11 can concurrently execute the detection operation for the object to be heated.

[0121] As shown in Fig. 11, in the fifth embodiment, for example, the 45 heating coils are divided into the three heating coil groups G1, G2, and G3. As shown in Fig. 12, for example, all the heating coils 11 aa to 11ec in the heating coil group G1 concurrently execute the detection operation for the object to be heated during the detection time period Td. Thereby, the detection cycle Tc4 necessary for all the heating coils 11 in the induction heating device 10e of the fifth embodiment to execute the detection operation for the object to be heated can be suppressed to a length about three times as long as the detection cycle Td necessary for the one heating coil 11 to execute the detection operation for the object to be heated. To exemplify using another example, the detection cycle Tc4 of the induction heating device 10e of the fifth embodiment is 1/5 of the detection cycle Tc3 of the second embodiment. In this manner, the induction heating device 10e of the fifth embodiment can shorten the time period during which the detection operation for the object to be heated is executed. Thereby, the detection operation for the object to be heated can rapidly be executed and the responsive induction heating device can be provided.

[0122] Especially, for the induction heating device 10e of the fifth embodiment, preferably, the adjacent heating coils are concurrently be detected to determine the shape and the position of the object to be heated during a transitional state for the object to be heated, to be moved on the induction heating device.

[0123] For example, when the detection current to detect the presence of the object to be heated is sequentially supplied to the plurality of heating coils 11 as in the first

embodiment, the detecting unit 18 for objects to be heated may make a mistake in determining the shape and the placement position of the object to be heated. For example, according to the induction heating device 10 of the first embodiment, even when one of the heating coils determines that no object to be heated is placed thereabove and, immediately thereafter, the object to be heated is moved to and placed above this heating coil, this heating coil determines that no object to be heated is placed thereabove. On the other hand, another heating coil executing the detection operation at a timing later than the timing of the detection operation of this heating coil may detect the object to be heated after its moving. In this manner, when the detection current is sequentially supplied to the plurality of heating coils 11, the detection unit 18 for object to be heated may make a mistake in determining the shape and the placement position of the object to be heated while the induction heating device 10e of the fifth embodiment can avoid any mistake in determining the shape or the placement position of the object to be heated by concurrently executing the detection operation by all the heating coils in the same heating coil group.

[0124] For the determination of the shape and the position of the object to be heated, it is effective to execute the detection operation for the object to be heated by one heating coil group, that is, by concurrently all the 45 heating coils while the number of heating coil groups is set such that the electric power necessary for the detection operation for the object to be heated does not exceed at least the rated electric power. According to the induction heating device 10e of the fifth embodiment, all the heating coils 11 in the heating coil group concurrently execute the detection operation while any plurality of heating coils 11 in the heating coil group may sequentially execute the detection operation.

(Sixth Embodiment)

[0125] An induction heating device 10f of the sixth embodiment is described with reference to the drawings.

[0126] Only the parts different from the first to the fifth embodiments are described in the sixth embodiment and the same parts as those in the first to the fifth embodiments are not described again.

[0127] Fig. 13 is a time chart of the detection operation for the object to be heated of the induction heating device 10f of the sixth embodiment according to the present disclosure, and shows an example of the time chart of the detection operation for the object to be heated.

[0128] Fig. 13 differs from Fig. 12 in that the heating coil detecting the object to be heated continuously executes the detection operation until the object to be heated is removed. In the induction heating device 10f of the sixth embodiment, after the detection of the object to be heated, the detection current to detect the object to be heated is continuously supplied to the heating coil until the heating coil does not detect the object to be heated.

[0129] When the detection operation is executed for the object to be heated, the inverter 16 connected to the heating coils 11 is driven to supply the detection current to detect the object to be heated to the heating coils 11. An inrush current flows through the heating coils 11 at a timing at which the supply of the detection current to the heating coils 11 is started from the state where no detection operation is executed for the object to be detected, that is, the state where no detection current is supplied to the heating coils 11. The magnetic fields generated by the inrush current and the object to be heated resonate with each other to produce a cooking pan sound such as "click".

[0130] When the detection operation for the object to be heated is regularly executed after the placement of the object to be heated on the induction heating device, the cacophonous sound such as "click" is generated at each timing of the execution of the detection operation for the object to be heated and gives uncomfortable feeling to the user.

[0131] As shown in Fig. 13, however, according to the induction heating device 10f of the sixth embodiment, when the object to be heated is placed above at least the heating coils 11bb and 11cb shown in Fig. 1 at, for example, a timing Tp1, only the heating coils 11bb and 11cb continue the detection operation that detect the object to be heated in their detection operation for the object to be heated. In the sixth embodiment, therefore, realization of the induction heating device is enabled that does not generate any cacophonous sound such as "click" by continuously supplying the current at the detection level necessary for the detection operation of the heating coils 11bb and 11cb.

[0132] As shown in Fig. 13, after the timing Tp1 at which the object to be heated is placed above the heating coils 11bb and 11cb shown in Fig. 1, only the pulses execute the detection operation for only the detection time period Td and, this is because a processing time period for determining the object to be heated is necessary. The induction heating device 10f of the sixth embodiment may supply a continuous current to the heating coils 11bb and 11cb immediately after the timing Tp1 at which the object to be heated is placed.

[0133] From the viewpoints that the leakage magnetic field is wastefully released and that the electric power efficiency is improved, as shown in Fig. 13, preferably, the continuous current supplied to the heating coils 11bb and 11cb is also discontinued simultaneously at the timing Tp2 at which the object to be heated is removed. The induction heating device 10f of the sixth embodiment can rapidly execute the next detection operation for the object to be heated by returning to the normal detection operation for the object to be heated at and after the timing Tp2.

(Seventh Embodiment)

[0134] An induction heating device 10g of the seventh

embodiment is described with reference to the drawings.

[0135] Only the parts different from the first to the sixth embodiments are described in the seventh embodiment and the same parts as those in the first to the sixth embodiments are not described again.

[0136] Fig. 14 is a time chart of the detection operation for the object to be heated of the induction heating device 10g of the seventh embodiment according to the present disclosure, and depicts an example of the time chart of the detection operation for the object to be heated.

[0137] Fig. 14 differs from Fig. 13 in that the execution frequency of the detection operation for the object to be heated is reduced until the object to be heated is removed, for the heating coils that detect the object to be heated. The induction heating device 10g of the seventh embodiment reduces the number of supply sessions of the detection current to detect the object to be heated to the heating coils until the heating coils do not detect the object to be heated after the object to be heated is detected.

[0138] When the detection operation for the object to be heated is executed, the inverter 16 connected to the heating coils 11 is driven to supply the detection current to detect the object to be heated, to the heating coils. An inrush current flows through the heating coils at a timing at which the supply of the detection current to the heating coils 11 is started from the state where no detection operation is executed for the object to be heated, that is, the state where no detection current is supplied to the heating coils 11. The magnetic fields generated by the inrush current and the object to be heated resonate with each other to produce a cooking pan sound such as "click".

[0139] When the detection operation for the object to be heated is regularly executed after the placement of the object to be heated on the induction heating device, the cacophonous sound such as "click" is generated at each timing to execute the detection operation for the object to be heated and gives uncomfortable feeling to the user.

[0140] In the seventh embodiment, as shown in Fig. 14, when the object to be heated is placed above at least the heating coils 11bb and 11cb in the configuration shown in Fig. 1 at, for example, the timing Tp1, the execution frequency (the number of execution sessions) of the detection operation for the object to be heated is reduced only for the heating coils 11bb and 11cb that detect the object to be heated in their detection operation for the object to be heated. Thereby, realization of the induction heating device is enabled whose number of generation sessions of the uncomfortable sound such as "click" is reduced.

[0141] When the induction heating device 10g of the seventh embodiment detects that the object to be heated is not placed above the heating coils 11bb and 11cb, the induction heating device 10g can rapidly execute the next detection operation for the object to be heated by returning to the normal detection operation for the object to be

heated at and after the timing Tp2.

(Eighth Embodiment)

[0142] An induction heating device 10h of the eighth embodiment is described with reference to the drawings.

[0143] Only the parts different from the first to the seventh embodiments are described in the eighth embodiment and the same parts as those in the first to the seventh embodiments are not described again.

[0144] Fig. 15 is an explanatory diagram of a relation between the input current I_{in} from the power source 40 and the output voltage V_c generated in the inverter 16 of the induction heating device 10h of the eighth embodiment according to the present disclosure. Fig. 15 depicts the relation between the input current I_{in} and the output voltage V_c for the detection unit 18 for object to be heated to detect the object to be heated in the circuit configuration shown in Fig. 4.

[0145] Fig. 15 differs from Fig. 5 in that two threshold value curved lines are shown that each indicate the relation of the threshold value between the input current value I_{in} from the power source 40 and the output voltage value V_c generated in the inverter 16 to determine whether the object to be heated is placed. The induction heating device 10h of the eighth embodiment detects the presence of the object to be heated using the two threshold value curved lines.

[0146] When the detection operation is executed for the object to be heated, the detection current is supplied to the adjacent heating coils 11 and, thereby, the magnetic fields are generated from the adjacent heating coils 11. The magnetic fields interfere with the heating coils 11 that execute the detection operation for the object to be heated. A current originated from the Lenz's law is therefore supplied to the heating coil that executes the detection operation for the object to be heated, and the detection operation for the object to be heated cannot accurately be executed because an error is generated in each of the input current value and the output voltage value used to determine the presence of the object to be heated.

[0147] Only for the trouble caused by the magnetic fields generated from the heating coils 11 incorporated in the same induction heating device, the level can be measured in advance of the error generated when the current flowing through the adjacent heating coils 11 and the magnetic fields interfere with each other. Fig. 15 shows the two threshold value curved lines that each connect the boundary values between the "AREA 1" to determine that the object to be heated is placed and the "AREA 2" to determine that the object to be heated is not placed, from the input current value and the output voltage value generated when the inverter 16 is driven. The two threshold curved lines are the solid line L1 applicable to the case where no interference of the magnetic fields from the adjacent heating coils 11 is received, and a dotted line L2 applicable to the case where the interference

of the magnetic fields from the adjacent heating coils 11 is received. The threshold value curved line L2 is a line that connects the boundary values to determine the "AREA 1" and the "AREA 2", acquired by measuring in advance the level of the error generated when the currents flowing through the adjacent heating coils 11 and the magnetic fields interfere with each other.

[0148] The induction heating device 10h of the eighth embodiment can properly use depending on the case the boundary values of the areas for the determination, that is, the threshold value curved lines L1 and L2 shown in Fig. 15 depending on whether the adjacent heating coils 11 concurrently execute the detection operation for the object to be heated. With the threshold value curved lines L1 and L2, the induction heating device 10h of the eighth embodiment can accurately determine the object to be heated. For example, in the case where no detection current is supplied to the adjacent heating coils 11, when the object to be heated above the heating coils 11 is detected, a first threshold value is used and, when the detection current is concurrently supplied to the adjacent heating coils to detect the object to be heated above the heating coils 11, a second threshold value is used.

[0149] The relation between the input current I_{in} from the power source 40 and the output voltage V_c generated in the inverter 16 is used in the eighth embodiment as the value to determine the object to be heated. Another variable may, however, be used only when the object to be heated can be determined using the variable such as the operation frequency or the conduction time period of the switching element.

(Ninth Embodiment)

[0150] An induction heating device 10i of the ninth embodiment is described with reference to the drawings.

[0151] Only the parts different from the first to the eighth embodiments are described in the ninth embodiment and the same parts as those in the first to the eighth embodiments are not described again.

[0152] Fig. 16 is an explanatory diagram of a relation between the input current I_{in} from the power source 40 and the output voltage V_c generated in the inverter 16 of the induction heating device 10i of the ninth embodiment according to the present disclosure. Fig. 16 shows the relation between the input current I_{in} and the output voltage V_c for the detection unit 18 for object to be heated to detect the object to be heated in the circuit configuration shown in Fig. 4.

[0153] As to the ninth embodiment, Fig. 16 differs from Fig. 15 in that three lines are shown each representing the relation of the threshold values between the value I_{in} of the input current from the power source 40 and the value V_c of the output voltage generated in the inverter 16.

[0154] In the case where the detection operation is executed for the object to be heated, when the current is supplied to the adjacent heating coils 11, magnetic fields

are generated from the adjacent heating coils 11 and the magnetic fields interfere with the heating coils 11 which execute the detection operation for the object to be heated. A current originated from the Lenz's law is therefore supplied to the heating coils 11 that execute the detection operation for the object to be heated, and the detection operation for the object to be heated cannot accurately be executed because an error is generated in each of the value I_{in} of the input current and the value V_c of the output voltage used to determine the presence, etc., of the object to be heated.

[0155] Only for the trouble caused by the magnetic fields generated from the heating coils incorporated in the same induction heating device, the level can be measured in advance of the error generated when the current supplied to the adjacent heating coils 11 and the magnetic fields interfere with each other. Fig. 16 shows the three lines that each connect the boundary values between the "AREA 1" to determine that the object to be heated is placed and the "AREA 2" to determine that the object to be heated is not placed, from the value I_{in} of the input current and the value V_c of the output voltage generated when the inverter 16 is driven. The three lines are the solid line L1 applicable to the case where no interference of the magnetic fields is received from the adjacent heating coils 11, the dotted line L3 applicable to the case where the adjacent heating coils 11 currently execute the heating operation and receive a small amount of interference of the magnetic fields from the adjacent heating coils 11 (during the heating operation with the minimal electric power), and the dotted line L4 applicable to the case where the adjacent heating coils 11 currently execute the heating operation and receive a large amount of interference of the magnetic fields from the adjacent heating coils 11 (during the heating operation with the rated electric power).

[0156] The induction heating device 10i of the ninth embodiment can properly use depending on the case the threshold value curved lines L1, L3, and L4 each representing the boundary values to determine the "AREA 1" and the "AREA 2" depending on whether the adjacent heating coils 11 execute the heating operation or, when the adjacent heating coils 11 execute the heating operation, whether the heating uses low electric power or the heating uses high electric power. By properly using the threshold value curved lines L1, L3, and L4 depending on the case, the induction heating device 10i of the ninth embodiment can accurately determine the object to be heated. For example, the first threshold value is used when the object to be heated is detected in the case where no current is supplied to the adjacent heating coils 11. The third threshold value is used when the object to be heated is detected in the case where the adjacent heating coils 11 execute the heating operation with the minimal electric power, and the fourth threshold value is used when the object to be heated is detected in the case where the adjacent heating coils execute the heating operation with the rated electric power.

[0157] The relation between the immigration current I_{in} from the power source 40 and the output voltage V_c generated in the inverter 16 is used in the ninth embodiment as the value to determine the object to be heated while another variable may be used only when the object to be heated can be determined using the variable such as the operation frequency or the conduction time period of the switching element.

(Tenth Embodiment)

[0158] An induction heating device 10j of the tenth embodiment is described with reference to the drawings.

[0159] Only the parts different from the first to the ninth embodiments are described in the tenth embodiment and the same parts as those in the first to the ninth embodiments are not described again.

[0160] Fig. 17 is an explanatory diagram of directions of the detected currents of the heating coils 11 in the induction heating device 10j of the tenth embodiment according to the present disclosure, and shows the relation of the direction of the detection current among the surrounding heating coils 11.

[0161] The induction heating device 10j of the tenth embodiment executes the detection operation for the object to be heated by supplying the detection current to detect the presence of the object to be heated to the plurality of heating coils 11 prior to receiving the operation command signal for indicating the start of the heating operation from the operation display unit 12. The induction heating device 10j supplies a micro current to the heating coils even when no object to be heated is placed.

[0162] When the detection current is supplied to the heating coils 11 above which no object to be heated is placed, no object is present that absorbs the magnetic fields generated from the heating coils 11 and the generated magnetic fields therefore propagate around the induction heating device. The propagating magnetic fields may adversely influence another electronic device causing an electromagnetic fault, etc., to break the electronic device, or to cause difficulty in the ordinary operation (malfunctioning) and, preferably, the level of the propagating magnetic fields therefore is reduced.

[0163] As shown in Fig. 17, in the induction heating device 10j of the tenth embodiment, for example, when the four heating coils 11aa, 11ba, 11ab, and 11bb concurrently execute the detection operation for the object to be heated in the configuration shown in Fig. 1, a current I_{aa} of the heating coil 11aa flows clockwise. On the other hand, currents I_{ba} and I_{ab} of the heating coils 11ba and 11ab respectively longitudinally and laterally adjacent to the heating coil 11aa flow counterclockwise. In this manner, in the induction heating device 10j of the tenth embodiment, the directions of the current are opposite to each other (the phase difference= n) for the heating coil 11aa and the heating coils 11ba and 11ab respectively longitudinally and laterally adjacent to the heating coil 11aa.

[0164] Thereby, the directions of the magnetic fields circumferentially generated by the supply of the detection current to the heating coils 11 are opposite to each other between the heating coils longitudinally and laterally adjacent heating coils, and the magnetic fields propagating in the air therefore annihilate each other. The induction heating device 10j of the tenth embodiment can therefore reduce the level of the propagation of the magnetic fields. Any adverse influence on the peripheral electronic devices, etc., can therefore be avoided even when the detection operation is executed for the object to be heated in the case where no object to be heated is placed.

[0165] The direction of the current I_{bb} of the heating coil 11bb is set to be same (the phase difference=zero) as that of the current I_{aa} of the heating coil 11aa to set this direction to be opposite to the direction of the currents I_{ba} and I_{ab} of the adjacent heating coils 11ba and 11ab.

[0166] In the tenth embodiment, the case is described where the adjacent heating coils 11 concurrently execute the detection operation of the object to be heated. In addition, for example, when the detection operation is executed for the object to be heated with intervals each correspond to two heating coils 11 as in the second embodiment shown in Fig. 8, the directions of the detection currents supplied to the heating coils 11aa and the heating coil 11ad in the configuration shown in Fig. 1 are set to be opposite (the phase difference= n) or substantially opposite to each other. Thereby, the leakage magnetic fields caused by the detection operation for the object to be heated can be reduced especially when no object to be heated is placed.

[0167] The heating coils 11 in each longitudinal line (column) and each lateral line (row) are disposed along a straight line as shown in Fig. 1 in each of the induction heating devices 10 of all the embodiments. The configuration is not limited to the above because the effect of the induction heating apparatus 10 according to the present disclosure can be achieved only when the heating coils 11 are arranged in lines.

[0168] As above, in the embodiments according to the present disclosure, the state of the placement of the object to be heated can be determined and can highly precisely be detected by properly executing the detection operation for the object to be heated using the plurality of heating coils.

Industrial Applicability

[0169] As above, the induction heating device according to the present disclosure can determine the presence or the placement state of the object to be heated by supplying the detection current to detect the presence of the object to be heated to the heating coils by the operation of the inverter prior to the start of heating the object to be heated. The object to be heated can therefore be detected without adding any new component only to detect the object to be heated, and the induction heating device is effective for the use of an induction heating cooking

device.

Reference Signs List

[0170]

10	induction heating device
11	heating coil
12	operation display unit
13	top plate
14	first object to be heated
15	second object to be heated
16	inverter
17	control unit
18	detection unit for object to be heated
40	power source
41	diode bridge
42	choke coil
43	smoothing capacitor
44	first switching element
45	second switching element
46	resonance capacitor
47	snubber capacitor
48	current detecting unit
49	voltage detecting unit

Claims

1. An induction heating device comprising:

a top plate on which an object to be heated is placed;
 a plurality of heating coils which are disposed below the top plate;
 an inverter which supplies a high frequency current to the plurality of heating coils;
 a control unit which controls an output of the inverter;
 an operation display unit which outputs an operation command to the control unit; and
 a detection unit for the object to be heated which detects whether the object to be heated is present on the top plate,
 wherein the control unit controls the inverter to supply a detection current for detecting presence of the object to be heated to the plurality of heating coils prior to receiving an operation command signal for indicating a start of a heating operation from the operation display unit, and
 wherein the detection unit for the object to be heated detects the presence of the object to be heated from an input current and/or an output voltage in an electrically conductive path for electric power transmission from a power source to the heating coils, during a detection time period which the detection current is supplied to

the heating coils.

2. The induction heating device of claim 1, wherein the control unit controls the inverter so as to sequentially supply the detection current to the plurality of heating coils and so as not to concurrently supply the detection current to heating coils adjacent to the plurality of heating coils to which the detection current is supplied.
3. The induction heating device of claim 1 or 2, wherein a current value of the detection current supplied to the heating coils is smaller than a current value of a heating current supplied to the heating coils to execute a heating operation for the object to be heated.
4. The induction heating device of any one of claims 1 to 3, wherein the control unit controls the inverter so as not to supply the detection current to heating coils adjacent to heating coils which execute a heating operation.
5. The induction heating device of any one of claims 1 to 4, wherein the control unit controls the inverter such that the detection current is also supplied to the heating coils that the object to be heated is detected after the detection unit for the object to be heated detects the object to be heated, and the control unit continues the detection operation using the detection unit for the object to be heated.
6. The induction heating device of any one of claims 1 to 5, wherein the plurality of heating coils include heating coil groups each including at least two of the heating coils, and wherein the control unit controls the inverter so as to concurrently supply the detection current to all the heating coils in the heating coil group.
7. The induction heating device of any one of claims 1 to 6, wherein the control unit controls the inverter so as to continuously supply the detection current to the heating coils that the object to be heated is detected after the detection unit for the object to be heated detects the object to be heated until the detection unit for the object to be heated does not detect the object to be heated.
8. The induction heating device of any one of claims 1 to 7, wherein the control unit controls the inverter such that number of sessions to supply the detection current to the heating coils which are detecting the object to be heated is set to be small compared to that of the heating coils which are not detecting the object to be

heated, after the detection unit for the object to be heated detects the object to be heated until the detection unit for the object to be heated does not detect the object to be heated.

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9. The induction heating device of any one of claims 1, 3, and 5 to 8, wherein the detection unit for the object to be heated sets a first threshold value used in detecting the presence of the object to be heated when no current is supplied to adjacent heating coils and a second threshold value used in detecting the presence of the object to be heated by concurrently supplying a current to the adjacent heating coils, and the detection unit for the object to be heated detects the presence of the object to be heated using the first threshold value or the second threshold value. 10 15
10. The induction heating device of any one of claims 1, 3, and 5 to 9, wherein the detection unit for the object to be heated sets the first threshold value used in detecting the presence of the object to be heated when no current is supplied to adjacent heating coils, a third threshold value used in detecting the presence of the object to be heated when the adjacent heating coils execute the heating operation with minimal electric power, and a fourth threshold value used in detecting the presence of the object to be heated when the adjacent heating coils execute the heating operation with rated electric power, and the detection unit for the object to be heated detects the presence of the object to be heated using any one of the first threshold value, the third threshold value, and the fourth threshold value. 20 25 30 35
11. The induction heating device of any one of claims 1, and 5 to 10, wherein the control unit controls the inverter such that the detection current supplied to each of the heating coils has a direction that is opposite to each other among the heating coils longitudinally and laterally adjacent to each other. 40 45 50 55

Fig. 1

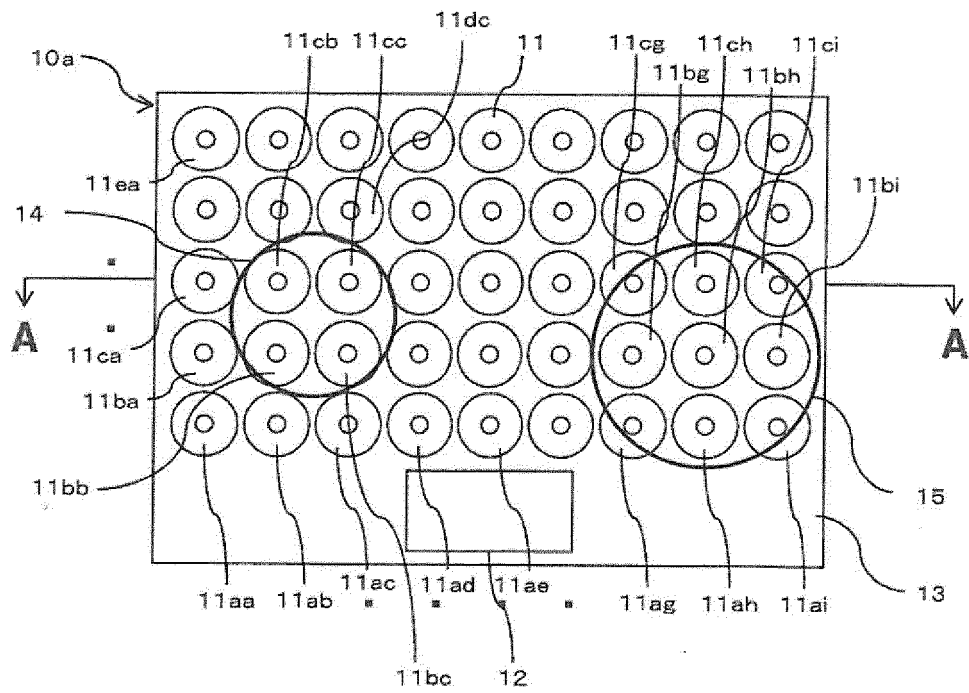


Fig. 2

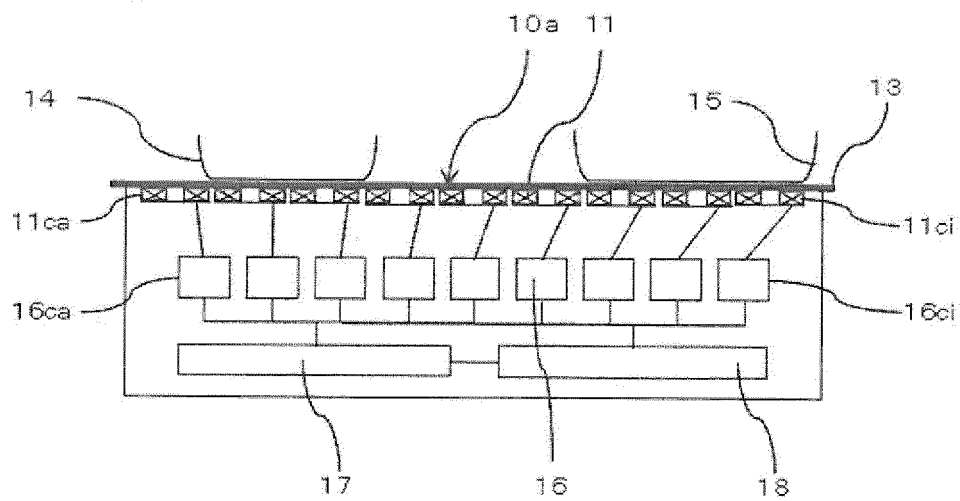


Fig.3

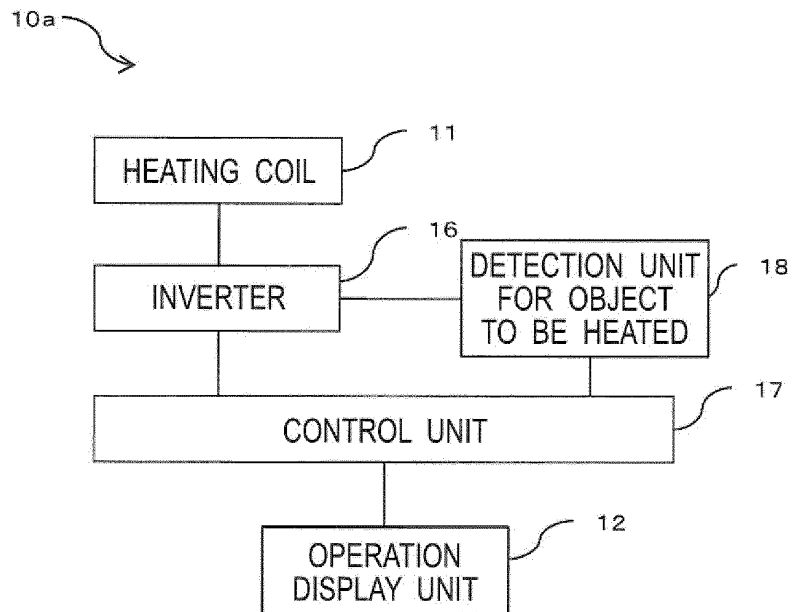


Fig.4

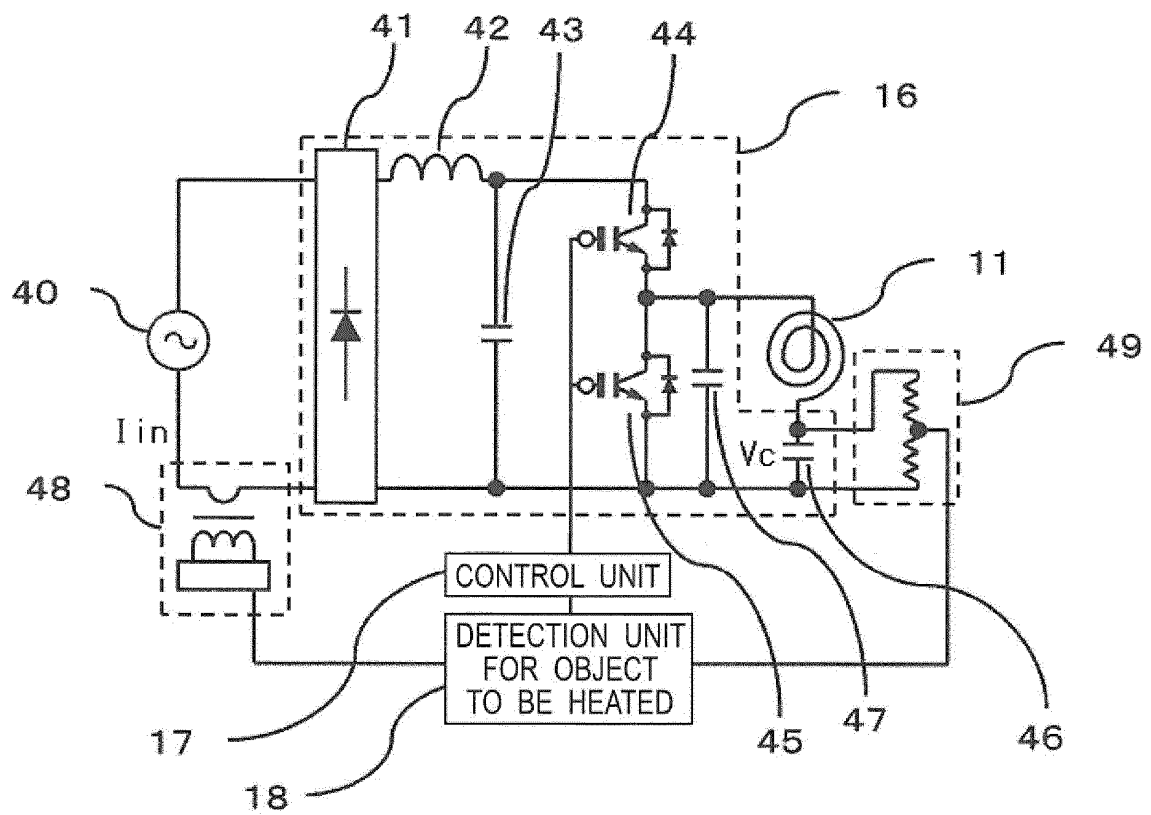


Fig.5

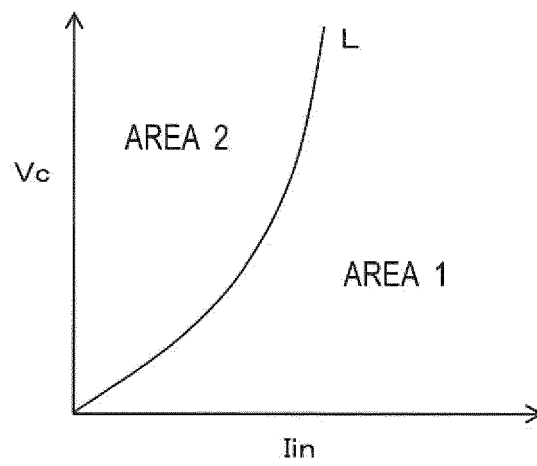


Fig. 6

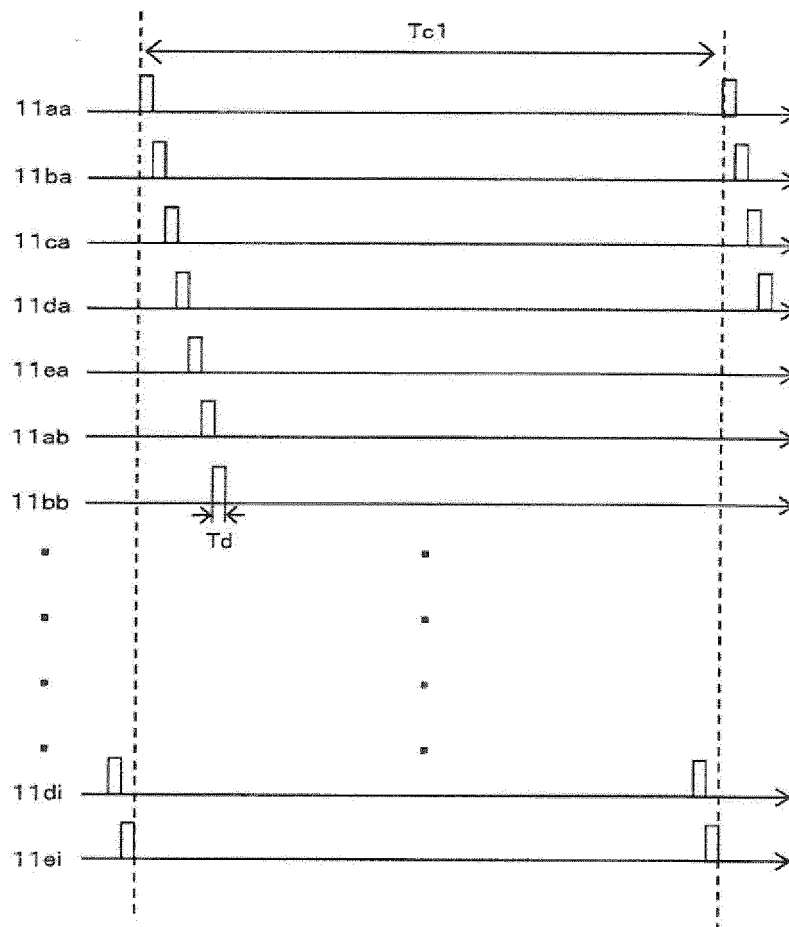


Fig. 7

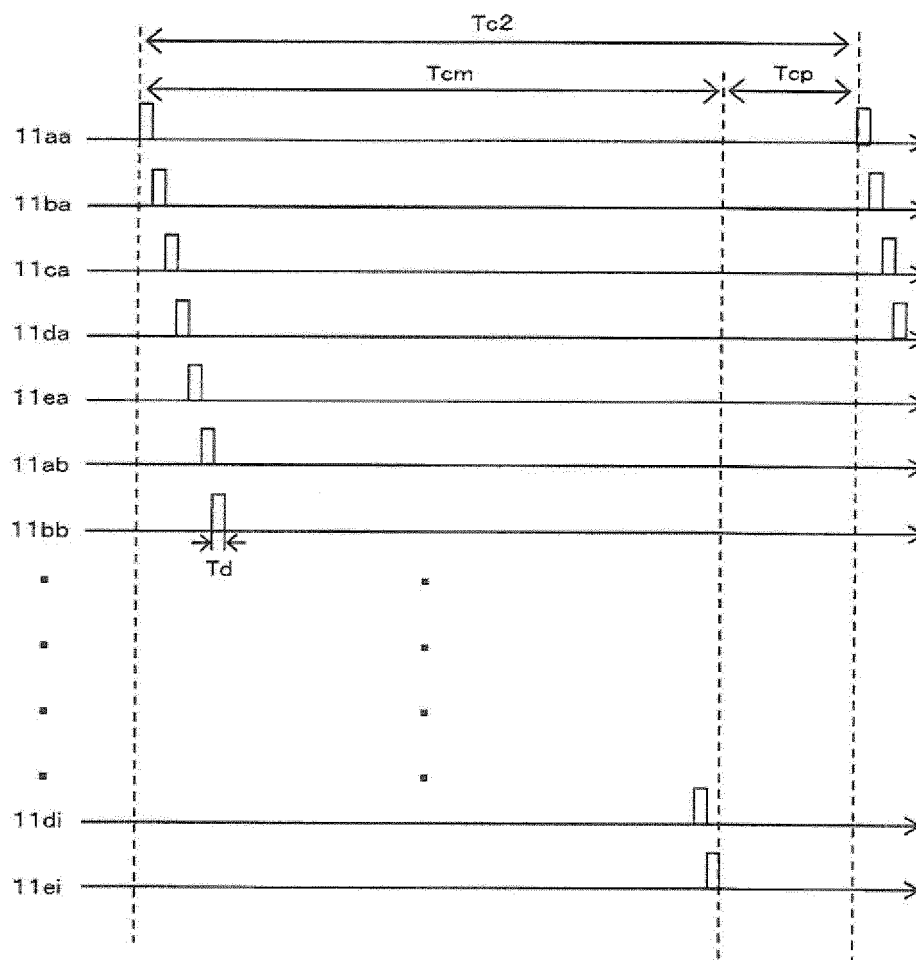


Fig.8

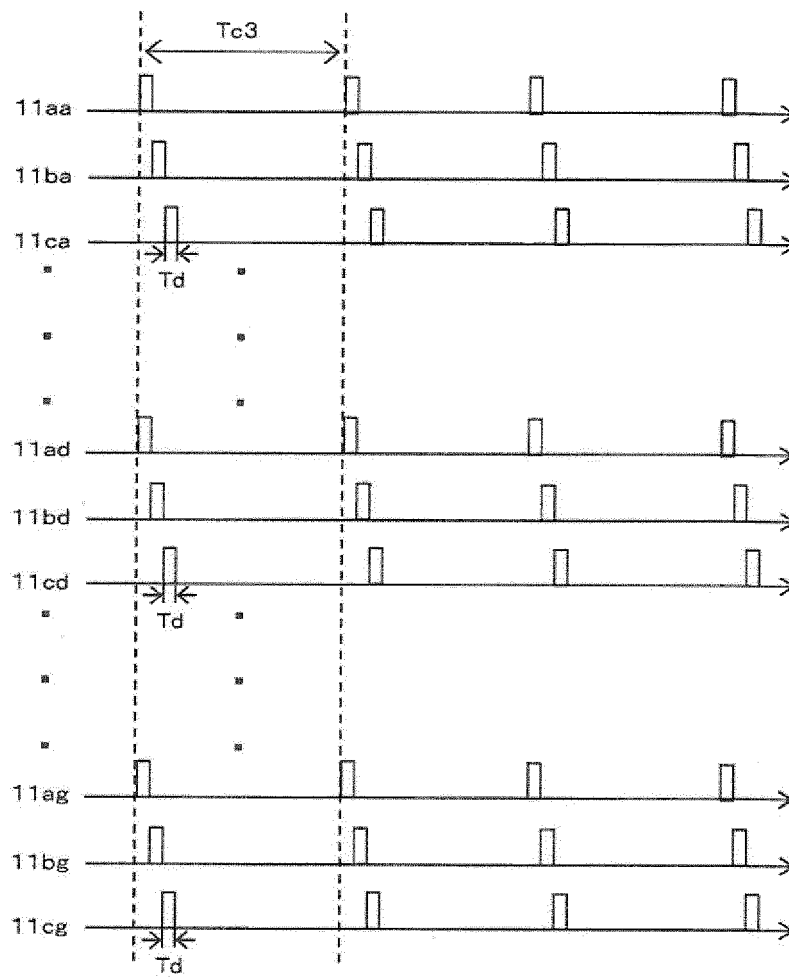


Fig.9

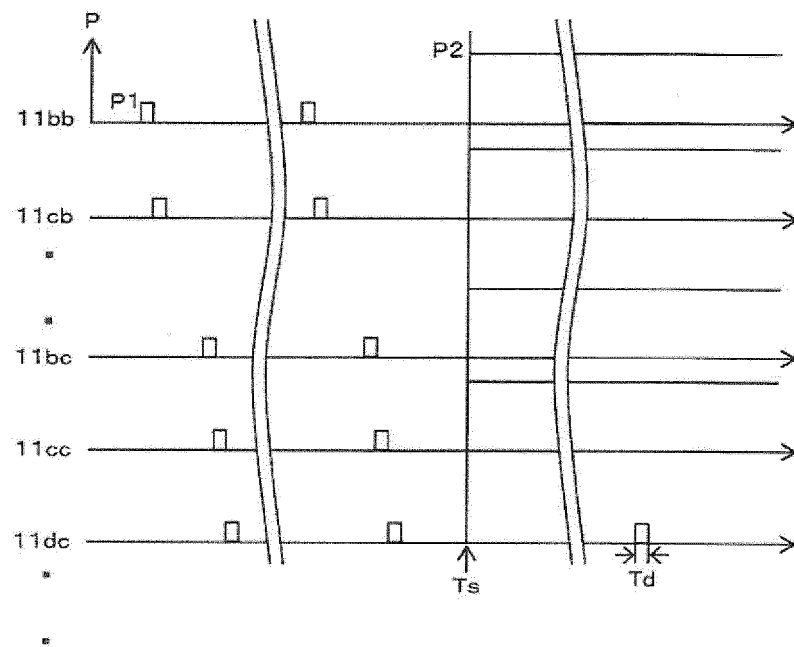


Fig. 10

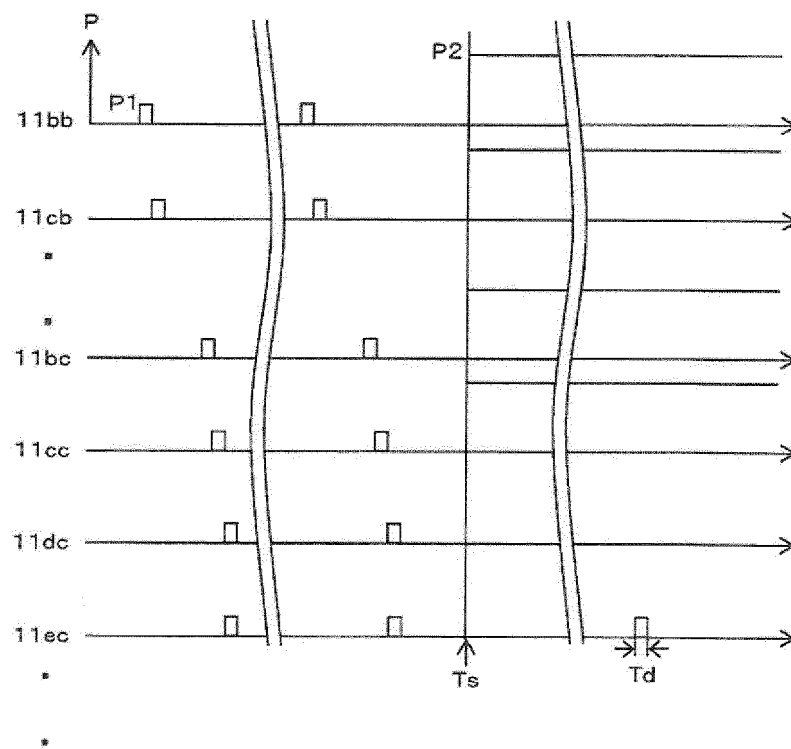


Fig. 11

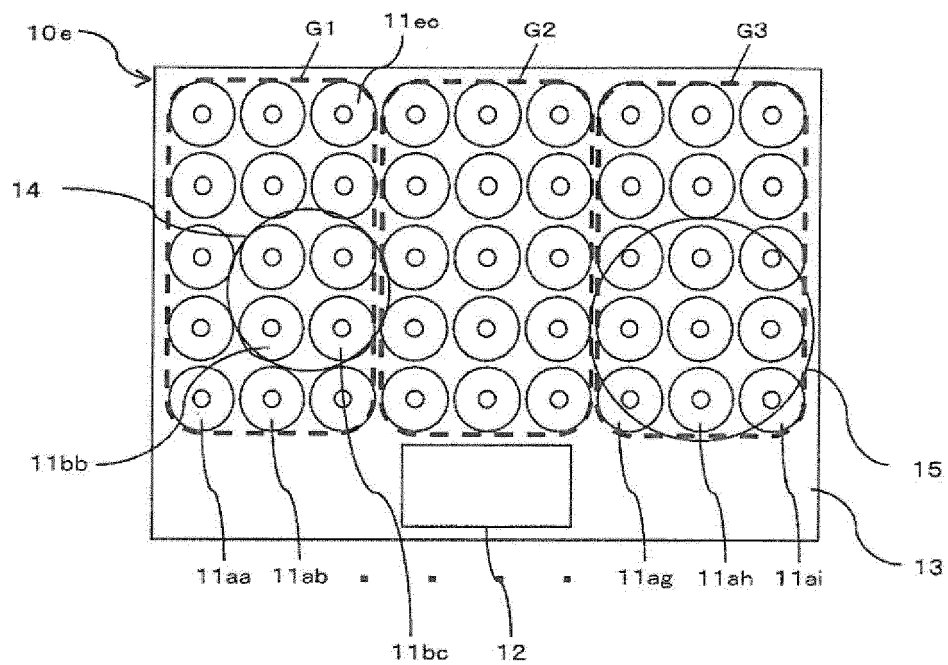


Fig. 12

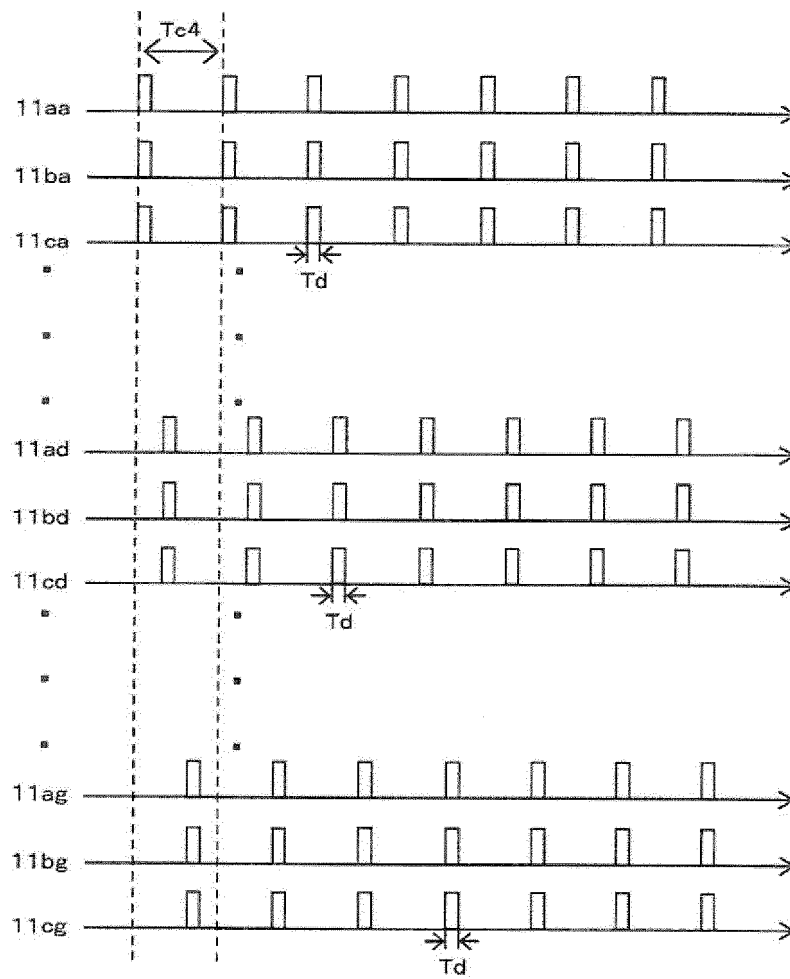


Fig.13

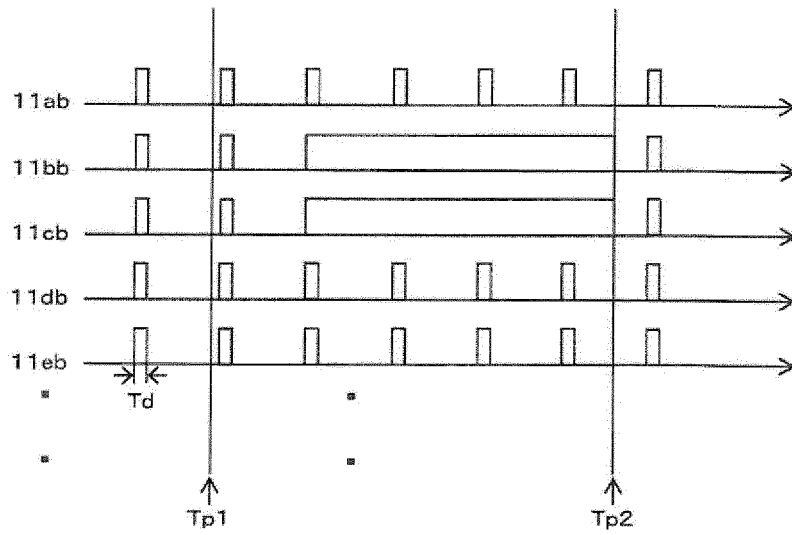


Fig.14

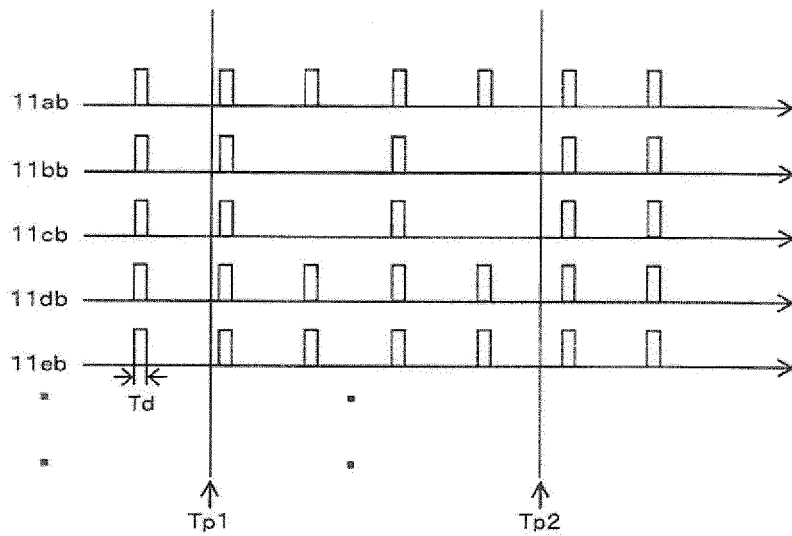


Fig.15

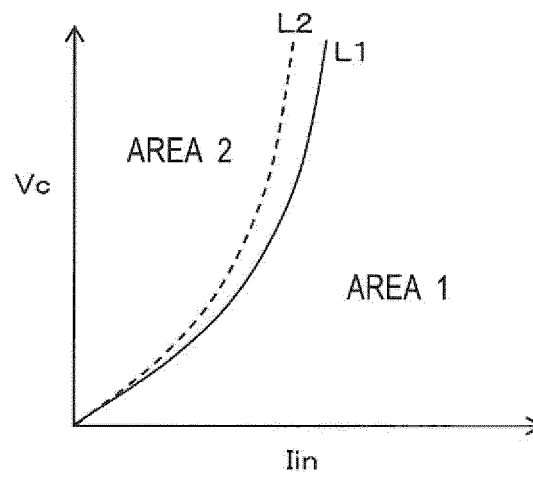


Fig.16

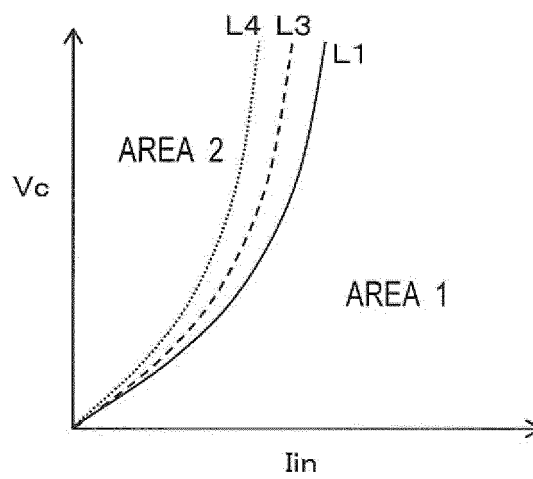
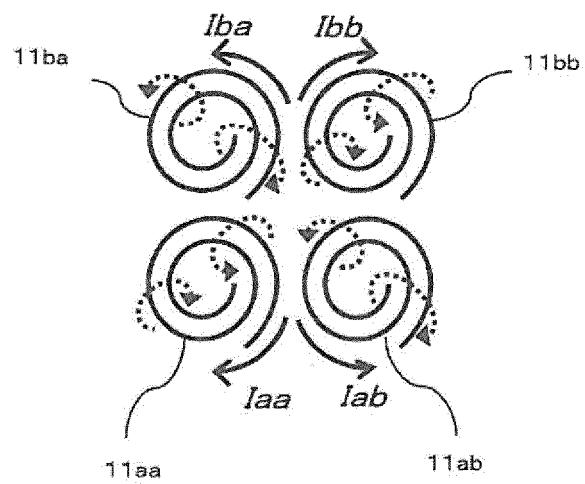


Fig.17



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/006264

A. CLASSIFICATION OF SUBJECT MATTER

H05B6/12 (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)

H05B6/12

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.
X	JP 2008-293871 A (Mitsubishi Electric Corp.),	1-6
Y	04 December 2008 (04.12.2008),	11
A	paragraphs [0041] to [0050] (Family: none)	7-10
Y	JP 2010-153060 A (Panasonic Corp.),	11
	08 July 2010 (08.07.2010),	
	fig. 16(B)	
	(Family: none)	
A	WO 2012/114405 A1 (Mitsubishi Electric Corp.),	1-11
	30 August 2012 (30.08.2012),	
	fig. 1	
	(Family: none)	

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

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Date of the actual completion of the international search
03 December, 2013 (03.12.13)Date of mailing of the international search report
10 December, 2013 (10.12.13)Name and mailing address of the ISA/
Japanese Patent Office

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/006264

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-27728 A (Matsushita Electric Industrial Co., Ltd.), 07 February 2008 (07.02.2008), paragraph [0018] (Family: none)	1-11
A	JP 2012-84286 A (Mitsubishi Electric Corp.), 26 April 2012 (26.04.2012), paragraphs [0014], [0015] (Family: none)	1-11

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

REFERENCES CITED IN THE DESCRIPTION

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- EP 1206164 B1 [0006]