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(54) INDUCTION COOKING HOB AND METHOD OF OPERATING AN INDUCTION COOKING HOB

(57) Induction cooking hob (1) for the thermal treatment of foodstuff (5) containing liquid; the induction cooking hob (1) comprising: at least one heating zone (3) configured to receive cookware (4) containing the foodstuff (5) to be thermally treated and including an induction coil (9) and a power converter (10) configured to supply electric power to the induction coil (9), in order to generate a time-varying electric field adapted to heat the cookware (4); a sensor assembly (14) configured to provide electric signals related to at least one physical quantity associated with the thermal treatment of the foodstuff (5); and a control unit (6) which is operatively connected to the power converter (10) and to the sensor assembly (14) and is configured to determine, based on the electric signals provided by the sensor assembly (14), when a dry cookware condition occurs due to liquid evaporation during thermal treatment of the foodstuff (5).

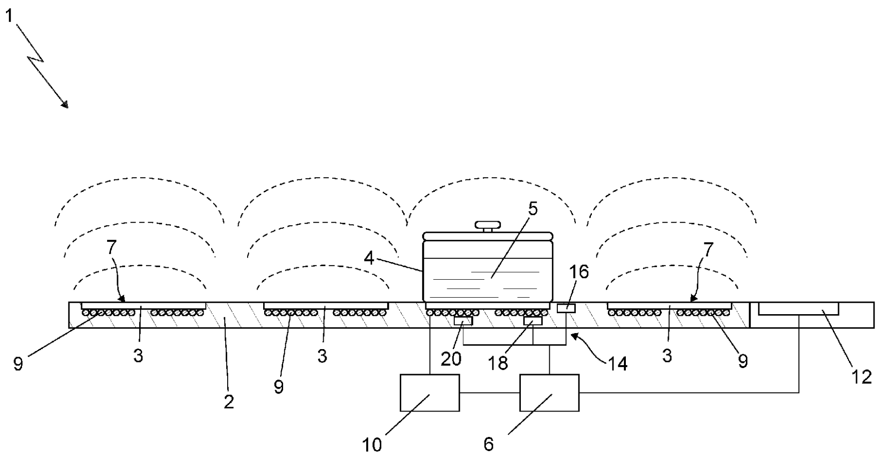

Fig. 1

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Description

Technical field

[0001] The present invention relates to an induction cooking hob for the thermal treatment of foodstuff.

[0002] Advantageously, the present invention also relates to a method of operating an induction cooking hob for the thermal treatment of foodstuff.

Background art

[0003] Induction cooking hob for the thermal treatment of foodstuff are well known in the art.

[0004] Induction cooking hobs typically comprise one or more heating zones, each heating zone being configured to receive cookware containing the foodstuff to be thermally treated.

[0005] In particular, for each heating zone, a such induction cooking hob comprises at least one induction coil and one electric power converter, in particular an inverter, configured for driving an alternating current through the induction coil, to generate a time-varying magnetic field.

[0006] Due to the inductive coupling between the induction coils and the cookware arranged on the heating zone, the magnetic field generated by the induction coil causes eddy currents circulating in the same cookware, which in turn generate heat within the cookware and the foodstuff contained therein.

[0007] Such an induction cooking hob may also comprise a control unit configured to control the one or more heating zones, in particular the respective power converter, so as to selectively control the heating power provided to the cookware arranged on the respective heating zone.

[0008] In addition, such an induction cooking hob may further comprise an acceleration sensor configured to provide electrical signals indicative of the vibration of the cookware on the respective heating zone and/or a temperature sensor configured to provide electrical signals indicative of the temperature of the induction coil of the respective heating zone.

[0009] The control unit, in turn, is configured to retrieve the electrical signals provided by the acceleration sensor and/or by the temperature sensor, and is configured to elaborate such electrical signals to implement assistance cooking functions.

[0010] For instance, some known assistance cooking functions may comprise informing the users when the foodstuff, in particular water, present within the cookware starts boiling.

[0011] Unfortunately, to operate properly, such assistance cooking functions requires stable operating conditions of the foodstuff within the cookware.

[0012] However, the heat provided by the heating zones may cause the evaporation of liquids from the foodstuff contained within the cookware, and this may result in an excessive amount of heat provided by the heating zone to the cookware, potentially causing burning of the foodstuff and damages to the cookware.

[0013] Therefore, even though the known induction cooking hobs work satisfyingly well, a need is felt in the sector to improve the induction cooking hobs, in particular so as to further improve the assistance cooking functions provided to the users and avoid burning of the foodstuff or damaging the cookware due to evaporation of liquids.

[0014] Aim of the present invention is to provide an induction cooking hob and a method of operating an induction cooking hob able to satisfy the above-mentioned needs.

Summary of the invention

[0015] According to the present invention, there is provided an induction cooking hob and a method of operating an induction cooking hob according to the respective independent claims.

[0016] Preferred non-limiting embodiments are claimed in the claims directly or indirectly depending on the independent claims.

[0017] In addition, according to the present invention, there is provided an induction cooking hob for the thermal treatment of foodstuff containing liquid, the cooking hob comprising:

- at least one heating zone configured to receive cookware containing the foodstuff to be thermally treated and including an induction coil and a power converter configured to provide electric power to said induction coil, in order to generate a time-varying magnetic field adapted to heat said cookware;

- a sensor assembly configured to provide electric signals indicative of at least one physical quantity associated with thermal treatment of said foodstuff; and

- a control unit which is operatively connected to said power converter and to said sensor assembly and comprises elaboration means configured to determine, based on the electric signals provided by said sensor assembly, when during thermal treatment of said foodstuff a dry cookware condition occurs due to evaporation of the liquid initially present within said cookware.

[0018] The present invention further relates to a method for operating the induction cooking hob comprising the following steps:

a) controlling said power converter to provide electric power to said induction coil, in order to generate the time-varying magnetic field adapted to heat said cookware;

b) measuring by means of said sensor assembly at least one physical quantity associated with the thermal treatment of said foodstuff; and

c) determining, based on the electrical signals provided by said sensor assembly, when a dry cookware condition occurs due to evaporation of the liquid from said cookware during thermal treatment of said foodstuff.

[0019] In this way, one achieves an improved and safer user experience of the induction cooking hob. In fact, when placing a cookware filled with a foodstuff containing liquid, in particular water, on the induction cooking hob and supplying heating power via the respective heating zone, the liquid contained in the cookware may start boiling and thereby quickly evaporate. Once the liquid has evaporated and such dry cookware condition occurs, temperature in the cookware may rise quickly, potentially causing damage to the same cookware and/or burning the dried foodstuff remaining within the cookware.

[0020] By measuring at least one physical quantity related to thermal treatment of the foodstuff contained in the cookware, which at least one physical quantity is sensitive to the amount of liquid present in the foodstuff contained in the cookware, it may be determined, based on an analysis of the determined at least one physical quantity, how much liquid or if any liquid at all is still present in the cookware. Accordingly, the thermal treatment of the cookware and the foodstuff contained therein, and in particular the supply of heating power, may be controlled to avoid causing damages to the same cookware and/or burning the dried foodstuff left within the cookware.

[0021] Alternatively or in addition, the control unit may be configured to control said heating zone in order to reduce the heating power supplied to said cookware when said dry cookware condition occurs.

[0022] In particular, the control unit may be configured to switch off said heating zone when said dry cookware condition occurs.

[0023] In this way, one avoids damaging the same cookware and/or avoids burning the foodstuff remaining on the cookware after all or at least a sufficiently large amount of the liquid is evaporated from the same cookware, as the control unit is able to automatically reduce and/or stop the supply of heating power to the cookware as soon as the liquid initially present within the cookware is evaporated.

[0024] Preferably though not necessarily, the induction cooking hob further comprises a user interface, which is operatively connected to said control unit and comprises a communication unit configured to communicate with a user; said control unit is configured to control operation said user interface in order to provide signals adapted to inform said user when said dry cookware condition occurs.

[0025] In this way, one achieves an improved user experience of the induction cooking hob, as the user can be promptly alerted as soon as all or at least a sufficiently large amount of the liquid initially present within the cookware is evaporated, and allows the user to take actions in order to avoid burning the remaining foodstuff within the cookware and/or damaging the same cookware, for instance by reducing the heating power provided by the corresponding heating zone and/or switching off the same heating zone. Said signal may comprise for instance a warning light, a flashing light and/or an acoustic alarm.

[0026] Preferably, but not necessarily, the sensor assembly comprises an acceleration sensor, in particular a microelectromechanical system (MEMS) acceleration sensor, configured to provide to said control unit an electrical acceleration signal related to the vibration of said foodstuff within said cookware.

[0027] Preferably, but not necessarily, said control unit is configured to determine, based on the electrical acceleration signals provided said acceleration sensor, if the vibrations of said cookware on the induction heating hob decreases below a predetermined threshold and/or if the amount of liquid present within said cookware drops below a predetermined quantity.

[0028] The magnitude of vibrations of the cookware may depend on the amount of liquid present within the same cookware and on a strength of boiling of the liquid in the cookware. Compared to a cookware fully filled with boiling liquid and assuming a same strength of boiling, a cookware filled with a small amount of boiling liquid will typically vibrate in a weaker fashion. By measuring vibrations of the cookware on the induction cooking hob, it may be determined how much liquid is present in the cookware or if any liquid is present at all.

[0029] Preferably, but not necessarily, said control unit is configured to retrieve from said acceleration sensor a set of time-dependent data indicative of the variation of the vibration of said cookware on said induction cooking hob during the thermal treatment of said foodstuff.

[0030] Besides carrying out a single vibration measurement at one point in time, a time series of vibration measurements at in particular equidistant points in time may be determined. The time series of vibration measurements may be obtained using measurements carried out at a fixed location of the induction cooking hob. If measurements are carried out at different points in time and at a plurality of different locations on the induction cooking hob, a multivariate time series of vibration measurements may be obtained. To determine if liquid is still present within the cookware, the measured time series of vibrations may be analyzed, in particular using sliding window techniques. If it is determined, for example, that vibration strength in a current sliding window is much smaller than in a previous sliding window, it may be determined how much liquid has evaporated in the meantime.

[0031] Preferably, but not necessarily, said control unit is configured to determine, based on the electrical acceleration signals provided by said acceleration sensor the amount of liquid contained present within said cookware.

[0032] A current amount of liquid present within the cookware may be obtained by comparing a vibration measurement to a set of pre-calibrated vibration measurements carried out with cookware with different amounts of liquid, essentially performing a type of nearest-neighbor classification to determine the amount of liquid currently in the cookware. Alternatively, using a physical model relating vibration strength to the amount of liquid in a cookware and a placement of the cookware with respect to an induction coil of the induction cooking hob, for example, the amount of liquid may be determined if other parameters of such a physical model are known or can be reliably estimated.

[0033] Preferably, but not necessarily, said sensor assembly comprises a temperature sensor configured to provide to said control unit an electrical temperature signal related to the temperature of said induction coil and/or about a portion of said induction cooking hob adjacent to said induction coil.

[0034] Preferably, but not necessarily, said control unit is configured to determine/estimate the temperature of said cookware based on the electrical temperature signal received from said temperature sensor.

[0035] The physical quantity measured by the sensor assembly may be related to a temperature of the cookware. In general, in case the induction cooking hob keeps providing a steady amount of heating power to the cookware, a temperature of the cookware may start to increase rapidly once liquid in the cookware has evaporated. Temperature of the cookware may be indirectly determined, e.g., by measuring temperature of the induction coil (at one place along the induction coil or at a plurality of different places) of the induction cooking hob and by algorithmically linking the measured temperature of the induction coil to the temperature of the cookware. By determining a point in time at which the algorithmically determined temperature of the cookware starts to rise rapidly, it may be determined if liquid in the cookware has evaporated.

[0036] Preferably, but not necessarily, said control unit is configured to determine/estimate when the temperature of said cookware exceeds a predetermined threshold during the thermal treatment of said foodstuff and said dry cookware condition occurs.

[0037] Accordingly, one is able to detect when the cookware becomes dry due to evaporation of liquid during thermal treatment of foodstuff. Indeed, when there is no more liquid absorbing the heating power provided by heating zone, all the heating power is absorbed by cookware and its temperature, as the temperature of the induction coil, may increase abruptly.

[0038] Measurements obtained using the at least one MEMS acceleration sensor for determining vibrations of the cookware may be combined with measurements obtained using the at least one temperature sensor to improve detection of fully evaporated liquid in the cookware. Specifically, in a first step the amount of liquid present in the cookware may be determined in a time-resolved manner based on the vibration signals obtained using the at least one MEMS acceleration sensor. Once the determined amount of liquid in the cookware drops below a pre-defined threshold, the more accurate coil temperature measurements may be used to determine the exact time point at which all liquid in the cookware has evaporated. Subsequently, heating power supplied by the induction cooking hob to the cookware may be stopped or reduced to avoid burning food in the cookware and/or damaging the cookware.

[0039] Preferably, but not necessarily, said control unit is configured to determine when dry cookware condition occurs on the basis of the variation rate of the temperature of said induction coil, in particular when the variation rate of the temperature of said induction coil exceeds a predetermined value.

[0040] The slope of temperature measurements of the induction coil may encode information on changes in temperature of the cookware on the induction cooking hob. The determined slope of the induction coil temperature measurements may in particular be algorithmically converted into a slope of the temperatures of the cookware. Using for example sliding window techniques, once a large increase in the slope of the temperature of the cookware is determined, it may be determined that the liquid in the cookware vessel is evaporated.

[0041] Preferably, but not necessarily, said sensor assembly comprises a current sensor configured to provide to said control unit an electrical current signal related to the current flowing through said induction coil.

[0042] Preferably, but not necessarily said control unit is configured to determine, based on the electrical current signal provided by said current sensor, when dry cookware condition occurs due to evaporation of liquid from said cookware during thermal treatment of said foodstuff.

[0043] As the amount of current flowing through the induction coil depends on the cookware that forms a load for the induction cooking hob, the current flowing through the induction coil encodes information on the cookware and the amount of liquid in the cookware. After (algorithmically) compensating for influences on the coil current caused by switching frequencies of inverters in the induction cooking hob and by a supplied power to the inverters, for example, determined changes in the coil current encode information on changes of the amount of liquid in the cookware which has evaporated. Once a sufficiently large change (e.g., by comparing to a pre-calibrated threshold) in the coil current is detected, the induction cooking hob may stop/reduce the supply of heating power to the cookware to avoid burning food in the cookware and/or damage the cookware.

Brief description of the drawings

[0044] A non-limiting embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

- Figure 1 illustrates schematically an induction cooking hob according to the present invention, with parts removed for clarity;

- Figure 2 is a diagram of a vibration of a cookware arranged on the induction cooking hob of Figure 1;

- Figure 3 is a diagram of a current flowing through a component of the induction cooking hob of Figure 1; and

Detailed description of the invention

[0045] With particular reference to Figure 1, number 1 indicates as a whole an induction cooking hob for the thermal treatment, in particular for heating and/or cooking, of foodstuff.

[0046] The foodstuff to be thermally treated preferentially is or at least comprises a liquid, in particular water.

[0047] It should also be noted that the foodstuff to be treated may vary throughout the overall thermal treatment process; i.e. it may be possible to add or remove ingredients to the foodstuff during the thermal treatment. In addition or alternatively, it may also possible that a portion or the entirety of the foodstuff may disappear during the thermal treatment process, e.g. by means of evaporation due to the heat provided by the induction cooking hob 1. According to the preferred embodiment illustrated in Figure 1, induction cooking hob 1 comprises a hob plate 2 and one or more heating zone 3, which are defined by portions of the hob plate 2, are adapted to receive cookware 4 containing the foodstuff 5 to be thermally treated, and are configured to provide heating power to heat the respective cookware 4 and/or the foodstuff 5 present within the respective cookware 4.

[0048] In addition, induction cooking hob 1 comprises a control unit 6 configured to control, in particular to selectively control, operation of each heating zone 3.

[0049] Cookware 4 may be of any kind. Cookware 4 could be a pot, a kettle, a baking tray, a pan, a plate, a bowl, ovenware, aluminum foil or the like. Cookware 4 could or could not comprise a respective lid.

[0050] In the specific case shown, induction cooking hob 1 comprises a plurality of heating zones 3, in particular four. Induction cooking hob 1 could, however, comprise only one heating zone 3, two, three, four or even more heating zones 3.

[0051] According to some possible embodiments, heating zones 3 may be static (i.e. their relative positions are fixed) or heating zones 3 may be dynamic (i.e. each heating zone 3 may be defined in dependence on the respective position on which the respective cookware 4 may be placed).

[0052] According to the embodiment of Figure 1, each heating zone 3 could comprise a respective support surface 7 configured to carry the respective cookware 4.

[0053] Preferentially, each support surface 7 may be defined by a respective portion of hob plate 2.

[0054] According to some preferred non-limiting embodiments, each heating zone 3 may comprise one or more respective induction coils 9 configured to generate an electromagnetic field for interacting with the respective cookware 4.

[0055] Preferentially, each induction coil 9 is selectively operable to be fed with alternating current, in order to generate a time-varying magnetic field adapted to induce eddy currents in the cookware 4 arranged on the respective heating zone 3 and cause the same cookware 4 to heat up.

[0056] In addition, induction cooking hob 1 preferably comprises power converters 10, in particular inverters 10, which are electrically connected to a correspondent induction coil 9 and are configured to supply alternating current to the same induction coils 9, so as to generate the time-varying magnetic field.

[0057] Preferentially, power converter 10, in particular inverter 10, comprises a switching module adapted to generate the alternating current to be fed to induction coil 9 from an alternating voltage. In particular, the switching module is able to regulate its actuation frequency to control the frequency of the alternating current to be fed towards induction coil 9.

[0058] According to some possible non-limiting embodiments, control unit 6 may be configured to control, in particular to selectively control, operation of each heating zone 3 in order to command the same heating zone 3 at least between an activated configuration in which the heating zone 3 is switched on, and a deactivated configuration in which the heating zone 3 is switched off. In other words, the heating zone 3 may be configured to heat the respective cookware and/or foodstuff 5 when being in the activated configuration, and to not generate heat when being in the deactivated configuration.

[0059] In addition, control unit 6 may be configured to control, in particular selectively control, operation of each heating zone 3 in order to regulate the heating power provided by the same heating zone 3 to the respective cookware 4 and/or foodstuff 5 when being in the activated configuration.

[0060] More in detail, control unit 6 may be configured to control power converters 10 to supply alternating current to induction coils 9 when the corresponding heating zones 3 are controlled in the activated configuration.

[0061] Preferentially, control unit 6 may be further configured to control each power converter 10, in particular its switching module, in order to regulate the frequency and/or the magnitude of the alternating current flowing through the respective induction coils 9, in such a way to regulate the electric power that these latter provide to the cookware 4 arranged on the respective heating zone 3.

[0062] In addition, control unit 6 may be configured to control power converters 10 to stop the supply of alternating current to the induction coils 9 when the corresponding heating zones 3 are controlled in the deactivated configuration.

[0063] According to the preferred non-limiting embodiment shown in Figure 1, induction cooking hob 1 may also comprise a user interface 12 configured to allow a user to instruct and/or control and/or communicate with induction cooking hob 1.

[0064] More in detail, user interface 12 may be configured to allow the user to input commands adapted to set the heating power of the respective heating zones 3 and/or to select a cooking program among a plurality of pre-established cooking programs.

[0065] Control unit 6 may be operatively connected to user interface 12 and may be configured to control the respective heating zones 3 according to the commands imparted by the user via the user interface 12.

[0066] More in detail, user interface 12 may be configured to allow for commanding, in particular selectively commanding, to switch on and to switch off heating zones 3; i.e. user interface 12 may be configured to allow to (selectively) command to control each heating zone 3 into the respective activated or deactivated configuration.

[0067] In addition, user interface 12 may be configured to allow for controlling each power converter 10, so as to regulate the frequency and/or the magnitude of the alternating current flowing through induction coils 9 of each heating zone 3, and set the electric power provided by the induction coils 9 to the cookware 4 arranged on the respective heating zone 3.

[0068] According to some embodiments, it may also be possible that user interface 12 is configured for allowing to switch off induction cooking hob 1 as a whole.

[0069] In addition or alternatively, user interface 12 may comprise a remote control device, such as a smartphone, tablet or the like, and/or a unit configured to communicate with the remote control device.

[0070] In addition or alternatively, induction cooking hob 1, in particular user interface 12, may also comprise a communication unit configured to interact and/or communicate with a user. In particular, communication unit may be configured to communicate with the user by means of visual signals and/or audio signals.

[0071] According to some possible embodiments, communication unit may be configured to receive audio commands from the user and/or to output audio signals to the user.

[0072] Alternatively or in addition, communication unit may be configured to visually indicate information and/or requests to the user.

[0073] According to the preferred non-limiting embodiment shown in Figure 1, induction cooking hob 1 may further comprise a sensor assembly 14, which is operatively connected to control unit 6.

[0074] In particular, sensor assembly 14 is configured to provide to control unit 6 electrical signals indicative of at least one measured/sensed physical quantity associated with the thermal treatment of cookware 4 and/or of foodstuff 5 present therein.

[0075] Preferentially, sensor assembly 14 may comprise at least one acceleration sensor/transducer 16, in particular a microelectromechanical system (MEMS) acceleration sensor 16, which is configured to provide to control unit 5 electrical acceleration signal related to the vibration of cookware 4 on induction cooking hob 1, in particular on hob plate 2, during the thermal treatment of foodstuff 5.

[0076] More in detail, acceleration sensor 16 may be configured to measure/sense the vibration of cookware 4 on the induction cooking hob 1, in particular on hob plate 2, due to boiling of foodstuff 5 within same cookware 4, in particular to the boiling of liquid contained in foodstuff 5.

[0077] According to the preferred non-limiting embodiment illustrated in Figure 1, acceleration sensor 16 is preferably carried by hob plate 2 and is arranged adjacent to a respective heating zone 3 and/or induction coil 9.

[0078] According to some possible embodiments, sensor assembly 14 may comprise a plurality of acceleration sensors 16, each arranged adjacent a corresponding heating zone 3 and adapted to sense/ measure the vibrations of cookware 4 on the respective heating zone 3.

[0079] In addition, sensor assembly 14 may comprise a plurality of acceleration sensors 16 for each heating zone 3.

[0080] In alternative, sensor assembly 14 may comprise only one acceleration sensor 16 arranged in order to be able to sense/measure the vibrations exerted by the cookware 4 on all the heating zones 3 present in the cooking hob 1.

[0081] According to the preferred non-limiting embodiment illustrated in Figure 1, sensor assembly 14 may comprise at least one temperature sensor 18, in particular a coil temperature sensor 18, which is configured to provide an electrical temperature signal indicative of the temperature at a respective induction coil 9.

[0082] More in detail, temperature sensor 18 may be configured to measure/sense the temperature of a respective induction coil 9 and/or a temperature of a portion of the hob plate 2, in particular of heating zone 3, adjacent to the respective induction coil 9.

[0083] Preferably, sensor assembly 14 comprises a plurality of temperature sensors 18, each configured to provide an electric signal indicative of the temperature of a respective induction coil 9.

[0084] In addition, sensor assembly 14 may comprise a plurality of temperature sensors 18 for each heating zone 3.

[0085] According to the preferred non-limiting embodiment illustrated in Figure 1, sensor assembly 14 may also comprise at least one current sensor 20, in particular a coil current sensor 20, which is configured to provide an electrical current signal indicative of the current flowing through a respective induction coil 9.

[0086] Preferably, sensor assembly 14 comprises a plurality of current sensors 20, each configured to provide an electric signal indicative of the alternating current flowing through a respective induction coil 9.

[0087] According to the preferred embodiment of the invention, control unit 6 comprises elaboration means which are configured to elaborate the electric signals provided by sensor assembly 14 and are configured to determine/estimate, based on the electric signals provided by sensor assembly 14, when a dry cookware condition occurs due to evaporation of liquid from cookware 4 during the thermal treatment of foodstuff 5.

[0088] In particular, such dry cookware condition is indicative of the fact that the liquid initially present within cookware 4 is evaporated due to the heating power provided by heating zone 3, in particular by induction coil 9 during the thermal treatment of foodstuff 5.

[0089] More in detail, dry cookware condition is preferably indicative of the fact that at least most of, if not the entirety, of the liquid initially present within cookware 4 is evaporated.

[0090] In even more detail, dry cookware condition preferably occurs when at least 80%, advantageously at least 90%, of the liquid initially present within cookware 4 is evaporated.

[0091] In addition, control unit 6 is preferably configured to control heating zone 3, in particular power converter 10, in order to reduce the heating power supplied to cookware 4 when such dry cookware condition occurs.

[0092] More in detail, control unit 6 is preferably configured to control heating zone 3, in particular power converter 10, in order to stop the heating power supplied to cookware 4 when same control unit 6 determined that the liquid has evaporated from cookware 4. In other words, control unit 6 is preferably configured to switch off heating zone 3 when such dry cookware condition occurs.

[0093] According to some possible embodiment of the present invention, control unit 6 may be further configured to control user interface 12 in order to command communication unit to provide a signal adapted to inform the user when such dry cookware condition occurs.

[0094] According to some embodiment of the invention, control unit 6 may be configured to retrieve from acceleration sensor 16 an electrical acceleration signal indicative of the variation of the vibration of cookware 4 on induction cooking hob 1 during the thermal treatment of foodstuff.

[0095] In other words, control unit 6 may be configured to retrieve from acceleration sensor 16 a set of time-dependent data indicative of, i.e. containing information about, the variation of the vibration of cookware 4 on induction cooking hob 1 during the thermal treatment of foodstuff 5.

[0096] In particular, when different acceleration sensors 16 are arranged at different location on induction cooking hob 1, a set of multivariate time-dependent data indicative of the variation of the vibration of cookware 4 on induction cooking hob 1 during the thermal treatment of foodstuff may be acquired by control unit 6.

[0097] Preferentially, such set of time-dependent data acquired from acceleration sensor 16 contains information about the magnitude of the vibration of cookware 4 on induction cooking hob 1 at different point of time.

[0098] According to some possible embodiments, such set of time-dependent data may be acquired by acceleration sensor 16 with a constant sampling rate.

[0099] According to an embodiment of the invention, control unit 6 may be configured to determine, based on the electrical acceleration signals provided by acceleration sensor 16, when the dry cookware condition occurs due to evaporation of liquid from cookware 4 during the thermal treatment of foodstuff 5.

[0100] In addition, control unit 6 may be further configured to determine, based on the electrical acceleration signals provided by acceleration sensor 16, and in particular on the magnitude of the vibrations measured by acceleration sensor 16, the amount of boiling liquid present within cookware 4.

[0101] According to an embodiment of the present invention, control unit 6 may be configured to determine based on the electrical acceleration signals provided by acceleration sensor 16, when all the liquid present within cookware is boiling. In particular, control unit 6 may be configured to determine when the magnitude of the vibration measured by acceleration sensor 16 reaches its peak, i.e. when the magnitude of the vibration measured by acceleration sensor 16 stops increasing.

[0102] In addition, control unit 6 may be configured to determine when the magnitude of the vibration measured by acceleration sensor 16 is decreasing, indicating that the liquid present within cookware 4 is progressively decreasing.

[0103] Moreover, control unit 6 may be configured to determine, based on the electrical acceleration data provided by acceleration sensor 16, when the vibration of cookware 4 on induction heating hob 1 decreases below a predetermined threshold, indicative that the dry cookware condition occurs due to evaporation of liquid from cookware 4 during the thermal treatment of foodstuff 5.

[0104] In particular, electronic control unit 6 may be configured to determine when the magnitude of the vibrations measured by acceleration sensor 16 decreases to a predetermined fraction of the maximum vibrations previously determined, for example 20% or 10%.

[0105] According to some possible embodiment of the present invention, control unit 6 may be configured to elaborate the electrical acceleration signals provided by accelerations sensors 16 according to the sliding window technique.

[0106] More in detail, control unit 6 may be configured to elaborate different sub-sets, i.e. windows, of the set of time-dependent data acquired from acceleration sensor 16 containing data acquired in different time intervals. Control unit 6 may be configured to determine an average vibration magnitude of cookware 4 for each of the considered sub-sets. In addition, control unit 6 may be configured to compare the average vibration magnitude measured in each of the considered sub-sets. Control unit 6 may be further configured to determine when the average vibration magnitude of a sub-set of data is lower by a predetermined amount than, i.e. is a predetermined fraction of, the average vibration magnitude of a sub-set of data acquired in a time interval previous in time.

[0107] According to some embodiment of the invention, control unit 6 may be configured to retrieve from temperature sensor 18 an electrical temperature signal indicative of the temperature of induction coil 9 and/or heating zone 3, in particular of a portion of hob plate 2 adjacent induction coil 9, during the thermal treatment of foodstuff 5.

[0108] More in detail, control unit 6 may be configured to retrieve from temperature sensor 18 a set of time-dependent data indicative of, i.e. containing information about, of the temperature of induction coil 9 and/or heating zone 3 during the thermal treatment of foodstuff 5.

[0109] In particular, when different temperature sensors 18 are arranged at different location on induction cooking hob 1, a set of multivariate time-dependent data indicative of the variation of the temperature of induction coil 9 and/or heating zone 3 during the thermal treatment of foodstuff 5 may be acquired by control unit 6.

[0110] According to some embodiment of the invention, control unit may be configured to determine/estimate the temperature of cookware 4 based on the temperature of induction coil 9 and/or heating zone 3.

[0111] In addition, according to an embodiment of the invention, control unit 6 may be configured to determine, based on the electrical temperature signals provided by temperature sensor 18, when the dry cookware condition occurs due to evaporation of liquid from cookware 4 during the thermal treatment of foodstuff 5.

[0112] More in detail, control unit 6 may be configured to determine/ estimate when the temperature of cookware 4 exceeds a predetermined set point during the thermal treatment of foodstuff 5.

[0113] According to some embodiment of the invention, control unit 6 may be configured to determine, based on the electrical temperature data provided by temperature sensor 18, a variation rate of the temperature of induction coil 9 and/or a portion of induction cooking hob, in particular hob plate 2, adjacent to induction coil 9.

[0114] In addition, control unit 6 may be configured to determine when dry cookware condition occurs on the basis of the variation rate of the temperature of induction coil 9, in particular when the variation rate of the temperature of induction coil 9 exceeds a predetermined threshold.

[0115] According to some possible embodiment of the invention, control unit 6 may be configured to determine, based on the electrical current signals provided by current sensor 20, when dry cookware condition occurs due to evaporation of liquid from cookware 4 during thermal treatment of foodstuff 5.

[0116] The current flowing through induction coil 9 depends on the induction coupling between induction coil 9 and cookware 4 and on the amount of foodstuff 5, in particular liquid, present within cookware 4.

[0117] Control unit 6 may be configured to control power converter 10, in particular switching module, to regulate the frequency and/or the magnitude of the alternating current provided to induction coil 9 so as to maintain constant the heating power provided by the respective heating zone 3.

[0118] Control unit 6 may be configured to determine, based on the electrical current signals provided by current sensor 20, if significative variations in the switching frequency of switching module and/or in magnitude of the electric power provided to induction coil 9 occurs, and to determine if the dry cookware condition occurs based on such variations.

[0119] More in detail, control unit 6 may be configured to determine, based on the electrical current signals provided by current sensor 20, if the current flowing through induction coil 9 exceeds a predetermined threshold and accordingly to determine if dry cookware condition occurs.

[0120] According to some possible embodiment of the invention, control unit 6 may be configured, based on the electrical current signals provided by current sensor 20, determine the current flowing through induction coil 9 at different switching frequencies of switching module.

[0121] In addition, control unit 6 may be configured to determine, based on the intensity of the current flowing through induction coil 9 at different switching frequencies of switching module, if dry cookware condition has occurred.

[0122] With reference to Figure 2 and 3, the operation of the above-described induction cooking hob 1 is the following.

[0123] First, a cookware 4 containing foodstuff 5 to be thermally treated is arranged on a heating zone 3, and the same heating zone 3, or better the corresponding power converter 10, is controlled to provide heating power to heat foodstuff 5 contained within cookware 4.

[0124] The supply of heating power to cookware 4 will cause the liquid present within foodstuff 5 first to start boiling and at the same time will cause the evaporation of the liquid contained within foodstuff 5.

[0125] As schematically represented in Figure 2, during the thermal treatment of foodstuff 5 present within cookware 4, the heating power provided by heating 3 will cause the progressive heating of foodstuff 5 and the liquid present within cookware 4 will eventually start boiling. In particular, with reference to the example illustrated in Figure 2, at time instant t_1 the liquid present within cookware 4 will start boiling.

[0126] At the same time, the vibrations of cookware 4 on induction cooking hob 1 will progressively increase up to reach a peak when all the liquid present within cookware 4 will be heat to boiling temperature. In particular, with reference to the example illustrated in Figure 2, at time instant t_3 all the liquid present within cookware 4 will be boiling.

[0127] Then, by continuing providing heating power to cookware 4, the liquid present within cookware 4 will progressively evaporate, and therefore the mass of boiling liquid will progressively reduce. Accordingly, the vibration of cookware 4 on induction cooking hob 1 will progressively decrease until stop when all the liquid will be evaporated.

[0128] With reference to the example illustrated in Figure 2, at time instant t_3 the vibration of cookware 4 will drop below a predetermined threshold a_1, indicative that the dry cookware condition has occurred.

[0129] With reference to example illustrated in Figure 3, the temperature of the induction coil 9, on the other hand, will increase rapidly when the liquid present within cookware 4 will be evaporated, as all the heat provided by heating zone will be adsorbed by cookware 4.

[0130] In addition, also the coil current will rise rapidly when the dry cookware condition occurs. In particular, Figure 3 illustrates a the rapid current increase that occurs in time instant t_4, when the dry cookware condition has occurred.

[0131] By elaborating the electrical signal provided by sensor assembly 14, control unit 6 is able to determine when the dry cookware condition occurs and it may reduce/stop the heating power provided to cookware 4 and/or it may control user interface to alarm the user.

[0132] In view of the above operation, the present invention is further directed to a method comprising the following steps:

(a) controlling power converter 10 to provide electric power to induction coil 9, in order to generate the time-varying magnetic field adapted to heat cookware 4;

(b) measuring by means of sensor assembly 14 at least one physical quantity associated with the thermal treatment of foodstuff 5; and

(c) determining, based on the electrical signals provided by sensor assembly 14, when the dry cookware condition occurs due to evaporation of the liquid from cookware 4 during thermal treatment of foodstuff 5.

[0133] Preferentially, steps (a) to (d) are executed in order of mentioning.

[0134] Clearly, changes may be made to induction cooking hob 1 and to its operation method without, however, departing from the scope protection defined by the scope of protection defined by the claims.

List of Reference Signs

[0135]

1	Induction cooking hob
2	Hob plate
3	Heating zone
4	Cookware
5	Foodstuff
6	Control unit
7	Support surface
9	Induction coil
10	Power converter
12	User interface
14	Sensor assembly
16	Acceleration sensor
18	Temperature sensor
20	Current sensor

Claims

1. Induction cooking hob (1) for the thermal treatment of foodstuff (5) containing liquid;
said induction cooking hob (1) comprising:

- at least one heating zone (3) configured to receive cookware (4) containing the foodstuff (5) to be thermally treated and including an induction coil (9) and a power converter (10) configured to supply electric power to said induction coil (9), in order to generate a time-varying electric field adapted to heat said cookware (4);
- a sensor assembly (14) configured to provide electric signals related to at least one physical quantity associated with the thermal treatment of said foodstuff (5); and
- a control unit (6) which is operatively connected to said power converter (10) and to said sensor assembly (14) and is configured to determine, based on the electric signals provided by said sensor assembly (14), when a dry cookware condition occurs due to evaporation of the liquid from said cookware (4) during thermal treatment of said foodstuff (5).

2. Induction cooking hob according to claim 1, wherein said control unit (6) is configured to control said heating zone (3) in order to reduce the heating power supplied to said cookware (4) when said dry cookware condition occurs.

3. Induction cooking hob according to claim 2, wherein said control unit (6) is configured to switch off said heating zone (3) when said dry cookware condition occurs.

4. Induction cooking hob according to any of the preceding claims, further comprising a user interface (12), which is operatively connected to said control unit (6) and comprises a communication unit configured to communicate with a user;
said control unit (6) being configured to control operation said user interface (12) in order to provide a signal adapted to alert said user when said dry cookware condition occurs.

5. Induction cooking hob according to any of the preceding claims, wherein said sensor assembly (14) comprises an acceleration sensor (16), in particular a microelectromechanical system (MEMS) acceleration sensor (16), configured to provide to said control unit (6) an electrical acceleration signal related to the vibration of said foodstuff (5) within said cookware (4).

6. Induction cooking hob according to claim 5, wherein said control unit (6) is configured to determine, based on the electrical acceleration signals provided by said acceleration sensor (16), if the vibrations of said cookware (4) on the induction heating hob (1) decreases below a predetermined threshold and/or the amount of liquid present within said cookware (4) drops below a predetermined quantity.

7. Induction cooking hob according to claim 5 or 6, wherein said control unit (6) is configured to retrieve from said acceleration sensor (16) a set of time-dependent data indicative of the variation of the vibration of said cookware (4) on said induction cooking hob (1) during the thermal treatment of said foodstuff (5).

8. Induction cooking hob according to claim 5, 6 or 7, wherein said control unit (6) is configured to determine, based on the electrical acceleration signals provided by said acceleration sensor (16) the amount of liquid contained present within said cookware (4)

9. Induction cooking hob according to any of the preceding claims, wherein said sensor assembly (14) comprises a temperature sensor (18) configured to provide to said control unit (6) an electrical temperature signal related to the temperature of said induction coil (9) and/or about a portion of said induction cooking hob (1) adjacent to said induction coil (9).

10. Induction cooking hob according to claim 9, wherein said control unit (6) is configured to determine/estimate the temperature of said cookware (4) based on the electrical temperature signal received from said temperature sensor (9).

11. Induction cooking hob according to claim 10, wherein said control unit (6) is configured to determine/estimate when the temperature of said cookware (4) exceeds a predetermined set threshold during the thermal treatment of said foodstuff (5) and said dry cookware condition occurs.

12. Induction cooking hob according to claim 9, 10 or 11, wherein said control unit (6) is configured to determine when dry cookware condition occurs on the basis of the variation rate of the temperature of said induction coil (9), in particular when the variation rate of the temperature of said induction coil (9) exceeds a predetermined value.

13. Induction cooking hob according to any of the preceding claims, wherein said sensor assembly (14) comprises a current sensor (20) configured to provide to said control unit (6) an electrical current signal related to the current flowing through said induction coil (9).

14. Induction cooking hob according to claim 13, wherein said control unit (6) is configured to determine, based on the electrical current signal provided by said current sensor (20), when dry cookware condition occurs due to evaporation of liquid from said cookware (4) during thermal treatment of said foodstuff (5).

15. Method of operating an induction cooking hob (1) according to any of the preceding claims;
the method comprising the step of:

d) controlling said power converter (10) to provide electric power to said induction coil (9), in order to generate the time-varying magnetic field adapted to heat said cookware (4);
e) measuring by means of said sensor assembly (14) at least one physical quantity associated with the thermal treatment of said foodstuff (5); and
f) determining, based on the electrical signals provided by said sensor assembly (14), when a dry cookware condition occurs due to evaporation of the liquid from said cookware (5) during thermal treatment of said foodstuff (5).

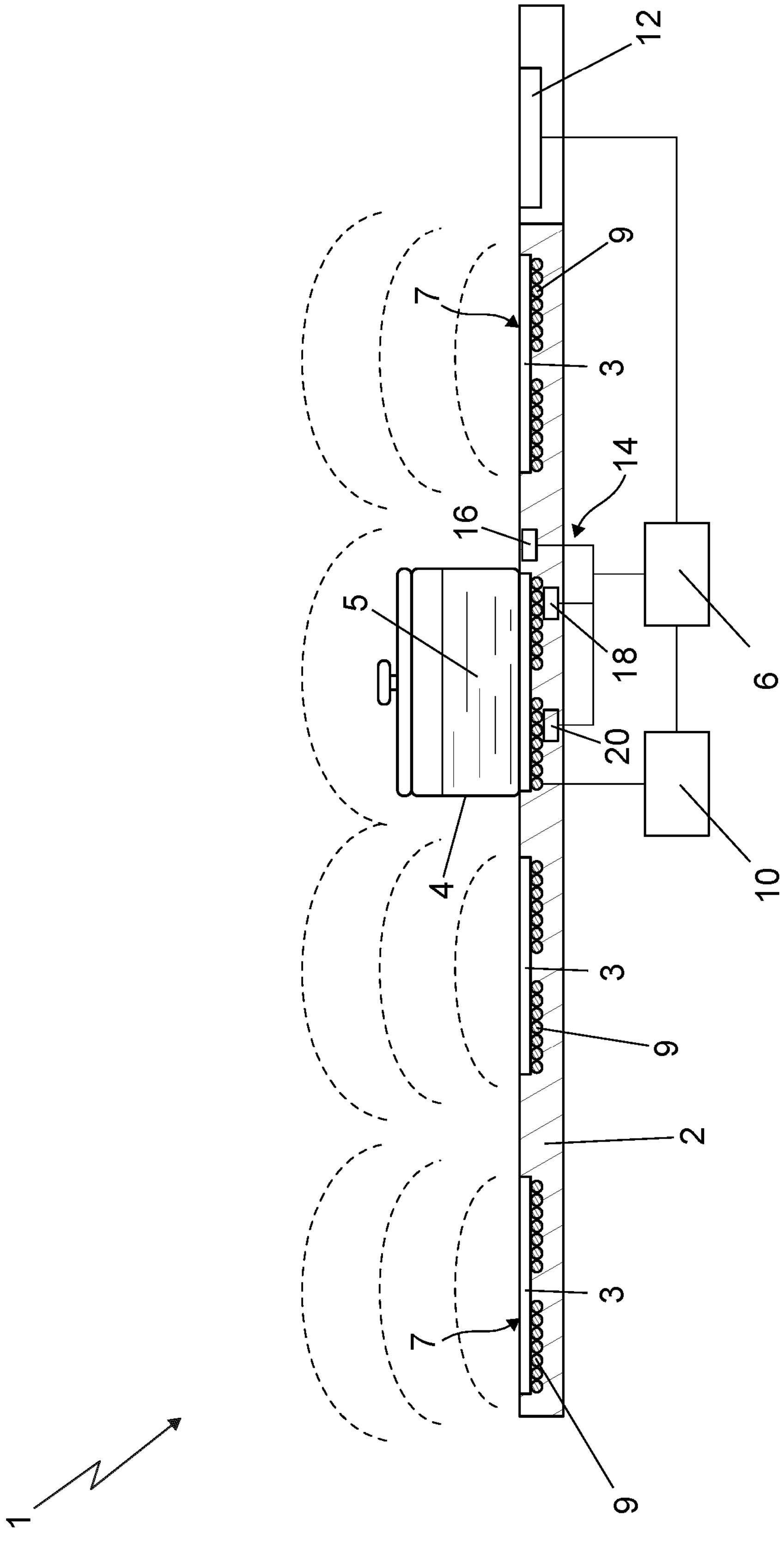

Fig. 1

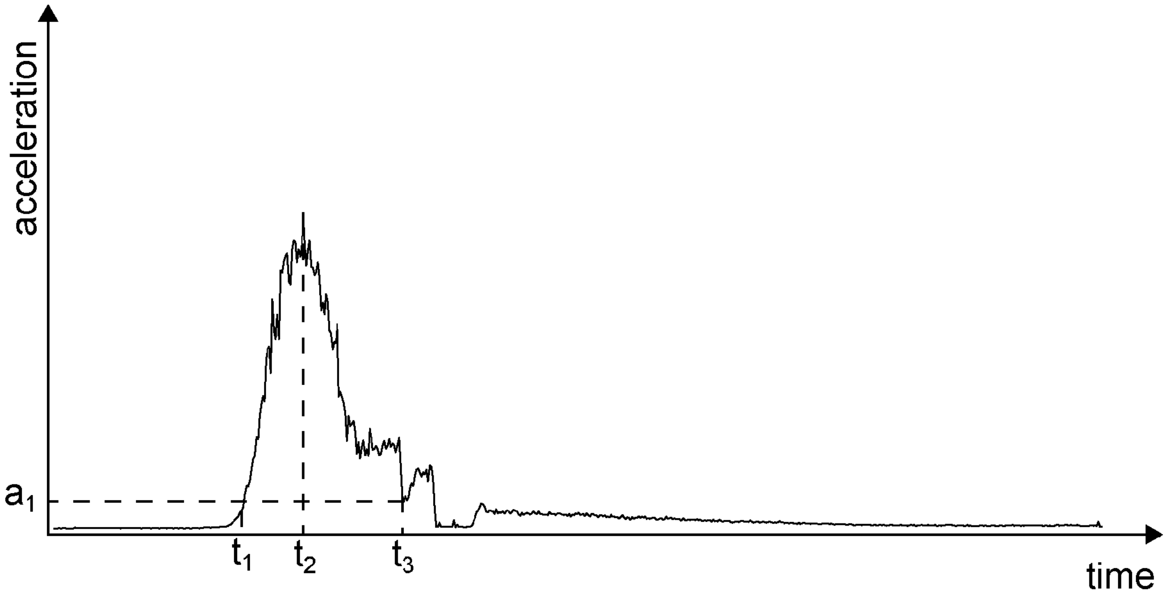

Fig. 2

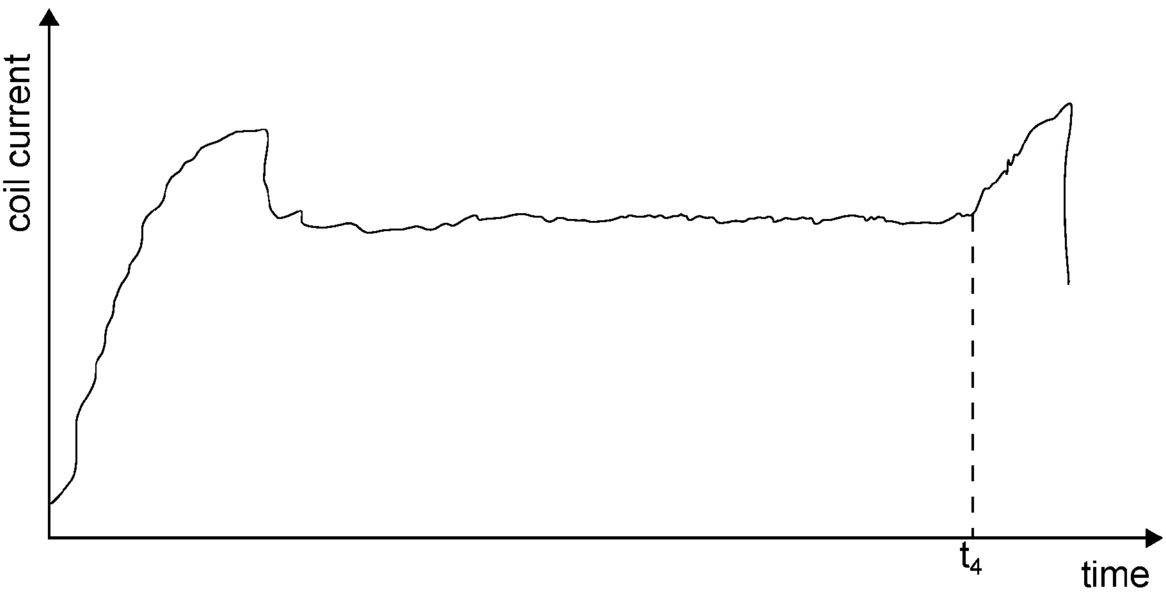

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 23 18 9708

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 January 2024	Pierron, Christophe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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