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(54) Title: LAUNDRY TREATMENT APPARATUS WITH HUMIDITY DETECTOR

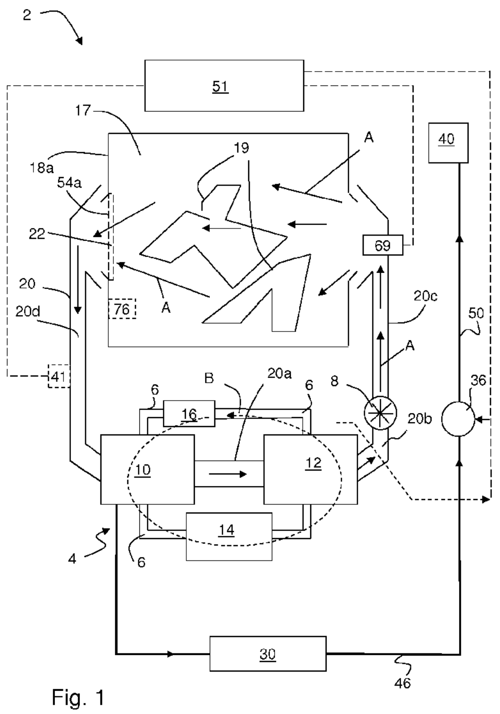

Fig. 1

(57) Abstract: The invention relates to a laundry treatment apparatus (2) comprising: a housing, a drum (18a) rotatably arranged within the housing and adapted for receiving laundry, a laundry humidity detector unit (69) comprising at least one emitting element adapted to emit ultrasonic waves and at least one receiving element adapted to receive ultrasonic waves, a control unit (51) adapted to control operation of the treatment apparatus using at least one laundry treatment program, wherein the at least one emitting element is adapted to emit ultrasonic waves having at least one frequency or a frequency range that is responsive to water absorbed by laundry, and wherein the at least one emitting element is arranged in the housing to emit the ultrasonic waves towards the inner space of the drum (18a) and the at least one receiving element is arranged in the housing to receive ultrasonic waves from the inner space of the drum (18a).

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LAUNDRY TREATMENT APPARATUS WITH HUMIDITY DETECTOR

The invention relates to a laundry treatment apparatus having a laundry humidity detector unit and a method of operating the treatment apparatus.

US 6,067,845 B discloses a method for determining the moisture content of textile goods in a laundry drier. An electric current is passed through the textile goods via electrodes which touch the textile goods and the laundry voltage drop across the textile goods is determined at the electrodes. The conductivity of the textile goods is determined from the laundry voltage. The moisture content of the textile goods is then determined from the conductivity.

US 2006/0260065 A1 discloses a method for drying laundry in a drum of a laundry machine, wherein the laundry has been wetted with a non-aqueous working fluid. The concentration of the non-aqueous working fluid is detected by using ultrasonic, wherein the drying is controlled in dependency of the detected working fluid concentration.

It is an object of the invention to provide an improved laundry treatment apparatus.

The invention is defined in claim 1. Particular embodiments are set out in the dependent claims.

According to claim 1, a laundry treatment apparatus is provided which comprises a housing and a drum rotatably arranged within the housing, e.g. a dryer or a washing machine having a drying function. The rotatable drum is adapted to receive laundry and may have a vertical, a substantially vertical, a horizontal, a substantially horizontal or an inclined rotation axis. A control unit of the apparatus is adapted to control the operation of the treatment apparatus using at least one laundry treatment program.

The apparatus comprises a laundry humidity detector unit having at least one emitting element which is adapted to emit ultrasonic waves and at least one receiving element which is adapted to receive ultrasonic waves. The at least one emitting element is arranged in the housing to emit the ultrasonic waves towards the inner space of the drum and the at least one receiving element is arranged in the housing to receive ultrasonic waves from the inner space of the drum. The at least one emitting element is adapted to emit ultrasonic waves which have at least one frequency or a frequency range that is responsive to water absorbed by laundry. Preferably, the at least one frequency or frequency range is selected such that a response is dependent on a water amount absorbed by laundry within the drum. For example, an ultrasonic wave response received by the at least one receiving element for dry laundry is different to an ultrasonic wave response for damp laundry.

As each humidity detection requires only a few seconds, the ultrasonic humidity detector unit provides a fast detection of laundry humidity or residual moisture content of the laundry inside the drum without requiring direct contact to the laundry. In particular, in comparison to conductivity humidity measurement, no 'blind threshold' exists when laundry does not contact electrical contacts for a conductivity measurement. In comparison to a conductivity humidity measurement which samples only a particular portion of the laundry load currently contacting the electric contacts, the ultrasonic humidity measurement samples the whole laundry load or the laundry portion exposed to the ultrasonic waves. In particular, each ultrasonic measurement provides an average value over a wide portion of the laundry load. In contrast to conductivity humidity measurements, an ultrasonic humidity measurement does not require drum rotation. An ultrasonic humidity measurement with the above humidity detector is effective at any moment during a treatment operation, e.g. such that a currently running treatment program may be adapted from the very beginning to the actual laundry humidity value.

According to a preferred embodiment the laundry humidity detector unit is connected via a signal line to the control unit and provides at least one signal to the control unit for controlling the at least one laundry treatment process. The control unit is adapted to stop a laundry treatment program or to modify at least one parameter of the currently executed laundry treatment program in dependency of the at least one signal from the laundry humidity detector unit. The detected laundry humidity may be used to terminate a running laundry treatment program at a desired residual humidity of the laundry. For example a stop condition for terminating a running treatment process may be a final desired humidity of the laundry e.g. cupboard-dry, iron-dry.

Preferably, the at least one frequency or frequency range is selected such that the response of the water absorbed by the laundry to the ultrasonic waves is at least one of the following:
(i) absorption of or damping of the ultrasonic waves,
(ii) reflection of the ultrasonic waves, and
(iii) scattering or diffraction of the ultrasonic waves.
For example, analysis of a response may be based on sound absorption (insertion loss) which indicates how much ultrasonic energy is dissipated within textiles fibers. Each of the above features (i)-(iii) is strongly dependent on the water content of the textiles, such that laundry humidity may be determined based on the detected ultrasonic response. The terms 'textile' and 'laundry' are used synonymously herein.

According to a preferred embodiment, the at least one emitting element or at least one of the emitting elements is adapted to emit ultrasonic waves with at least two different frequencies and/or frequency ranges. Alternatively or additionally a first emitting element emitting a first frequency or frequency range and a second emitting element emitting a second frequency of frequency range are provided. The ultrasonic waves at a first frequency or frequency range are responsive to water absorbed by laundry and the ultrasonic waves at a second frequency or frequency range are not responsive to water absorbed by laundry. Alternatively the ultrasonic waves at a second frequency or frequency range are responsive to water absorbed by laundry having a value of absorptivity, reflectivity or scattering different from the ultrasonic waves at the first frequency or frequency range. In particular, the or at least one of the receiving elements is adapted to detect the ultrasonic waves at the different frequencies or frequency ranges and to provide corresponding signals to the control unit for evaluation. By evaluating the signals, the humidity detection may be calibrated or a detected water content is statistically improved. A calibration measurement may be executed to calibrate the humidity detection system at the beginning of a humidity detection process. Further, a laundry volume measurement may be executed at the second frequency or frequency range which is independent from water content of the laundry.

Preferably, the at least one emitting element or at least one of the emitting elements is adapted to emit ultrasonic waves with at least two different frequencies/frequency ranges. Alternatively or additionally a first emitting element emitting a first frequency or frequency range and a second emitting element emitting a second frequency of frequency range are provided. The ultrasonic waves of the different frequencies/ranges are adapted or selected to be differently responsive to different types of textiles of the laundry stored in the drum, e.g. polyester, flax, flannel, silk, sponge, wool, cotton, polyamide. Signals corresponding to the different ultrasonic waves frequencies are supplied to the control unit and the control unit is adapted to evaluate the signals to determine the type or types of textiles of the laundry stored in the drum. In particular, the or at least one of the receiving elements is adapted to detect the ultrasonic waves at the different frequencies/ranges and to provide corresponding signals to the control unit for evaluation of different textile types.

Each textile type has a characteristic ultrasonic frequency absorption pattern, in particular for a fixed frequency or frequency range different textiles attenuate ultrasonic waves differently. Thus ultrasonic absorption analysis may be used for textile composition analysis. For example, a user may be warned when any delicate (wool) clothes are detected in the drum and if e.g. a high temperature laundry treatment program is selected as the laundry treatment program.

Preferably, a single (fixed) frequency or frequency range may be selected for executing absorption analysis to detect the textile type, whereby a low-cost sensing device may be provided.

Additionally or alternatively to the detection of ultrasonic absorbance the humidity detection system may be based on another physical parameter of ultrasonic field, for example phase shift. Phase shift is independent on absorbance and relates to textiles different response when dealing with different frequencies.

The above ultrasonic textiles recognition only requires a few seconds and it has a high resolution. Further, no additional components are required besides the above described laundry humidity detector unit, such that with the same components humidity and type of textile may be determined.

The at least one emitting element or at least one of the emitting elements may also implement the function of the receiving element or at least one of the receiving elements. In other words, at least one emitting element combines both functions of emitting and receiving ultrasonic waves, such that an ultrasonic transceiver is provided. For example at least one (combined) emitting/receiving element and at least one receiving(-only) element may be provided. This embodiment provides that fewer components have to be mounted in the housing which in turn reduces assembly time and costs as well as the required mounting space for the humidity/textile type detection system.

In case of a plurality of receiving elements, these may be arranged at the following positions:

a) with respect to the inner space of the drum, the receiving element is arranged opposite to the emitting element,

b) with respect to the inner space of the drum, the receiving element is arranged at the same side as the emitting element (for example the emitting element may also be the receiving element), or

c) with respect to a main axis of wave emission direction of the emitting element, the receiving element is arranged at an angle with respect to the main axis.

According to a preferred embodiment, the rear wall of the drum is stationary mounted in the housing, such that the rear wall of the drum does not rotate with the rotatable drum. For example, the drum rear wall is located opposite to a laundry loading opening of the drum. At least one of the receiving elements is arranged at the drum rear wall, at least one of the emitting elements is arranged at the drum rear wall, or at least one of the emitting elements and at least one of the receiving elements are arranged at the drum rear wall. In particular an opening is provided in the drum rear wall for the emitting elements and/or receiving element(s), such that an emitting/receiving surface of the elements faces into the inner space of the drum without an obstacle. In other words nothing (except laundry) is interposed between emitter/receiver. Further, the drum rear wall provides a large area for arranging the emitting element(s) and receiving element(s) such that the different and/or a plurality of elements can be arranged at spaced apart positions, e.g. distributed over different height levels.

Alternatively to arranging at least one (of the) receiving and/or emitting elements at the rear wall of the drum (e.g. in case the rear wall is not stationary but fixedly connected to the rotatable drum) the at least one receiving and/or emitting elements are arranged at the inner or rear side of a front frame which is forming part of the supporting structure of the laundry treatment apparatus. The receiving and/or emitting element(s) may be arranged at one or more of the following positions at a section of the front frame which is facing the interior of the drum: a lower region of the front frame (e.g. close to or at a fluff filter insert opening), a side region of the loading opening formed in the front frame, and an upper region of the front frame (e.g. close to a drum illumination device). The at least one (of the) receiving and/or emitting elements may be arranged at the front frame even in case the drum rear wall is stationary, i.e. receiving and/or emitting elements may be arranged at the front frame and at the stationary rear wall. Here and generally one or more or all of the ultrasonic element(s) may be provided as receiving and emitting element and may then be denoted as ultrasonic transceiver element.

Preferably, the ultrasonic waves emitted by the at least one emitting element are frequency modulated and additionally or alternatively pulsed. For example ultrasonic frequency-modulated pulses may be directed towards the laundry load, wherein due to the interaction between laundry and ultrasonic wave changes occur in the ultrasonic sound field structure. The resulting sound field may be detected and analyzed based on frequency change and trajectory in the drum. As described above, the analysis may be based on sound absorption. As described below, analysis may be based additionally or alternatively on phase and/or frequency shift, that is how the phase of an ultrasonic signal is changed or shifted (e.g. over a traveling path and/or over time) or how the ultrasonic frequency is changed (shifted towards greater/lower wavelengths) by interaction with laundry. These parameters, absorbance and phase and/or frequency shift, strongly depend on fabric blend and water content of textiles, such that these characteristic may be used for detecting moisture content of clothes and specific type of fabric.

The control unit may be adapted to receive signal(s) from the laundry humidity detector unit, to process the received signal(s) and to control the operation of the treatment apparatus during the at least one laundry treatment program in dependency of the signal(s). For example a drying program is terminated as soon as a (predetermined) laundry humidity threshold is reached.

The signal received by the control unit from the laundry humidity detector unit may be indicative of one or more of the following:
a) absorption of the ultrasonic waves by the water absorbed by the laundry,
b) reflection of the ultrasonic waves by the water absorbed by the laundry, and
c) scattering or deflection of the ultrasonic waves by the water absorbed by the laundry.
By processing the signal by means of the control unit the humidity of the laundry or the water content of the laundry may be determined.

Additionally or alternatively the control unit receiving signal(s) from the laundry humidity detector unit is adapted to - or the laundry humidity detector unit is adapted to - determine a phase and/or frequency shift and/or a phase and/or frequency shift difference of the ultrasonic waves when being transmitted, reflected or scattered on the path through the inner space of the drum by water absorbed by laundry. The control unit is adapted to control the operation of the laundry treatment apparatus during the at least one laundry treatment program in dependency of the phase and/or frequency shift or phase and/or frequency shift difference. In case a phase shift (difference) is determined by the laundry humidity detector unit, this signal is (additionally) provided to control unit to control the operation of the treatment apparatus. The phase signal is evaluated by the control unit to improve water content detection and/or laundry type (blend) determination.

The control unit may be adapted to process the signal(s) received from the laundry humidity detector unit for estimating a residual laundry treatment time in dependency of the signal(s). For example in case the treatment apparatus is a laundry dryer or a washing machine having drying function the residual treatment time may be the residual drying time. To estimate a residual treatment time a processing of the emitted signal and received signal(s) may include determining the ratio of these signals.

Preferably, the treatment apparatus further comprises a heat pump system for heating and/or cooling a processing medium used for treating the laundry. For example a heat pump dryer or heat pump washer-dryer, wherein the processing medium is drying air circulated through the drum. The control unit is adapted to control the operation of the heat pump system in dependency of signal(s) provided from the laundry humidity detector unit to the control unit. For example in a dryer the heat pump system is switched off when the detected residual amount of water is lower than a threshold value or when the detected residual total amount of water is lower than a threshold. Preferably, the threshold value may depend on a target residual humidity, e.g. damp, cupboard-dry or iron-dry.

The heat pump system may comprise a compressor, wherein the compressor power of the compressor is adjustable under the control of the control unit and wherein the control unit is adapted to adjust the compressor power in dependency of signal(s) provided from the laundry humidity detector unit to the control unit. Preferably the compressor having the adjustable power is a variable speed compressor where the speed of the compressor may be controlled by the control unit. In case a variable speed compressor is provided, the compressor motor speed may be adjusted in dependency of water content absorbed by laundry. The compressor motor may be operated at high speed at the beginning of a drying cycle and additionally or alternatively the compressor may be operated at a reduced speed when the water content of the laundry is low. For example the compressor speed (or speed profile) is high at the beginning of a drying cycle and in the course of drying the laundry the compressor speed is stepped down at each time a predetermined humidity threshold value is reached, e.g. at a particular threshold the compressor is stepped down one or more speed steps, wherein more than one humidity threshold may be provided.

Alternatively or additionally to controlling the power of the compressor by the control unit, a variable expansion device (e.g. variable expansion valve) may be provided in the refrigerant loop of the heat pump system. By controlling the opening degree or flow rate of the refrigerant through the variable expansion device, the cooling power of the heat pump system can be adjusted via the control unit.

The control unit may be adapted to control a motor unit for rotating the drum, wherein the control unit is adapted to control via the motor unit a drum rotation mode convenient for detecting the water absorbed by the laundry. For example the drum is rotated and water absorbed by laundry is detected at different drum positions or is averaged while drum is rotated. Alternatively the control unit may control the motor unit to stop the drum rotation while detecting the laundry water absorbed by laundry using the laundry humidity detector.

In a further embodiment the control unit is adapted to control the speed of a blower motor so that the speed of a blower conveying the process or drying air is variable. For example the control unit controls the blower motor to provide a high, medium or low drying air flow rate of the air flowing through the drum. In such an arrangement preferably separate drum and blower motors are provided, however in an embodiment thereof the blower motor and drum motor are a combined or single motor so that under the control of the control unit the drum and blower speed are controlled and varied synchronously.

Preferably, the control unit is adapted to determine the absolute amount of water absorbed from the laundry in the drum by evaluating the signal provided from the laundry humidity detector unit.

According to a preferred embodiment, the laundry humidity unit is further adapted to detect the amount or volume of laundry in the drum. For example by using above described second ultrasonic wave frequency or frequency range which is not responsive to water absorbed by laundry. As described above two frequencies or frequency ranges may be used wherein a first frequency/range is used for determining absorption by water and a second frequency/range is used to determine absorption by laundry. A detected degree of inner drum space occupation by laundry may be used to determine spinning and/or drum rotation speeds during laundry treatment.

According to a first example, when a combined emitter/receiver element is used or the emitter element and receiver element are arranged at the same side of the drum, a reflected signal is sufficient for a high-resolution measurement. The reflection time is proportional to the sound pathway length, such that determination of laundry amount is based on signal source/receiver delay (detected e.g. by sound wave runtime measurements and/or phase changes or jitter over time).

According to a second example, when emitter element and receiver element(s) are arranged at opposite sides of the drum (e.g. emitter at front and receiver at rear part of drum) their position with respect to load is used to determine the amount of laundry. In particular, at least one emitter element and receiver element (emitter/receiver couple) may be arranged at the lower drum part, and an additional emitter/receiver couple may be arranged at the top drum part to achieve a sufficient resolution. The term 'emitter/receiver couple' relates to an emitter element and receiver element which are aligned or basically aligned with respect to the (main) emitting direction of the emitting element. When a low amount of laundry is arranged in the drum, the lower emitter/receiver couple is blind (as the emitter and receiver is covered by laundry), while upper emitter/receiver couple is not covered, i.e. the receiver element is able to detect a signal from the emitter element. In case the drum is filled with a big amount of laundry, the signal of the upper emitter/receiver couple will be influenced.

Preferably, the control unit is adapted to rotate the drum during the laundry amount or volume detection. Thereby an averaging of the detected signal at different positions of the drum or drum angular positions is provided.

The treatment apparatus may further comprise a load weight detector adapted to detect the weight of laundry loaded into the drum. For example the load weight detector detects a parameter of a motor driving the drum, e.g. motor torque, current, voltage, power and/or moment of inertia. The laundry weight is derived from the detected parameter. Preferably, the control unit is adapted to receive the signal from the laundry load level detector and the signal of the load weight detector, and is adapted to control the at least one laundry treatment program in dependency of both, the laundry load signal and the laundry weight signal.

According to a preferred embodiment, the laundry treatment apparatus is a dryer or a washing machine having drying function, which further comprises a process air channel adapted to guide process air to the inner space of the drum and adapted to guide process air from the inner space of the drum. A temperature sensor is arranged for detecting the process air temperature. The temperature sensor provides a temperature signal to the control unit, wherein the control unit is adapted to control the at least one laundry treatment program in dependency of the signal provided by the laundry humidity detector unit and the temperature signal provided from the temperature sensor.

Ultrasonic speed increases with increasing temperature, such that the interaction between laundry or textiles and an ultrasonic field depends on the temperature of textiles (which may be detected indirectly via process air temperature). The precision and reliability of ultrasonic measurement may be further refined by taking into account the load temperature (temperature of laundry in the drum), such that the combined temperature/ultrasonic signal improves the accuracy of water content determination. In particular the temperature signal may be used to calibrate ultrasonic signals as absorption, reflection, scattering and phase-shift of an ultrasonic signal is dependent on temperature. Preferably, the detected (temperature/ultrasonic) signal may be used for mutual calibration of the (ultrasonic/temperature) sensor, e.g. by means of the ultrasonic humidity detector unit the temperature sensor may be calibrated. Additionally or alternatively a conductivity humidity sensor may be used to calibrate the ultrasonic humidity detector unit unit and vice versa. For example a calibration is based on a particular sensor which is known to be accurate for a specific (humidity or temperature) range, e.g. a conductivity humidity sensor is used for calibrating the ultrasonic humidity detector at high humidity levels and high laundry load.

An example of thermal info used for improving the ultrasonic measurements is described in the following: Process air temperature (e.g. at drum outlet) is almost constant during most of the cycle. After an initial warming-up period, laundry temperature stabilizes, and further load temperature rise only occurs when approaching the end of a drying cycle due to lower moisture content of the laundry. Since temperature variations can affect laundry interaction with an ultrasonic field, temperature constancy during most of the cycle implies that during this time any variation in ultrasonic sound field proprieties sensed by ultrasonic receiving elements is due to variations in load moisture content. As laundry water content decreases, sound attenuation becomes greater while sound speed gets lower, such that a function may be defined that links residual laundry moisture M_R to both sound intensity attenuation I_A and, if available, phase shift φ.

$$M_R = f(I_A)$$

or

$$M_R = f(\varphi; I_A)$$

In particular, phase shift φ and attenuation I_A are two independent variables as they refer to different physical principles. By measuring both variables the accuracy of a humidity detection is increased, while only one ultrasonic humidity detector unit as described above is sufficient to detect both variables.

Preferably, the treatment apparatus further comprises a second laundry humidity detector unit which is configured to detect the laundry humidity by conductivity or capacitive measurement. The second laundry humidity detector unit provides a humidity signal to the control unit, wherein the control unit is adapted to control the at least one laundry treatment program in dependency of the signal provided by the laundry humidity detector unit and the humidity signal provided from the second laundry humidity detector unit. In contrast to the above ultrasonic humidity detector unit a conductivity or capacitive humidity sensor requires direct laundry contact for determining laundry humidity. By combining the ultrasonic humidity measurement to data from a capacitive or conductivity sensor S the accuracy of the ultrasonic measurement is improved. A combination between the two signals (ultrasonic and conductivity/capacitive) may be managed in multiple ways, one of which is to define a function of both signals

$$M_R = f(S; I_A)$$

For this function one or more threshold values or a look-up table may be defined e.g. to trigger a cycle end and/or to estimate time to cycle end.

Preferably, the treatment apparatus further comprises a laundry weight or volume detector which provides a signal to the control unit. The control unit is adapted to determine a laundry treatment parameter in dependency of the signal from the laundry weight or volume detector and the signal provided from the laundry humidity detector unit. For example a determined laundry treatment parameter may be the residual laundry drying time.

The laundry humidity detector unit may be adapted to supply the signal from the at least one receiving element to the control unit, wherein the control unit is adapted to evaluate the signal to determine an agitation value indicative of the degree of movement of the laundry in the drum during drum rotation. With this embodiment it is determined whether laundry is tumbling (drum rotation speed correct) or is adhering to a drum wall (drum rotation speed too high). In case it is detected that the laundry is adhering to the drum wall, the control unit is adapted to reduce the drum rotation speed until a tumbling/agitation of the laundry is achieved. Thus, the drum rotation speed is adapted to the specific amount or type of laundry, such that during a tumbling sequence of a laundry treatment operation efficient tumbling is provided at all times. In particular such an evaluation may also be made in the laundry humidity detector unit forming 'part' of the control unit. Preferably, a signal from a receiving element may be combined with a signal of an emitting element, e.g. to determine phase shift, time delay, etc. The phase shift may comprise, include or by a phase jitter

In the following a preferred embodiment is described which relates to a laundry treatment apparatus having a drum with a vertical rotation axis, in particular a laundry washing machine or a washer-dryer. Unless otherwise mentioned, above described features and embodiments may be used or implemented for below described treatment apparatus individually or in any combination and sub-combination.

The laundry treatment apparatus comprises: a tub, a drum arranged within the tub and having a vertical rotation axis, a laundry load level detector, a control unit adapted to control operation of the treatment apparatus using at least one laundry treatment program, a laundry level detector unit comprising at least one emitting element adapted to emit ultrasonic waves and at least one receiving element adapted to receive ultrasonic waves, a control unit adapted to control operation of the treatment apparatus using at least one laundry treatment program, wherein the at least one emitting element is adapted to emit ultrasonic waves responsive to laundry, and wherein the at least one emitting element is arranged in the housing to emit the ultrasonic waves towards the inner space of the drum and the at least one receiving element is arranged in the housing to receive ultrasonic waves from the inner space of the drum. As described above the at least one emitting element and at least one receiving element may be the same element, i.e. a transceiver. Preferably, the at least one receiving element or the (at least one) transceiver is primarily responsive to reflection of ultrasonic waves at a laundry outer surface, i.e. the (exposed) outer surface of laundry facing the inner space of drum.

Preferably, the laundry load level detector is further adapted to detect a water level within the drum or tub. For example, the water level inside the drum may be detected during a water supply sequence at the beginning of a washing cycle to provide that a desired amount of water is supplied into the drum, e.g. such that the laundry is immersed in water for a thorough washing operation.

Preferably, the laundry level detector unit is arranged at an upper region of the drum or above the drum and is adapted to detect a distance between the laundry level detector unit or a maximum filling level of the drum and the upper surface of the laundry stored in the drum. Reflection time is proportional to sound pathway length, such that the distance is determined based on signal source/receiver delay or sound travel time. For example a frequency range of the at least one emitting element between 1-2 MHz may be used to determine the distance.

Preferably, the control unit is adapted to rotate the drum during the laundry load level detection or the water level detection using the laundry load level detector. Thereby the detected load level is averaged over different positions of the laundry or over different angular drum positions. For example, the drum may be continuously rotated at a low rotation speed during the load level detection to average the detected load level. A low drum rotation speed prevents that the laundry adheres to the drum wall due to centrifugal force. Alternatively, the drum is rotated at intervals, wherein a load level measurement is executed when the drum is stopped, such that the load level is averaged over different angular positions of the drum.

Preferably, the laundry treatment apparatus further comprises a load weight detector adapted to detect the weight of laundry loaded into the drum. Preferably, the load weight detector detects a parameter of a motor driving the drum. As described above the load weight detector may be adapted to detect a parameter of a motor driving the drum, e.g. motor torque, current, voltage, power and/or moment of inertia.

Preferably, the control unit is adapted to receive the signal from the laundry load level detector and the signal of the load weight detector, and is adapted to control the at least one laundry treatment program in dependency of both, the laundry load signal and the laundry weight signal.

Preferably, the control unit is adapted to control a water supply valve, wherein the control unit supplies a water amount for at least one laundry treatment program in dependency of the laundry load level signal and additionally or alternatively the laundry load signal.

Reference is made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying figures, which show:

Fig. 1 a schematic view of a laundry dryer,

Figs. 2a-c exemplary plots to illustrate the absorbance and phase shift of ultrasonic waves for different wetting levels of cotton (Figs. 2a-b) and to illustrate the absorbance of ultrasonic waves for different types of textile (Fig. 2c),

Figs. 3a-c schematic views of a dryer drum having horizontal rotation axis showing possible arrangements for ultrasonic emitter(s) and receiver(s),

Fig. 4 a front view of a dryer partially disassembled,

Fig. 5 a schematic view of a washing machine drum having a vertical rotation axis with ultrasonic emitter and receiver for detection of laundry load level and/or water level, and

Fig. 6 a schematic cross sectional side view of another embodiment of the dryer having ultrasonic transceivers arranged at a front frame.

The following figures are not drawn to scale and are provided for illustrative purposes.

Fig. 1 shows a schematically depicted laundry dryer 2. The dryer 2 comprises a heat pump system 4, including a closed refrigerant loop 6 which comprises in the following order of refrigerant flow B: a first heat exchanger 10 acting as evaporator for evaporating the refrigerant and cooling process air, a compressor 14, a second heat exchanger 12 acting as condenser for cooling the refrigerant and heating the process air, and an expansion device 16 from where the refrigerant is returned to the first heat exchanger 10. Together with the refrigerant pipes connecting the components of the heat pump system 4 in series, the heat pump system 4 forms the refrigerant loop 6 through which the refrigerant is circulated by the compressor 14 as indicated by arrow B.

The process air flow A within the dryer 2 is guided through a laundry storing compartment 17 of the dryer 2, i.e. through a compartment for receiving articles to be treated, e.g. a drum 18a. The articles to be treated are textiles, laundry 19, clothes, shoes or the like. The process air flow is indicated by arrows A in Fig. 1 and is driven by a process air blower 8. The process air channel 20 guides the process air flow A outside the drum 18a and includes different sections, including the section forming the battery channel 20a in which the first and second heat exchangers 10, 12 are arranged. The process air exiting the second heat exchanger 12 flows into a rear channel 20b in which the process air blower 8 is arranged. The air conveyed by blower 8 is guided upward in a rising channel 20c to the backside of the drum 18a. The air exiting the drum 18a through the drum outlet (which is the loading opening 54a of the drum 18a) is filtered by a fluff filter 22 arranged close to the drum outlet in or at the channel 20. The optional fluff filter 22 is arranged in a front channel 20d forming another section of channel 20 which is arranged behind and adjacent the front cover of the dryer 2. The condensate formed at the first heat exchanger 10 is collected and guided to the condensate collector 30.

The condensate collector 30 is connected via a drain conduit 46, a drain pump 36 and a drawer pipe 50 to an extractable condensate drawer 40. I.e. the collected condensate can be pumped from the collector 30 to the drawer 40 which is arranged at an upper portion of the dryer 2 from where it can be comfortably withdrawn and emptied by a user. The dryer 2 comprises a control unit 51 for controlling and monitoring the overall operation of the dryer 2. According to Fig. 1, the control unit 51 also controls the drain pump 36. Additionally, the control unit 51 is able to control other parts of the dryer 2.

The dryer 2 further comprises a laundry humidity detector unit 69 which comprises at least one ultrasonic emitting element 70a-c (Figs. 3a-c, 5) and least one receiving element 72a-c (Figs. 3a-c, 5). For example as shown in Fig. 1, the humidity detection unit 69, i.e. its emitting element(s) 70a-c and receiving element(s) 72a-c, may be arranged at a stationary rear wall of the drum 18a. The emitting element(s) 70a-c is (are) adapted to emit ultrasonic waves having at least one frequency or frequency range that is responsive to water absorbed by laundry. The receiving element(s) 72a-c is (are) arranged in the housing of the dryer to receive ultrasonic waves from the inside of the laundry storing compartment 17. The control unit 51 receives a signal from the humidity detection unit 69 via a signal line, such that a (running) dryer operation may be adapted to the effective or actual humidity of the laundry 19 in the drum 18a.

The humidity detection unit 69 is adapted to measure (residual) humidity of the laundry 19 by analysis of ultrasonic soundwave absorption and/or variations from sound waves crossing the laundry load. The emitting element(s) 70a-c generate ultrasonic waves which may be frequency-modulated pulses. These pulses are directed towards the laundry load. Interaction between the ultrasonic waves and laundry load induce one or more of the following phenomena: absorption, transmission, refraction, diffraction and/or reflection.

Thus, due to the interaction the sound field structure of the emitted ultrasonic waves or pulses is changed. The resulting sound field is detected via the receiving element(s) 72a-c.

Analysis of the detected sound field may be based on sound absorption ('insertion loss') (Figs. 2a, 2c), which indicates how much ultrasonic energy is dissipated within textiles fibers. Additionally or alternatively analysis may be based on phase shift (Fig. 2b) (and/or frequency shift), which indicates how ultrasonic frequency is changed (shifted towards greater wavelengths) by interaction with the laundry 19. These parameters, absorbance and phase and/or frequency shift, strongly depend on fabric blend and water content of textiles, so this characteristic can be exploited as described below for detecting humidity of clothes (Figs. 2a-b) and determine the type of fabric (Fig. 2c).

Sound frequency(-ies) or frequency ranges used for analysis are optimized based on target physical properties. For example an ultrasonic frequency (range) could be chosen to maximize differential absorption by textiles which are natural sound absorber/insulator.

The plot depicted in Fig. 2a illustrates the absorbance (insertion loss) of cotton for different wetting levels, wherein the wetting level decreases from level 3 (dripping wet) over level 1 to dry (not wetted). Fig. 2b illustrates the phase shift of cotton for different wetting levels. As shown in the plots of Figs. 2a-b, different humidity levels of laundry or textiles may be clearly detected by means of the ultrasonic humidity detection unit 69.

An ultrasonic measurement of laundry humidity provides a fast measurement as each ultrasonic measure requires only a few seconds. Additionally an ultrasonic moisture measurement samples the whole load, i.e. it provides an average value over a wide portion of load. In particular, in contrast to humidity detectors using conductivity or capacitive measurements, the ultrasonic measurement does not require drum rotation for a measurement. An ultrasonic humidity measurement is effective at any moment during a drying cycle.

Humidity sensing by means of ultrasonic absorption and/or phase and/or frequency shift may be further improved by combining it with temperature detection. For example and as shown in Fig. 1, the control unit 51 receives a temperature signal from a temperature sensor 41 which is arranged at or in the process air channel 20 to detect the process air temperature which is indicative of the laundry temperature. I.e. the temperature of laundry or textiles in the drum 18a is detected indirectly via process air temperature. In a first approximation, at least during most of the cycle, a stable temperature gradient exists between process air and textiles, wherein empirical tests show that this temperature gap is of about 4 °C in heat pump tumble dryers (air warmer than textiles). Since interaction between textiles and an ultrasonic wave or field depends on temperature of textiles (sound speed increases with increasing temperature), knowledge about load temperature may be used to further refine ultrasonic measurements precision and reliability.

The air temperature at a drum outlet is almost constant during most of a drying cycle. After an initial warming-up, textiles temperature stabilizes, and further laundry load temperature rise occurs only when approaching a cycle end, due to lower moisture content of the laundry. Since temperature variations can affect textiles interaction with ultrasonic field, temperature constancy during most of the cycle implies that during this time any variation in sound field proprieties sensed by ultrasonic receiving elements 72a-c is due to variations in load moisture content. As laundry humidity or water content decreases, sound attenuation becomes greater while sound speed gets lower.

Thus, a function can be defined that links residual moisture M_R both to sound intensity attenuation I_A and, if available, phase shift φ.

$$M_R = f(I_A)$$

or

$$M_R = f(\varphi; I_A)$$

It has to be noticed that phase shift φ and attenuation I_A are two independent functions of residual moisture as they refer to different physical principles, i.e. they are not two different points of view for the same phenomenon. Thus, effective added value is provided by measuring both these quantities wherein only one humidity detector 69 is sufficient for measuring both quantities.

The accuracy of ultrasonic humidity measurement may be further improved by combining them with data from a humidity detection sensor 76 which is based on load conductivity and/or capacity measurement. As shown in Fig. 1, an optional conductivity humidity sensor 76, i.e. its respective electrical contacts, is arranged inside the drum 18a, such that laundry 19 may contact the electrical contacts of the humidity sensor 76, in particular during tumbling the laundry. Combination between measurements of the two humidity detectors 69, 76 may be managed in multiple ways, one of which is to define a function of both signals

$$M_R = f(S; I_A)$$

For example, one or more threshold values or a look-up table may be defined for triggering a drying cycle end and/or to estimate time to a cycle end (when a desired/predetermined laundry humidity level is reached).

Figs. 3a-c show schematic views of a horizontal rotation axis R dryer drum 18a and its loading opening 54a, wherein exemplary mounting positions for ultrasonic emitter element(s) 70a-c and receiving element(s) 72a-c are depicted.

As described above, anything placed between ultrasonic emitting element(s) 70a-c and receiving element(s) 72a-c is detected with this sensing system via ultrasonic field modification. Therefore ultrasonic sensing may be used to determine the amount of textiles in the drum 18a. For example emitting elements 70a-c and receiving elements 72a-c may be arranged at the same side of the drum 18a (Fig. 3b-c) or at opposing sides of the drum 18a (Fig. 3a).

As shown in Fig. 3a, three emitting elements 70a-c are arranged at a (stationary) rear wall of the drum 18a and three corresponding receiving elements 72a-c are arranged at a front wall of the drum 18a and at the loading opening 54a (e.g. at a dryer door for closing the opening 54a - as such not show in the schematic drawing but providing a mounting basis for the elements).

At least one couple 70c, 72c of emitting element and receiving element is arranged at the lower drum part, and one couple 70a, 72a at the top to get sufficient resolution of the laundry load. When a small amount of laundry 19 is in the drum 18a, the lower couple 70c, 72c is blind, while the upper couple 70a, 72a is not. On the other hand, if the drum 18a is filled with a high amount of laundry, the signal from the upper couple 70a, 72a will be influenced by this.

The main difference between this ultrasonic system and an equivalent optical one (i.e. collimated light beam source/receiver paired facing each other) is that an optical system would require a high number of source/receiver couples for achieving satisfactory resolution: each couple could only “see” if there is something between the two elements, exactly along the pathway of light. This would require a large array of sensors, in order to get the desired resolution.

As sound waves are less directive than light beams (i.e. they spread on a wider 3D angle or wider sound propagation cone) a proper receiver positioning permits to get info also about textiles which lie near, not only along a cross-section area along a path between the active areas of the source (emitter) and receiver. This means that few sensors (e.g. 2-4) provide high-resolution information about the amount of load in the drum 18a.

When considering the example shown in Fig. 3a, the lower couple 70c, 72c is almost totally covered by laundry 19, such that no useful info is provided by it. The two upper couples 70a-b, 72a-b emit and receive ultrasonic waves whose shape, intensity and direction strongly depend on textiles amount. This ultrasonic sensing procedure works regardless of drum rotation, such that a load amount may be detected while the drum 18a stands still. As each measurement requires only a few seconds, the load measurement can be done before starting a drying cycle, such that a drying cycle duration can be updated from the very beginning of the cycle. Detecting a load amount as described above requires no additional components to the ones used for ultrasonic humidity detection, and it could substitute weighing the laundry.

As shown in Figs. 3b-c, the emitting/receiving couple 70a, 72a is arranged at the same side of the drum 18a. Instead of using two separate elements 70a, 72a a combined emitter/receiver, i.e. a transceiver (not shown) may be used instead or additionally to the emitting element(s) 70a-c and receiving element(s) 72a-c. In the embodiments of Figs. 3b-c reflected ultrasonic waves are analyzed to provide a high-resolution measurement. Reflection time is proportional to sound pathway length, such that this embodiment for load amount detection is based on signal emitter/receiver delay.

Each different textile type has a characteristic ultrasonic frequency absorption pattern. For example, for a fixed frequency different textiles attenuate sound differently, which is illustrated in the plot of Fig. 2c.

Ultrasonic absorption (insertion loss), e.g. ranging from 20 kHz to 90 kHz, is dependent on the different textiles types (here: flannel, linen, polyamide, wool). Thus, ultrasonic absorption analysis can be used to analyze the composition of textiles inside the drum. For example, wool is easily detectable due to its specific ultrasonic resistivity or absorption pattern. Such a system allows the machine to warn a user (e.g. by means of the control unit

51 via a display) when any delicate (e.g. wool) clothes are accidentally loaded into the drum, while e.g. a cotton treatment program has been selected.

When including ultrasonic textile type detection in a washing machine or tumble dryer, a single frequency for absorption analysis may be chosen to provide a low-cost sensing device. Based on data shown in Fig. 2c, 60 kHz could be a suitable frequency for textiles type detection, since almost no superposition is visible between the curves for the different textile types.

Ultrasonic textiles recognition has a higher resolution with respect to any other algorithm/system/sensor aimed to this. Additionally it would require no additional components to the ones used for laundry humidity detection.

Fig. 4 shows a front perspective view of a partially disassembled condenser dryer that uses a heat pump system 4 as described with respect to Fig. 1. In the shown state the loading door of the dryer 2, a right cover, a lower shell of a bottom unit and a bottom panel are removed. The outer appearance of the depicted dryer 2 is defined by a top cover, a left cover or wall, a front cover 60 having a loading opening 54a and a front top panel 62. The front top panel 62 frames a drawer cover 64 of the condensate drawer 40, wherein here the drawer 40 has a condensate container that is completely pushed in a drawer compartment located at the upper part of the dryer 2. The right portion of the front top panel 62 forms an input section 66 wherein here the details of the input section 66 are not shown (like indicators, a display, switches and so on).

The loading opening 54a is surrounded by a loading frame 68 which is formed in the front cover 60. In loading direction behind the bottom section of the loading frame 68 a filter compartment/process air channel 20 is arranged which is adapted to receive the fluff filter 22 and which is formed in a front frame. At the back side of the loading opening 54a in the front frame the drum 18a is arranged. In the embodiment shown the drum 18a is a rotating drum cylinder that is extending between the back side of the front frame and the front side of a rear frame. The open rear end of cylindrical rotatable drum 18a is closed by a compartment back wall 74 which is mounted at the rear frame. Back wall 74 is preferably provided as a separate element to the rear frame (not shown), formed for example from a metal plate. The compartment back wall 74 is disposed stationary, whereas the rotatable drum 18a is rotatably coupled to the compartment back wall 74. In the shown embodiment the rotation axis R of the drum 18a is horizontal, however, the rotation axis may be inclined with respect to the horizontal axis or may be even vertical with some modifications to the shown embodiment, however without the requirement to modify other groups of the dryer 2.

As indicated in Fig. 4, the condensate drawer 40 has a draw handle 82 at the drawer cover 64 to be gripped by the user for pushing the condensate drawer 40 in or pulling it out of the condensate drawer compartment (not shown) that is extending into the interior of the dryer 2. Fig. 3 gives a view onto the compartment back wall 74 which has a plurality of back wall openings 84 through which processing air A enters the laundry storing compartment 17 from the back side or rear side of the drum 18a. In the center of the compartment back wall 74 and surrounded by the air back wall openings 84 a cone 86 is arranged which is extending into the laundry storing compartment 17 and has a laundry detangling function.

The above described ultrasonic emitting element(s) 70a-c and/or receiving element(s) 72a-c may be arranged at a rear side of the back wall 74, such that ultrasonic waves or pulses are emitted/received via one or more of the back wall openings 84. This provides that nothing (except laundry) is interposed between emitting elements 70a-c and receiving elements 72a-c.

Fig. 5 shows a schematic view of a washing machine drum 18b having a vertical rotation axis R' with an ultrasonic emitting element 70a and receiving element 72a for laundry load level and/or water level detection. Unless otherwise mentioned the above described embodiments and components relating to laundry humidity detection, textile type detection, laundry load or volume detection for a dryer having a horizontal drum rotation axis R according to Figs. 1 to 4 may be used for a washing machine according to Fig. 5.

Emitter/receiver couple 70a, 72a as described above may be used to determine the laundry load and/or a water level insider the drum 18b. As shown in the example of Fig. 5, the couple 70a, 72a may be arranged in a loading door closing the loading opening 54b. Instead of two separate elements 70a, 72a a combined emitting/receiving element (transceiver) may be used as described above. Load amount as well as water level may be detected by analyzing the reflection time of an ultrasonic wave or pulse (at the upper laundry surface or water surface) which is proportional to sound pathway length, i.e. the measurement is based on signal source/receiver delay.

In all embodiments the receiver and/or emitter elements or additional receiver and/or emitter elements may be arranged at the loading door adapted for covering the loading opening 54a and/or at a front frame (below) of the laundry treatment apparatus. E.g. in addition or instead the receiver and/or emitter elements arranged at the back wall 74.

Fig. 6 shows a schematic cross sectional side view of another embodiment of a dryer 2b having ultrasonic transceivers 104a-c arranged at a front frame 68. Elements shown in Fig. 6 and corresponding to elements or to function of elements as shown in the above figures have the same reference numeral and are not further described. As compared to the dryer 2 illustrated in Fig. 1, the dryer 2b is a condenser dryer without heat pump system but with a heater element (not shown) and an air/air heat exchanger 106 for respectively heating and dehumidifying the drying air circulated through the air channel 20 and the drum 18.

The transceivers 104a, b, c are all arranged at the inner rim of the front frame 68. The front frame surrounds the loading opening 54a which is closed by a loading door 102 during drying. The front frame 68 is forming part of the supporting structure of the dryer and is covered at the front side by the front cover 60, which in turn forms part of the outer casing 3 of the dryer. The front frame has an inner surface arranged between the closed loading door 102 and the drum 18, and which faces the inner space of the drum (laundry storing compartment 17).

The lower transceiver 104a is arranged below an insert opening for receiving a fluff filter (not shown) and may be arranged neighboring to a conductivity humidity sensor (not shown). The middle transceiver 104c is arranged in a middle region of the front frame inner surface to the left or right of the loading door. Alternatively transceivers may be provided at both sides. The upper transceiver 104b is arranged at the upper region of the front frame 68.

As indicated by the arrows U, the ultrasonic sound wave are emitted (transmitted) by the transceivers 104 into the laundry storing compartment 17 and the reflected or deflected sound waves are recorded when falling back to the surface of the transceivers.

The arrangement of transceivers (or instead separate transducers (emitter elements) and receivers (receiver elements) at the front frame is particularly useful in case the drum 18 has a back wall that is fixedly connected to the drum mantle and thus rotates when the drum is rotated.

Reference Numeral List

2, 2b	laundry dryer
4	heat pump system
6	refrigerant loop
8	blower
10	first heat exchanger
12	second heat exchanger
14	compressor
16	expansion device
17	laundry storing compartment
18a-b	drum
19	laundry
20	process air channel
20a	battery channel
20b	rear channel
20c	rising channel
20d	front channel
22	fluff filter element
30	condensate collector
36	drain pump
40	condensate drawer
41	temperature sensor
46	drain conduit
50	drawer pipe
51	control unit
54a-b	loading opening
58	left cover
60	front cover
62	front top panel
64	drawer cover
66	input section
68	loading frame / front supporting frame
69	ultrasonic humidity detection unit
70a-c	ultrasonic emitter element
72a-c	ultrasonic receiver element
74	compartment back wall
76	conductivity humidity detector
82	drawer handle
84	back wall opening
86	detangling cone
102	loading door
104a, b, c	ultrasonic transceiver
106	air/air heat exchanger; condenser
A	process air flow
B	refrigerant flow
R, R'	drum rotation axis
U	ultrasonic wave propagation

Claims:

1. Laundry treatment apparatus (2) comprising:
a housing,
a drum (18a-b) rotatably arranged within the housing and adapted for receiving laundry,
a laundry humidity detector unit (69) comprising at least one emitting element (70a-c) adapted to emit ultrasonic waves and at least one receiving element (72a-c) adapted to receive ultrasonic waves,
a control unit (51) adapted to control operation of the treatment apparatus using at least one laundry treatment program,
wherein the at least one emitting element (70a-c) is adapted to emit ultrasonic waves having at least one frequency or a frequency range that is responsive to water absorbed by laundry, and
wherein the at least one emitting element (70a-c) is arranged in the housing to emit the ultrasonic waves towards the inner space of the drum (18a-b) and the at least one receiving element (72a-c) is arranged in the housing to receive ultrasonic waves from the inner space of the drum (18a-b).

2. Laundry treatment apparatus according to claim 1,
wherein the laundry humidity detector unit (69) is connected via a signal line to the control unit (51) and provides at least one signal to the control unit for controlling the at least one laundry treatment process, and
wherein the control unit (51) is adapted to stop a laundry treatment program or to modify at least one parameter of the currently executed laundry treatment program in dependency of the at least one signal from the laundry humidity detector unit (69).

3. Laundry treatment apparatus according to claim 1 or 2, wherein the at least one frequency or frequency range is selected such that the response of the water absorbed by the laundry to the ultrasonic waves is at least one of the following:

absorption of or damping of the ultrasonic waves,
reflection of the ultrasonic waves,
scattering or diffraction of the ultrasonic waves,
a phase shift of the ultrasonic waves, and
a frequency shift of the ultrasonic waves.

4. Laundry treatment apparatus according to claim 1, 2 or 3,

wherein the at least one emitting element (70a-c) is adapted to emit ultrasonic waves with at least two different frequencies or frequency ranges, or a first one of the emitting elements is adapted to emit a first frequency or frequency range and a second one of the emitting elements is adapted to emit a second frequency of frequency range,

wherein the ultrasonic waves at a first frequency or frequency range are responsive to water absorbed by laundry, and

wherein the ultrasonic waves at a second frequency or frequency range are not responsive to water absorbed by laundry or are responsive to water absorbed by laundry having a value of absorptivity, reflectivity, scattering, phase shift or frequency shift different from the ultrasonic waves at the first frequency or frequency range.

5. Laundry treatment apparatus according to any of the previous claims,

wherein the at least one emitting element (70a-c) is adapted to emit ultrasonic waves with at least two different frequencies or frequency ranges, or a first one of the emitting elements is adapted to emit a first frequency or frequency range and a second one of the emitting elements is adapted to emit a second frequency of frequency range, and

wherein the ultrasonic waves of the different frequencies are differently responsive to different types of textiles of the laundry stored in the drum, wherein signals corresponding to the different ultrasonic waves frequencies/ranges are supplied to the control unit and the control unit is adapted to evaluate the signals to determine the type or types of textiles of the laundry stored in the drum (18a-b).

6. Laundry treatment apparatus according to any of the previous claims, wherein the or at least one of the emitting elements (70a-c) also implements the function of the or at least one of the receiving elements (72a-c).

7. Laundry treatment apparatus according to any of the previous claims, wherein

a) with respect to the inner space of the drum, the receiving element (72a-c) is arranged opposite to the emitting element (70a-c),

b) with respect to the inner space of the drum, the receiving element (72a-c) is arranged at the same side, or

c) with respect to a main axis of wave emission direction of the emitting element (70a-c), the receiving element (72a-c) is arranged at an angle.

8. Laundry treatment apparatus according to any of the previous claims,
- wherein the rear wall (74) of the drum (18) is stationary mounted in the housing and wherein

at least one of the receiving elements (72a) is arranged at the drum rear wall,

at least one of the emitting elements (70a-c) is arranged at the drum rear wall, or

at least one of the emitting elements (70a) and at least one of the receiving elements (72a) are arranged at the drum rear wall (74); or

- wherein the rear wall of the drum is fixedly connected to the drum (18) and

at least one of the receiving elements is arranged at a front supporting frame (68),

at least one of the emitting elements is arranged at the front supporting frame (68), or

at least one of the emitting elements (104a, b, c) and at least one of the receiving elements (104a, b, c) are arranged at the front supporting frame (68).

9. Laundry treatment apparatus according to any of the previous claims, wherein the ultrasonic waves emitted by the at least one emitting element (70a-c) are at least one of:
a) frequency modulated,
b) pulsed, and
c) phase-modulated.

10. Laundry treatment apparatus according to any of the previous claims, wherein the control unit (51) is adapted to receive signal(s) from the laundry humidity detector unit (69), adapted to process the received signal(s) and to control the operation of the treatment apparatus during the at least one laundry treatment program in dependency of the signal(s).

11. Laundry treatment apparatus according to any of the previous claims, wherein the signal received by the control unit (51) from the laundry humidity detector unit (69) is indicative of one or more of the following:
a) absorption of the ultrasonic waves by the water absorbed by the laundry,
b) reflection of the ultrasonic waves by the water absorbed by the laundry,
c) scattering or deflection of the ultrasonic waves by the water absorbed by the laundry
d) a phase shift of the ultrasonic waves by the laundry, and

e) a frequency shift of the ultrasonic waves by the laundry.

12. Laundry treatment apparatus according to any of the previous claims,

wherein the control unit (51), which is adapted to receive signal(s) from the laundry humidity detector unit (69), is adapted to or the laundry humidity detector unit (69) is adapted to determine a phase or frequency shift and/or a phase or frequency shift difference of the ultrasonic waves when being transmitted, reflected or scattered on the path through the inner space of the drum (18a-b) by water absorbed by laundry, and

wherein the control unit (51) is adapted to control the operation of the laundry treatment apparatus during the at least one laundry treatment program in dependency of the phase shift or phase shift difference.

13. Laundry treatment apparatus according to any of the previous claims, wherein the control unit (51) is adapted to process the signal(s) received from the laundry humidity detector unit for estimating a residual laundry treatment time in dependency of the signal(s).

14. Laundry treatment apparatus according to any of the previous claims, further comprising a heat pump system (4) for heating and/or cooling a processing medium used for treating the laundry, wherein the control unit (51) is adapted to control the operation of the heat pump system (4) in dependency of signal(s) provided from the laundry humidity detector unit (69) to the control unit (51).

15. Laundry treatment apparatus according to claim 14, wherein the heat pump system (4) comprises a compressor (14) and the compressor power or speed of the compressor (14) is adjustable under the control of the control unit (51), wherein the control unit (51) is adapted to adjust the compressor power or speed in dependency of signal(s) provided from the laundry humidity detector unit (69) to the control unit (51).

16. Laundry treatment apparatus according to claim 14 or 15, wherein the heat pump system (4) comprises a variable refrigerant flow expansion device (16) and wherein the control unit (51) is adapted to control the expansion device (16) to adjust the flow rate of the refrigerant flowing through the expansion device in dependency of signal(s) provided from the laundry humidity detector unit (69) to the control unit (51).

17. Laundry treatment apparatus according to any of the previous claims, comprising a variable speed blower (8) adapted to convey the drying air at a variable flow rate under the

control of the control unit (18), wherein preferably the control unit controls the blower to adjust the drying air flow rate in dependency of signal(s) provided from the laundry humidity detector unit (69) to the control unit (51).

18. Laundry treatment apparatus according to any of the previous claims, wherein the control unit (51) is adapted to control a motor unit for rotating the drum and wherein the control unit (51) is adapted to control via the motor unit a drum rotation mode convenient for detecting the water absorbed by the laundry.

19. Laundry treatment apparatus according to claim 18, wherein the control unit (51) is adapted to control the motor unit to stop the drum (18a-b) while detecting the laundry water absorbed by laundry using the laundry humidity detector unit (69).

20. Laundry treatment apparatus according to any of the previous claims, wherein the control unit (51) is adapted to determine the absolute amount of water absorbed from the laundry in the drum by evaluating the signal provided from the laundry humidity detector unit (69).

21. Laundry treatment apparatus according to any of the previous claims, further comprising a load weight detector adapted to detect the weight of laundry loaded into the drum (18a-b).

22. Laundry treatment apparatus according to any of the previous claims, wherein the laundry treatment apparatus is a dryer or a washing machine having drying function, further comprising:

a process air channel (20) adapted to guide process air to the inner space of the drum (18a-b) and adapted to guide process air from the inner space of the drum (18a-b), and

a temperature sensor (41) arranged for detecting the process air temperature,

wherein the temperature sensor (41) provides a temperature signal to the control unit (51), and

wherein the control unit (51) is adapted to control the at least one laundry treatment program in dependency of the signal provided by the laundry humidity detector unit (69) and the temperature signal provided from the temperature sensor (41).

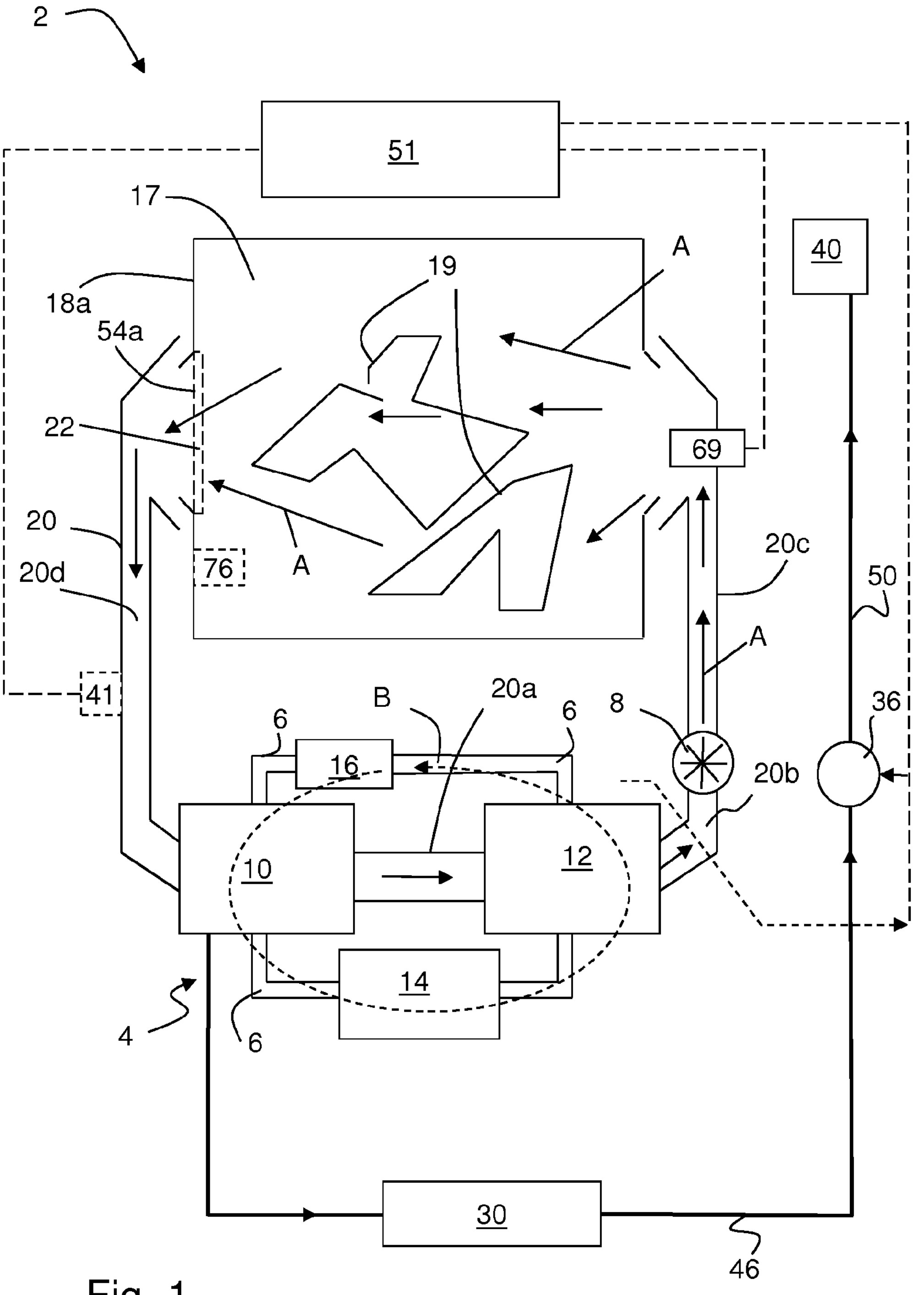
23. Laundry treatment apparatus according to any of the previous claims, further comprising a second laundry humidity detector unit (76) configured to detect the laundry humidity by conductivity or capacitive measurement,

wherein the second laundry humidity detector unit (76) provides a humidity signal to the control unit (51), and

wherein the control unit (51) is adapted to control the at least one laundry treatment program in dependency of the signal provided by the laundry humidity detector unit (69) and the humidity signal provided from the second laundry humidity detector unit (76).

24. Laundry treatment apparatus according to any of the previous claims, further comprising a laundry weight or volume detector providing a signal to the control unit (51), wherein the control unit (51) is adapted to determine a laundry treatment parameter in dependency of the signal from the laundry weight or volume detector and the signal provided from the laundry humidity detector unit (69).

25. Laundry treatment apparatus according to any of the previous claims, wherein the laundry humidity detector unit (69) is adapted to supply the signal from the at least one receiving element (72a-c) to the control unit (51) and the control unit (51) is adapted to evaluate the signal to determine a agitation value indicative of the degree of movement of the laundry in the drum (18a-b) during drum rotation.


2
51
17
18a
54a
22
20
20d
41
76
A
19
A
69
20c
40
50
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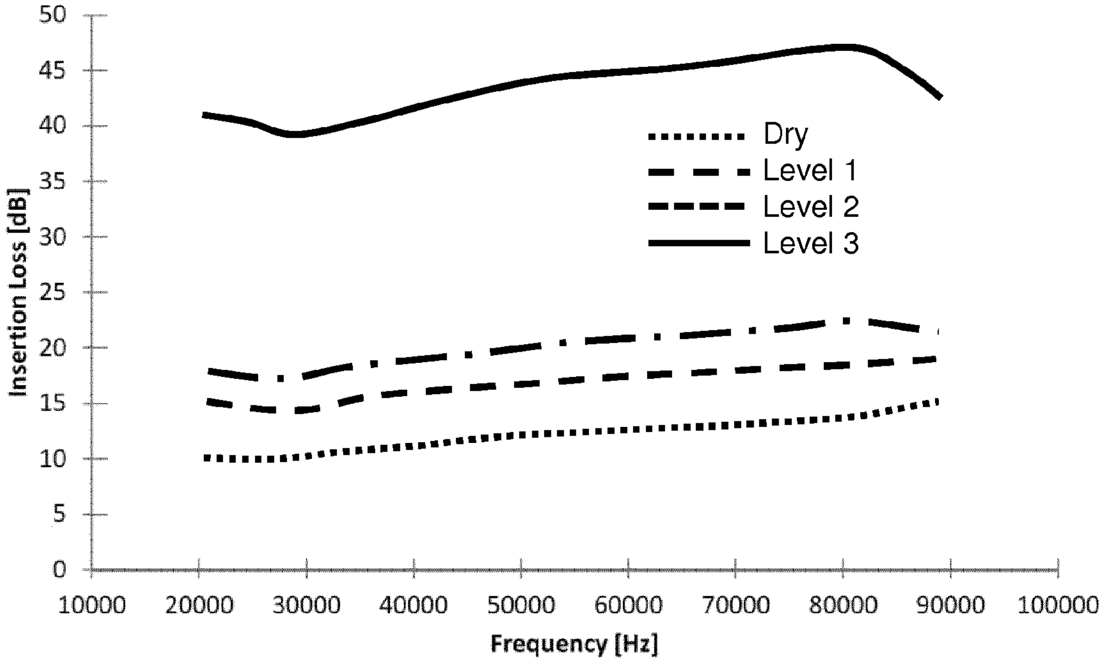
B
20a
6
6
16
20b
10
12
14
4
6
30
46

Fig. 1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45
40
35
30
25
20
15
10
5
0
Insertion Loss [dB]
Dry
Level 1
Level 2
Level 3
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100000
Frequency [Hz]

Fig. 2a

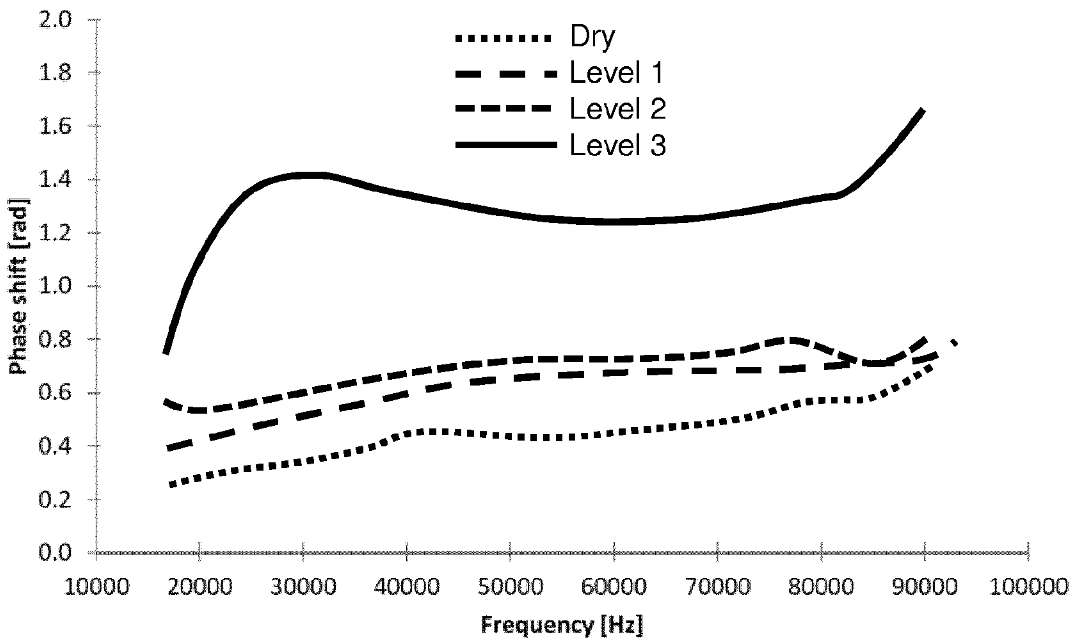
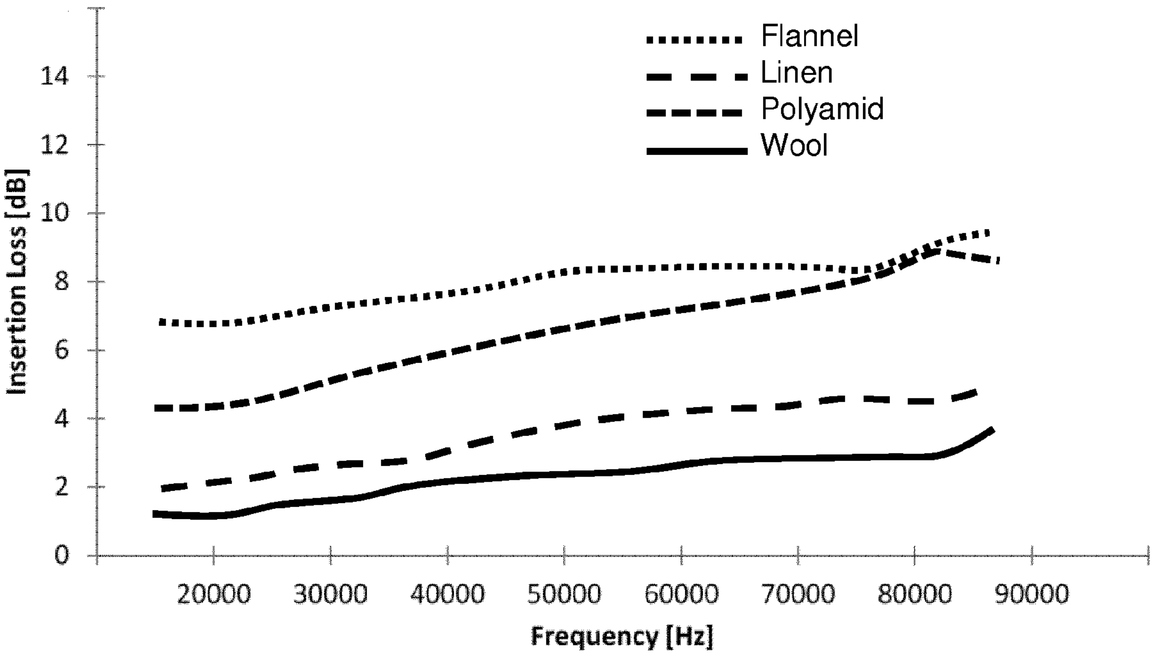
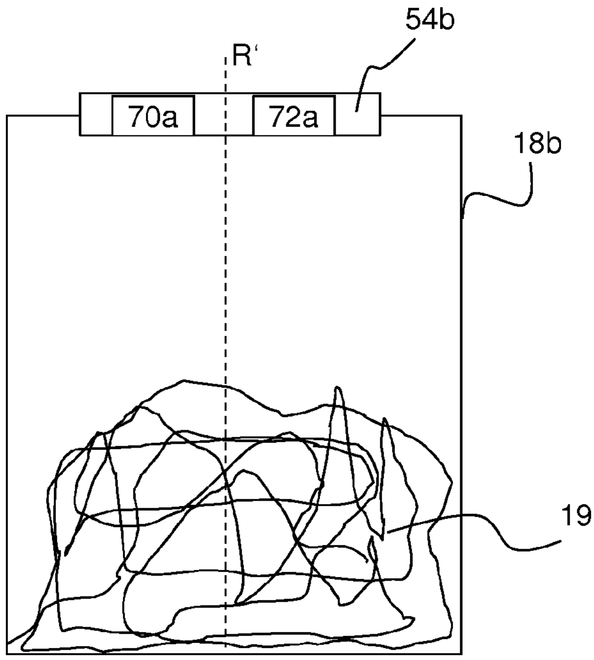

2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Phase shift [rad]
Dry
Level 1
Level 2
Level 3
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Frequency [Hz]

Fig. 2b



Flannel
Linen
Polyamid
Wool
Insertion Loss [dB]
0
2
4
6
8
10
12
14
20000
30000
40000
50000
60000
70000
80000
90000
Frequency [Hz]

Fig. 2c



54b
R'
70a
72a
18b
19

Fig. 5

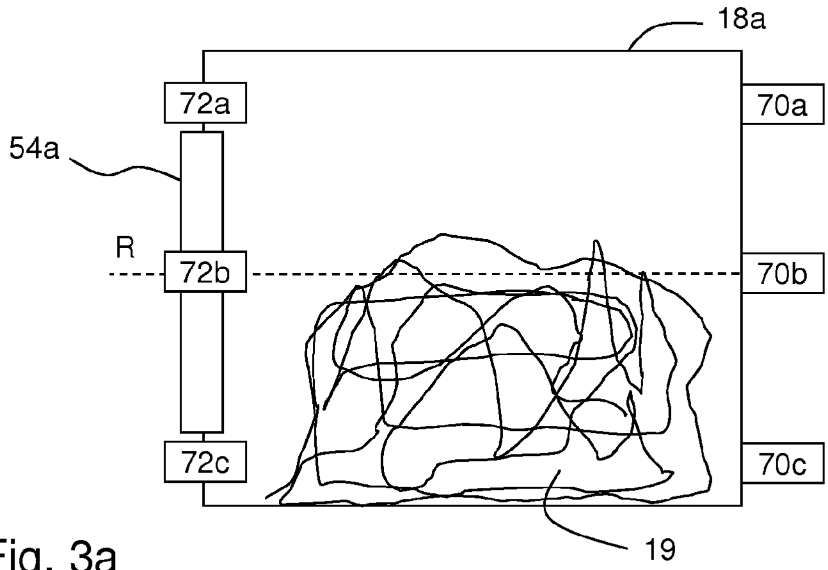


Fig. 3a

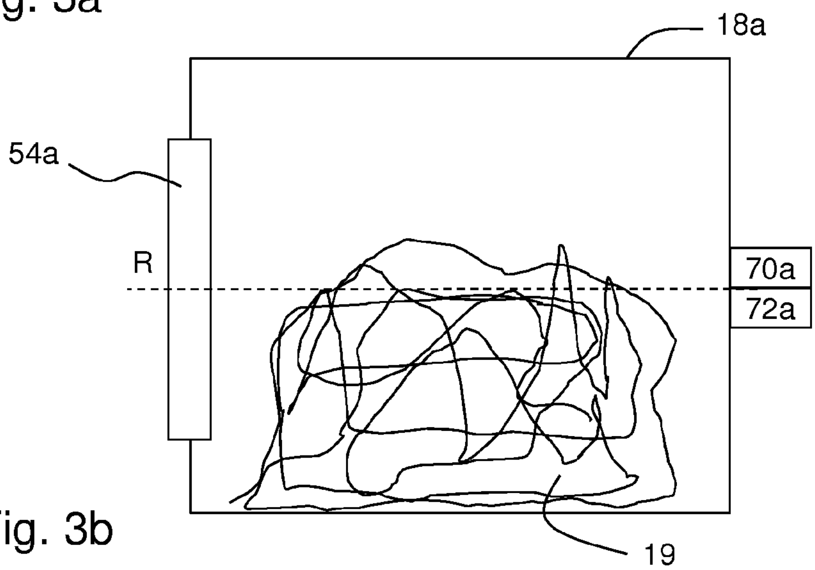


Fig. 3b

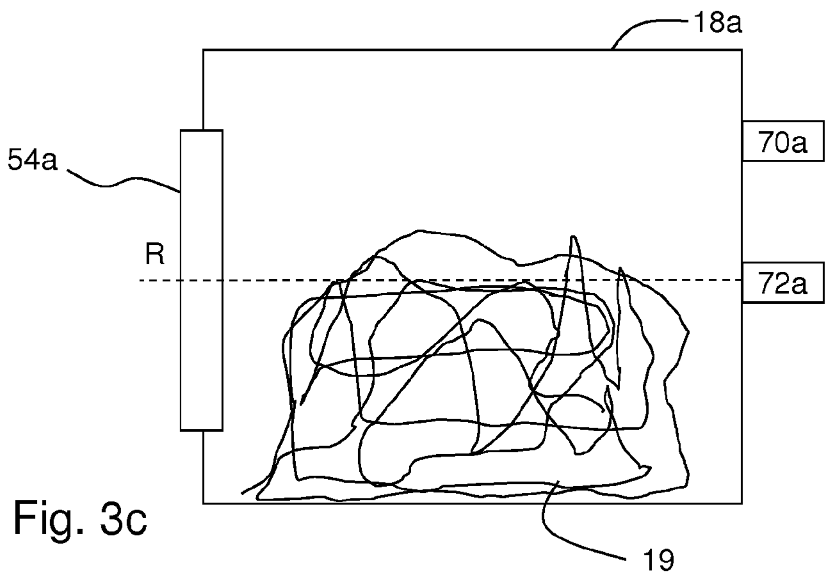


Fig. 3c

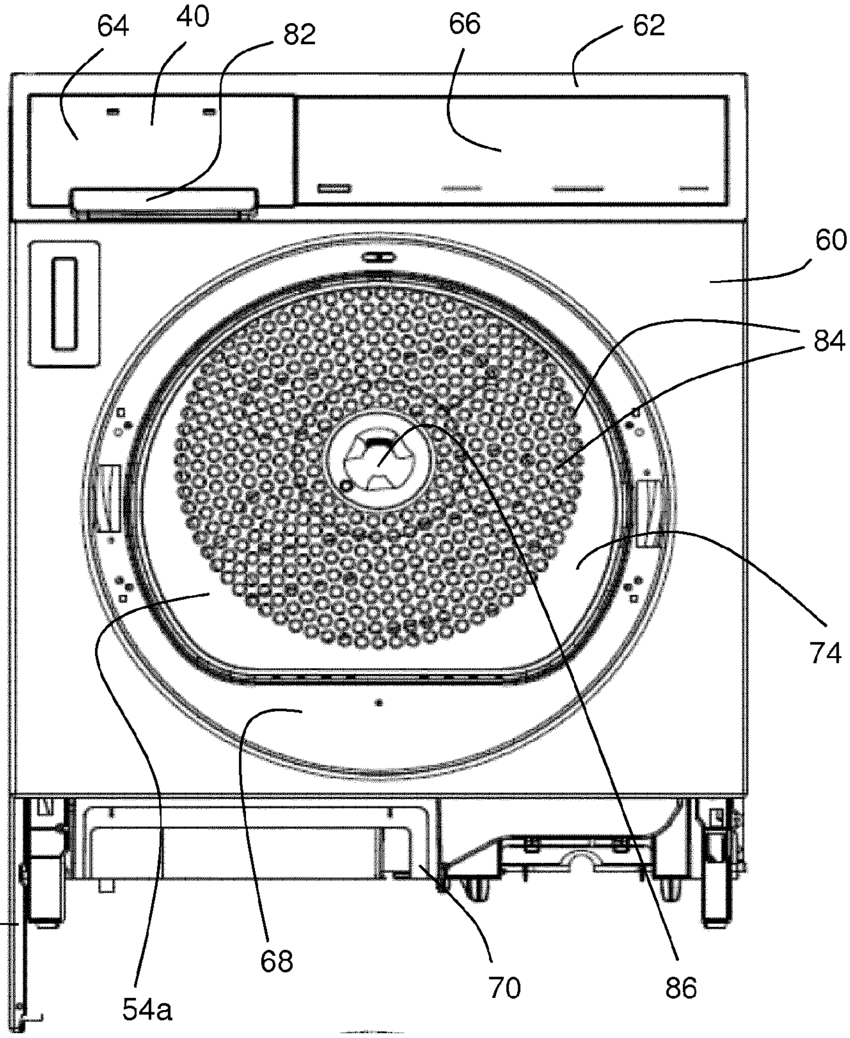

2
64
40
82
66
62
60
84
74
58
54a
68
70
86

Fig. 4

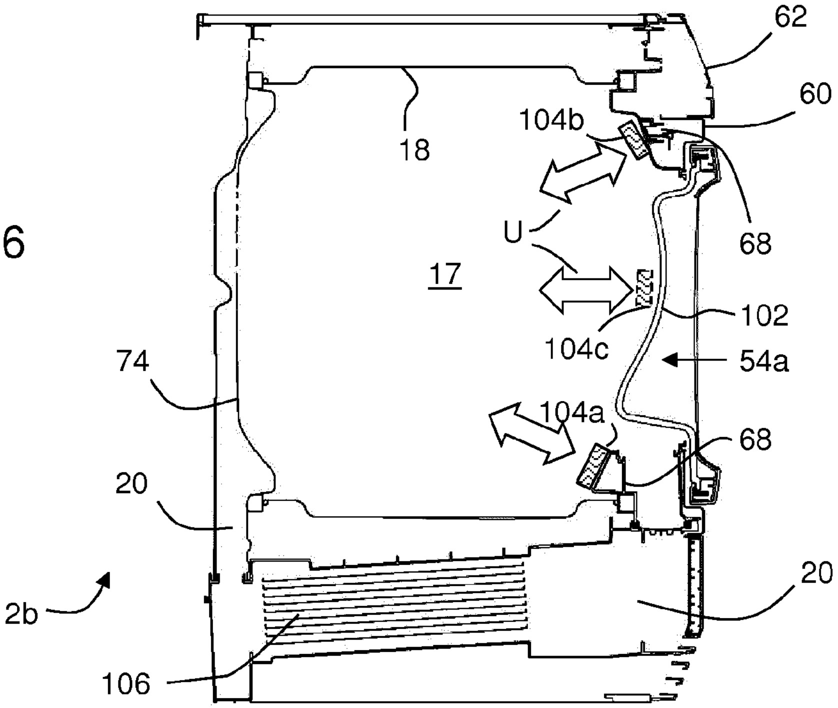

62
60
104b
18
68
U
17
102
104c
54a
74
104a
68
20
20
2b
106

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/066450

A. CLASSIFICATION OF SUBJECT MATTER
INV. D06F58/28
ADD.

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)
D06F

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	EP 1 352 121 B1 (LG ELECTRONICS INC [KR]) 12 April 2006 (2006-04-12) paragraph [0007] - paragraph [0019] paragraph [0024] - paragraph [0031] figure 1	1-3,6-25 4,5
Y A	JP 2009 039145 A (PANASONIC CORP) 26 February 2009 (2009-02-26) paragraph [0001] - paragraph [0006] paragraph [0013] - paragraph [0025] paragraph [0045] - paragraph [0051] figures 1-3	1-3,6-25 4,5
Y	EP 2 436 833 A1 (PANASONIC CORP [JP]) 4 April 2012 (2012-04-04) paragraph [0013] paragraph [0016] - paragraph [0020] figure 1	23

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 March 2015	08/04/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bermejo, Marco

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

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International application No
PCT/EP2014/066450

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