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(54) **Method of conducting a drying cycle in a laundry treating machine, laundry treating machine and electronic controller unit**

(57) The present application in particular relates to a method of conducting a drying cycle for drying wet laundry (7) in a laundry treating machine (1). It is proposed that at least one operational condition of the drying cycle is controlled in a function of latent power (LP) corresponding to the power factually needed for evaporating residual moisture from the laundry (7).

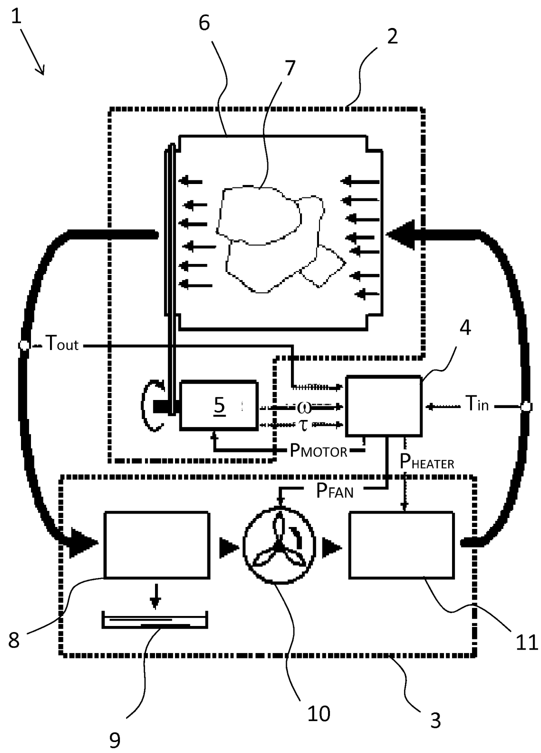

FIG. 1

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Description

[0001] The present invention in particular relates to a method of conducting a drying cycle in laundry treating machines, such as for example domestic laundry dryers or domestic laundry wash-dryers.

[0002] Laundry drying cycles and programs implemented with laundry treating machines are adequate for obtaining reduced moisture levels of laundry after laundry cleaning cycles. Regarding laundry drying cycles, it is desirable to automatically stop the drying cycles at desired or selected moisture levels of laundry. Here it may be and has already been contemplated to use specific moisture or humidity sensors for determining the laundry moisture levels. However, such sensors in general are quite expensive and complex to implement.

[0003] Other attempts of estimating the laundry moisture level have been proposed, inter alia based on signals available from the laundry treating machine. However, the proposed methods still leave room for improvement in efficiency, accuracy and cost.

[0004] Therefore, it is an object of the invention to provide an improved method of controlling a drying cycle of a laundry treating machine. In particular a respective method shall be provided which shall be easily implementable and which shall be suitable for more accurately conducting drying cycles of laundry treating machines. The proposed method in particular shall also allow for automatically determining end- or stop-points of drying cycles for drying laundry. Further, a laundry treating machine and a respective electronic controller unit implementing a respective method shall be provided.

[0005] The above mentioned object is solved by claims 1, 14 and 15. Embodiments of the invention result from respective dependent claims.

[0006] According to claim 1, a method of conducting or controlling a drying cycle for drying wet laundry in a laundry treating machine or apparatus is provided. The laundry treating machine may for example be a laundry dryer or a washer-dryer, both in particular implemented as household type appliances.

[0007] Drying cycles in respective machines are conducted with the aim of drying wet laundry present after wet washing cycles applied to laundry.

[0008] Respective drying cycles may be adapted to extract moisture from the wet laundry, and to automatically end in case that a defined or selected or preset residual moisture level or moisture content is reached. The term residual moisture level in particular shall relate to the amount or relative amount of moisture, i.e. water, still present in laundry, after a washing cycle, or, in particular, after a certain duration of the drying cycle.

[0009] A drying cycle as such may constitute an overall drying phase of drying laundry, but may also relate to selected sections or subsections of a superior or embracing drying phase or drying program to be executed by the laundry treating machine. This in particular shall mean that a drying program may comprise several drying cycles. The single drying cycles, however at least one of them may be conducted or controlled according to a method as proposed herein.

[0010] An exemplary moisture level may for example relate to residual moisture contents suitable for or adequate for ironing the laundry after drying. Moisture levels suitable for ironing may be in the range of about 12%.

[0011] Another exemplary moisture level may relate to residual moisture contents suitable for or adequate for immediately putting dried laundry into a wardrobe and the like. In the latter case, the moisture level preferably is close to 0% in order to avoid mould stains and the like.

[0012] In the exemplary moisture levels as mentioned beforehand, the drying cycles for wet laundry have to be conducted differently, as the residual moisture content in case for ironing has to be somewhat higher than the moisture content of laundry ready to be put into the wardrobe. As can be seen, the drying cycles are required to be stopped at adequate laundry moisture levels, which, as set out further below, will and is possible with the method proposed herein.

[0013] The proposed method requires that at least one operational condition of the drying cycle, in particular an end or stop condition, is controlled in or as a function of latent power corresponding to or representative of the power factually needed for evaporating residual moisture, in particular needed for evaporating a given amount of moisture, from the wet laundry.

[0014] The terms "corresponding to" or "representative of" in particular shall express, that the latent power either may be an exact or an approximate value or measure of the factual power needed for evaporating moisture. In case that the latent power represents an approximate value, it is desirable that the approximation accuracy is best in the region of or at the end or stop condition of the drying cycle. Examples or embodiments of such methods are given below in more detail.

[0015] It has been found out by the inventors, that using the latent power as herein proposed is comparatively effective in accurately determining or identifying end, stop or halt conditions for laundry drying cycles. In particular, the proposed method is adequate for halting or stopping the drying cycle at given or defined moisture or drying levels of laundry, placed in a drying drum of the laundry treating machine.

[0016] A further advantage, which will also be described further below, is that the latent power can be determined or calculated from operational or operating parameters of the laundry treating machine. Such determination and/or calculation can be carried out with reduced effort and complexity as compared to known techniques. In particular, comparative expensive moisture sensors can be dispensed with.

[0017] Further, the accuracy of stopping or halting the drying cycle at given moisture levels of the laundry can be greatly improved as compared to known solutions, in particular solution using only a measure of electromechanical effort to rotate the laundry drum.

[0018] One particular advantage of the proposed method is that it is possible to automatically stop the drying cycle at the desired moisture level, in particular without extra or additional user interaction.

[0019] As already mentioned, and according to embodiments of the invention, the latent power may be used for controlling, in particular automatically controlling, a stop or halt condition of the drying cycle in which drying of the laundry is stopped or halted.

[0020] The stop condition may for example be an end-point or intermediate end-point of a drying program executed by the laundry drying machine. Note that a drying process or program may comprise several drying phases or drying cycles, each of which may be controlled according to the proposed method.

[0021] It shall be noted, that with the proposed method, the latent power may be used as a sole parameter or control variable for the drying process. The latent power may be determined or calculated as set out further below.

[0022] In particular, automatically controlling the end condition of the drying cycle or end of operation of the drying cycle of the laundry dryer can greatly improve ease of use of the laundry treating machine. As an example, the drying cycle can be stopped if a preset or user selected moisture level is reached. Preset moisture levels may for example be fixed in operating programs selectable by the user. The selection of desired moisture levels by the user may also be carried out according to a user input via a user interface.

[0023] If required or desired, post-drying processes or procedures occurring after stopping the drying cycle of the laundry treating machine may be considered in controlling the drying cycle. If for example, it is known that laundry will remain in a drying chamber of the laundry treating machine for a certain period of time after stopping the drying cycle, and the moisture level of laundry shall still be suitable for ironing, the drying cycle could be stopped at a somewhat higher moisture level taking into account the post-drying processes.

[0024] If a certain moisture level has to be obtained at a certain future point of time, and conventional operation of the drying cycle would finish by far earlier, the method could in a variant be adapted to pause the drying cycle for a certain period of time and resume drying at a later point of time in order to obtain the desired moisture level at the preset future point of time. Here, the method may comprise a step or function of extrapolating the moisture level in order to be able to determine intermediate waiting or idle times. A respective function may also be used to determine and to indicate to a user the residual time until the desired moisture level is reached, i.e. the time remaining up to the end of the drying cycle.

[0025] In this connection, it shall be mentioned that the latent power and/or a difference between the latent power and a latent power threshold or a time course thereof can be displayed, in particular to at least indicate the progress of drying.

[0026] In embodiments, the latent power is calculated from at least one operational parameter and/or operating parameter of the laundry treating machine.

[0027] Operational parameters in particular shall relate to fixed parameters influencing or relevant or affecting operation of the machine, in particular the drying cycle.

[0028] Operating parameters in particular shall relate to parameters that may vary or change during operation of the machine, and which influence, are relevant, affect or are representative of certain operational states of the laundry treating machine. Variations or changes in the operating parameters may be caused or affected by operation of the machine itself.

[0029] Using parameters as mentioned above has the advantage that a wealth of different drying processes can be handled with a single method. The operational and/or operating parameter/s may be selected from the group as set out below. Note that at least one of the parameters may be used.

[0030] In general, laundry dryers use air as a process medium which is passed through laundry, contained in a drying chamber in most cases implemented as a drying drum. In passing the process medium through laundry, moisture contained in the laundry is extracted and discharged via the process medium or process air. In more detail, hot or heated and dry air is applied to laundry in the drying chamber. The air takes up moisture and exits the drying chamber with higher humidity and lower temperature as compared to the input.

[0031] The mentioned temperatures, i.e. a process air temperature at a dryer input and a process air temperature at a dryer output may be used as parameters as indicated mentioned above. The temperatures may be jointly used, or they may be used independently, in particular as single parameters. The terms dryer input and dryer output in particular shall relate to a process medium input and output, respectively, of a drying unit or a dryer module, in particular a drying chamber, of the laundry treating machine.

[0032] A further parameter that may be utilized for determining or calculating the latent power is the power consumption needed for drying. The power consumption may be deduced or extracted from the power input of the laundry treating machine or a dryer unit of the laundry treating machine during the drying cycle. Power consumption of driving motors, such as for example motors for driving a drying drum, may also be used.

[0033] In general, as the weight of the laundry gradually decreases during the drying cycle, the motor power or drying power consumption may gradually decrease in analogy to the moisture content of laundry. For example, the fact that the motor power and/or drying power consumption decreases and enters or approaches a plateau may be indicative of the fact that laundry has reached a minimum or comparative low moisture content, which in turn may be used as a stop condition for the drying cycle.

[0034] Other parameters that may be considered are temperature, heat and/or power transfer characteristics of the dryer, or in general respective characteristics of a dryer unit of the laundry treating machine. The mentioned characteristics may vary between different dryer types. Thus adequate consideration thereof may be beneficial for the desired drying result. A similar parameter that may be used, and which may also vary from dryer to dryer, relates to the power loss or power losses of the dryer or a respective dryer unit.

[0035] Parameters relating to the flow of drying medium, in particular drying or process air, may be related to the power transfer and power transfer characteristics of the drying airflow.

[0036] Other suitable parameters related to the dryer or drying unit may be the drying drum speed, the drying drum torque, the speed of a fan for circulating drying air, structural data of laundry drying components of the laundry treating machine, in particular such as geometry, used materials and others.

[0037] Finally also parameters such as the power consumption of a heat pump compressor and the power consumption of a heating element for heating drying air or the drying medium may be considered.

[0038] Using one or several, in particular an arbitrary combination of, parameters as mentioned above is effective in accurately determining or calculating the latent power, which in turn may result in a more accurate control of drying cycles.

[0039] In embodiments, the latent power may be calculated on operating and/or operational parameters of a drying drum module of the laundry treating machine. The operating and/or operational parameter may be at least one of power transfer and power transfer characteristics of the drying airflow, in particular a process air temperature at an input of a drying drum, a process air temperature at the drying drum output, a flow rate of drying air through the drying drum, the power consumption of a drying drum driving motor, thermal transient contributions of the drying drum module, power losses in or at the drying drum module, structural data of laundry drying components of the laundry treating machine, such as geometry and used materials.

[0040] As can be seen, the parameters may be specifically selected for the drying drum module of the laundry treating machine. The drying drum module may comprise a drying drum and related elements and components needed for operating the laundry treating machine in a drying mode.

[0041] In embodiments the latent power is calculated, in particular approximated, on the basis of operational and operating parameters of the drying drum module according to the following formula:

$$LP \cong K_1 \cdot T_{in} + K_2 \cdot T_{out} + K_3 \cdot \omega \cdot \tau \qquad (1)$$

[0042] In the formula (1), representing a linear combination of three factors, LP is the latent power, T_{in} is the temperature of drying air entering the drying drum, T_{out} is the temperature of drying air leaving the drying drum, ω is the drying drum speed, τ is the drying drum torque, and K_1, K_2 and K_3 represent a first group of weighting factors or coefficients.

[0043] The proposed formula (1) has been found to be appropriate in end or final phases of a drying cycle. Based on the formula (1), the latent power LP can at least be approximated and the drying cycle can be stopped or halted at the desired laundry moisture level.

[0044] The first group of weighting factors or coefficients may be experimentally calibrated and once calibrated, may be stored in a memory of the laundry treating machine for continued use. The other parameters T_{in}, T_{out}, ω and τ, needed for calculation, may be determined by sensors or directly from the machine operational data.

[0045] The formula (1) given above is based on the more general fact that the latent power may be determined or calculated based on data related to the drying drum module as a function of power contributions related to process air (P_{AIR}), driving motor(s) (P_{MOTOR}), heat transfer characteristics, in particular thermal transient contributions of the system ($P_{SYS-TRANS}$), and power loss (P_{LOSS}). The contribution of the air P_{AIR} may depend on the input and output temperatures at the drying drum inlet and outlet, respectively, and on the drying air flow rate. The power losses P_{LOSS} may be related or dependent on temperatures of the drying air and environment.

[0046] On a more general basis, the latent power may be determined or estimated as a function of the above mentioned contributions, i.e. $LP \cong func(P_{AIR}, P_{MOTOR}, P_{SYS-TRANS}, P_{LOSS})$.

[0047] In embodiments, the latent power may be calculated or determined based on operating and/or operational parameters of a heating or heat exchanging module of the laundry treating machine. This requires that the laundry treating machine comprises a heating module for heating process air and/or a heat exchanging module for heating and/or drying/condensing process air.

[0048] Here it shall explicitly be mentioned, that the proposed method may be applied to laundry treating machines either comprising conventional heating elements for drying process air and/or comprising a heat exchanging modules, such as heat pump modules, involved in laundry drying.

[0049] In the previous embodiment related to the heating or heat exchanging module, the operating and/or operational parameter may be at least one of a power transfer and transfer characteristic of the drying airflow, an input power of a heating element for heating drying air, an input power of a heat exchanger, in particular for heating and/or drying air, power losses in or at the heating module or heat exchanging module, an air temperature at an input of the heating module or heat exchanging module, a process air temperature at an input and/or output of the heating or heat exchanging module, speed and/or power consumption of a drying air fan, thermal transient contributions of the heating or heat exchanging module, power losses in or at the heating or heat exchanging module, structural data of the laundry drying components of the laundry treating machine, in particular such as geometry, used materials and the like.

[0050] Any of the mentioned parameters and combinations thereof may be used in determining or calculating the latent power. The calculation of the latent power may be enhanced by using an appropriate set of parameters.

[0051] In particular in case that the latent power is calculated on operational and operating parameters of the heating module and/or heat exchanging module, the latent power in an end phase of a drying cycle may be approximated according to the following formula:

$$LP \cong K_4 \cdot T_{in} + K_5 \cdot T_{out} + K_6 \cdot P_{DRY\_POWER\_IN} \quad (2)$$

[0052] In formula (2) LP is the latent power. T_{in} is the temperature of drying air entering the heating or heat exchanging module. T_{out} is the temperature of drying air leaving the heating or heat exchanging module. $P_{DRY\_POWER\_IN}$ is either related to the power consumption of a heater of the heating module or to the power consumption of a compressor of the heat exchanging module. K_4, K_5 and K_6 represent a second group of weighting factors or coefficients.

[0053] The above formula (2) has been found to be adequate for controlling in particular the end points or end sections of a drying cycle in case that operational and operating data from a heating module or heat exchanging module are used. The second group of weighting factors may be determined experimentally, and, if the case may be, may be stored in an electronic controller related memory of the laundry treating machine.

[0054] The proposed formulae (1) and (2) describe comparatively simple linear combinations of respective factors, and can easily be calculated from the known weighting factors and operational and operating parameters. The operational and operating parameters may be measured or determined via suitable sensors, for example. Hence, a comparatively simple yet accurate and effective way of determining the latent power on the basis of parameters relating to a heating or heat exchanging module can be implemented.

[0055] As already indicated above, the first and second groups of weighting factors may in embodiments be experimentally calibrated. Calibration of the weighting factors may be conducted once or may be carried out repeatedly, in particular prior and/or during a drying cycle. The weighting factors may be stored in a memory related to an electronic controller unit of the laundry treating machine. The stored weighting factors may be used for subsequent calculations of the latent power and/or for cross-checking or verifying new calibrations.

[0056] In embodiments, a latent power threshold is used as a parameter for stopping the drying cycle. Here it shall be noted again, that the drying cycle may be implemented or be part of a drying program of the laundry treating machine. In particular, a stop or halt condition for a drying cycle as proposed herein may relate to an intermediate drying phase of a drying program of the laundry treating machine.

[0057] The latent power threshold may be related to the residual moisture content of laundry. As an example and as already indicated above, the latent power threshold may relate to moisture levels adequate for ironing or for putting laundry immediately into a wardrobe without further drying. The threshold may be preset by the laundry treating machine, in particular in accordance with a fixed program, or it may be based on a user input on a user interface.

[0058] In embodiments, the latent power threshold is defined or calculated prior to or during the drying cycle. The latent power threshold may be updated or recalculated during a drying operation.

[0059] The latent power threshold may be determined, calculated, adapted or updated based on at least one of the following parameters: laundry quantity, i.e. the amount of laundry contained in the drying chamber, an initial dryer temperature, the type of drying program, laundry weight, fabric type of the laundry, desired residual humidity at the end of the drying cycle, ambient temperature, an inner temperature of the laundry drying machine, in particular for incorporating machine operative conditions prevailing before or during a drying cycle.

[0060] In addition, parameters such as working parameters of a heat pump system used for drying and/or heating drying air, in particular a heat pump refrigerant medium temperature or pressure, power consumption, compressor speed and others, may be used for determining, calculating, adapting and/or updating the latent power threshold.

[0061] As further parameters for determining the latent power threshold, working parameters of a heater used for drying and/or heating process air can be used, such as for example the power consumption of the heater, the heating temperature, the drying air temperature and the like. The amount of condensed moisture, a machine alarm condition, the slope of a graph representing the time course of the latent power during a drying cycle may also be used as parameters for determining, calculating, adapting and/or updating the latent power threshold.

[0062] The parameters related to determining, calculating, adapting and/or updating the latent power threshold, as mentioned above, may be used individually or in arbitrary combinations, in particular in order to obtain adequate latent power thresholds which may lead to enhanced drying results.

[0063] In embodiments, the proposed method may comprise the steps of:

a. starting a drying program;
b. evaluating laundry to be dried,
c. selecting or determining a latent power threshold,
d. activating laundry drying modules of the laundry treating machine,
e. acquiring operational and/or operating parameters of the laundry treating machine, in particular laundry drying modules, required for calculating an actual latent power or approximated latent power,
f. calculating the actual latent power or approximated latent power,
g. comparing the actual latent power or approximated latent power with the latent power threshold, and
h.α) stopping the drying cycle if the actual latent power is smaller or corresponds to the latent power threshold or approximated value thereof or
h.β) returning to step e) in case that the actual latent power lies above the latent power threshold.

[0064] The steps a to h represent a drying cycle of the laundry treating machine controlled according to a method as proposed herein. A respective drying cycle may be used as a stand-alone drying cycle, or it may be implemented in or be part of a more extensive drying program. This shall in particular mean that the drying cycle may represent one of several phases of a drying program.

[0065] In embodiments, the step (g) may be enabled only when the actual latent power has been determined to be greater than the determined latent power threshold and having a decreasing course over time.

[0066] The proposed method steps are comparatively simple and it can be seen that the drying operation of the laundry treating machine can be accurately controlled.

[0067] In a variant of the previously proposed method, in step c) the latent power threshold is calculated from operational and/or operating parameters of the laundry treating machine. At least step c) may be repeated several times during a drying cycle in order to update the latent power threshold. As to the calculation of the latent power threshold, further reference is made to the description above.

[0068] According to claim 14, a laundry treating machine is proposed, which comprises a laundry drying unit. The laundry drying unit comprises an electronic controller unit configured to operate the laundry drying unit by a method as proposed above, in particular including all embodiments and variants of the method.

[0069] The laundry treating machine may be a tumble dryer or a washer dryer. The laundry drying unit may comprise conventional heating elements for heating the process air, or it may comprise a heat pump system for adequately processing the process air. Reference is also made to the description above, which contents apply mutatis mutandis to the laundry treating machine.

[0070] According to claim 15, an electronic controller unit is proposed which is adapted to control a laundry treating machine, such as for example as proposed beforehand.

[0071] The electronic controller unit comprises a memory in which a program is stored, which is configured to carry out in a laundry treating apparatus a method as described above in particular including all embodiments and variants as given above and further above.

[0072] In addition it shall be mentioned that the invention also may be related to an electronic controller program product adapted to execute a method as proposed above when executed on an electronic controller of a laundry treating machine. The electronic controller program product may comprise a storage unit having stored instructions which upon execution on an electronic controller unit of a laundry treating machine will implement a method as described in more details further above.

[0073] Exemplary embodiments of the invention will now be described in connection with the annexed drawings, in which:

FIG. 1 shows a schematic representation of a drying circuit of a laundry treating machine;

FIG. 2 shows a diagram of the time behavior of moisture content and drying rate during a drying cycle; and

FIG. 3 shows a flowchart of an exemplary drying algorithm.

[0074] FIG. 1 shows a schematic representation of a drying circuit of a laundry treating machine 1. The laundry treating machine 1 in particular may be, but shall not be restricted to, a domestic laundry tumble dryer appliance for drying laundry and cloth. For simplification, the term "appliance" will be used instead of "laundry treating machine 1", however this shall not restrict the scope of protection.

[0075] The appliance 1 comprises a drum module 2, a heat exchanger module 3, respectively surrounded in FIG. 1 by a dashed box for enhanced visibility, and an electronic control unit 4.

[0076] The drum module 2 comprises a driving motor 5 adapted and configured to drive a drying drum 6 in which wet laundry 7 to be dried is accommodated.

[0077] The heat exchanger module 3 comprises a condenser 8 for condensing water from humid drying air. Condensed water is collected in a tank 9 schematically indicated in FIG. 1.

[0078] The heat exchanging module comprises a fan 10 for generating an airflow of process air, which airflow is indicated by arrows in FIG. 1.

[0079] The heat exchanger module 3 further comprises a heater 11, in particular an electronic heater, adapted and configured for reheating the process air after having passed the condenser 8.

[0080] The electronic control unit 4 is configured and adapted to control operation of the appliance 1. In particular the electronic control unit 4 comprises a memory in which a program is stored which upon execution carries out a method in accordance with the present invention.

[0081] For drying laundry 7, the appliance is operated as follows: During a drying cycle, the driving motor 5 rotates the drying drum 6 in which the laundry 7 is accommodated. The fan 10 of the heat exchanger module 3 in combination with adequate ducting and air guides (not shown) generate an airflow of process air through the drying drum 6.

[0082] In more detail, the process air first passes the heater 11, i.e. a hot exchanger, and is heated up and then enters the drying drum 6. The heated and dry process air absorbs moisture of the laundry 7 and then exits the drying drum 6 with reduced temperature and elevated humidity content.

[0083] The humid process air is then passed to and through the condenser 8, i.e. a cold exchanger, where humidity is extracted from the process air by condensation. After that, dry and cooled down process air reenters the heater and is heated up again to recirculate through the drying drum 6.

[0084] It shall be noted, that the present invention may apply to appliances in which an evaporator and condenser of a heat pump system are used as the cold and hot exchangers, respectively. The invention may also be applied to appliances in which an air to air exchanger and an electric heating element may be used as the cold and hot exchangers, respectively.

[0085] The electronic control unit 4 as shown in FIG. 1 is adapted and configured to control operation of the appliance 1, and to acquire a plurality of functional, i.e. operational and operating, parameters.

[0086] Exemplary parameters are the temperature T_{in} of the process air at the drying drum input, i.e. an input temperature T_{in}, the temperature T_{out} of the process air at the drying drum output, i.e. an output temperature T_{out}, a rotational speed ω of the drying drum 6, a torque τ of the drying drum 6, and power consumption P_x of selected components and subunits, in particular the power consumption of the heater 11, the fan 10 and the driving motor 5.

[0087] The water quantity extracted from the laundry per second is commonly known as the drying rate (DR). The time course of the drying rate (DR) is visualized in FIG. 2 (solid line). FIG. 2 also shows the moisture content of the laundry during a drying cycle (dashed line).

[0088] During the drying process or the drying cycle, the drying rate has a typical course in which in particular four different phases A to D can be identified or defined (see FIG. 2):

A first phase A constitutes the warm-up phase. In this transient period the appliance 1, the laundry or clothes, and the water contained in the laundry get warm and are heated up.

A second phase B constitutes a phase of almost constant drying rate DR. The drying rate DR reaches a plateau and essentially remains unchanged, i.e. pretty much stable.

In a third phase C in which the moisture content drops or falls, the drying rate DR goes gradually down. This decrease is mainly caused by the poor remaining moisture content in the laundry. The moisture content in this third phase C may be 15 % or even less. Due to the poor water content, extraction of the residual water becomes more and more difficult as the drying cycle proceeds, so that the drying rate gradually drops.

In the fourth phase D the drying rate still decreases but drops slower than in the third phase, and may reach a minimum value. In the fourth phase the fabrics or laundry are practically dried. It becomes comparatively hard to extract further water.

[0089] As already indicated, the time behavior of the water or moisture content MC of the laundry 7 over the first to fourth phase A to D is shown in FIG. 2 by a dashed line.

[0090] In the third and/or fourth phase C, D, when the laundry 7 is almost dried, the drying rate DR is significantly lower than its maximum which in the exemplary embodiment is reached in the second phase B.

[0091] Therefore, the trend of the drying rate DR may be used for automatically stopping or halting the drying cycle at a desired moisture level. In particular, the drying cycle can be stopped or halted as soon as the drying rate DR drops below a convenient or predefined threshold.

[0092] Practically, a direct measurement of drying rate DR is not feasible, and, if at all, requires pretty much effort. In particular it is the finding of the invention that it is possible use a quantity correlated to the drying rate DR. The quantity is the latent power which may be calculated or approximated, wherein the following relationships may apply:

$$LP = DR * r_0 \quad (3)$$

[0093] In the above formula (3), LP is the latent power [in W], i.e. the power necessary to evaporate the laundry water, wherein DR is the drying rate [in kgH_2O/s] and r_0 [in J/kg] is the water latent heat at the reference temperature of 273 K. Practically, the latent power LP has a very similar course compared to the drying rate DR and, according to the present invention, it can be used in place of DR.

[0094] The present invention in particular provides a procedure for estimating the latent power LP in the dryer and establishes conditions, such as a threshold, for ending or halting, in particular in an automated way, the drying cycle.

[0095] The inventors found out that the latent power LP can be estimated or approximated by computing a flow energy balance that considers all, or at least a selection of relevant energy flows across a closed volume.

[0096] With reference to the FIG. 1, two functional modules, i.e. volumes, can be identified for the appliance 1:

A first functional module is essentially constituted by the drum module 2. The drum module comprises, as set out above, the drying drum 6, in case of an operational condition the laundry 7, and the driving motor 5.

[0097] As an influx, the drum module 2 in particular receives the hot and dry air flow related to the process gas, and the mechanical power from the driving motor 5. The efflux from the drum module 2 in particular may comprise the exiting humid air flow and a heating loss towards the environment. Inside the drum module 2 water is evaporated from the laundry 7.

[0098] Considering all contributions mentioned above for the drum module 2, the latent power LP can be calculated or approximated as a function of four parameters:

$$LP = func(P_{AIR}, P_{MOTOR}, P_{SYS\_TRANS}, P_{LOSS}) \quad (3)$$

[0099] In the above formula (3), P_{AIR} corresponds to the air contribution, and may depend on the temperatures T_{IN} and T_{OUT} at the drying drum input and output, respectively, and on the air flow rate through the drying drum 6. P_{MOTOR} is the contribution of the drive motor 5. P_{SYS_TRANS} represents the thermal transient contribution of the system. And P_{LOSS} represents the power losses, which are related in particular to the air and environment temperatures.

[0100] The latent power LP may be regarded to be described as a function of T_{IN}, T_{OUT}, rotational speed ω of the drying drum 6, torque τ of the drying drum 6, air fan speed, and it may further depend on the structure and/or operation of the appliance, such as geometry, used materials and so on.

[0101] In the final phase of the drying cycle contributions of the thermal transient can be neglected and the latent power LP can be conveniently approximated as a linear combination already mentioned further above:

$$LP \cong K_1 \cdot T_{IN} + K_2 \cdot T_{OUT} + K_3 \cdot \omega \cdot \tau \quad (4)$$

[0102] This formula (4) is comparatively simple but is efficient in automatically controlling drying cycles, in particular end conditions of drying cycles of laundry dryers.

[0103] A second functional module of the appliance 1 is represented by the heat exchanger module 3. The heat exchanger module 3 comprises the cold and hot exchangers, i.e. the condenser 8 and the heater 11.

[0104] At the input of the heat exchanger module 3 connected to an output of the drum module 2, the heat exchanger module 3 receives during a drying operation humid air. Further, the heat exchanger module 3 receives the power required for operating the drying air heating device ($P_{DRY\_POWER\_IN}$). At the output of the heat exchanger module 3, heated and dry process air is provided to be transferred to the drum module 2. In addition, heating loss (P_{LOSS}) towards the environment occurs and may be considered.

[0105] Considering all contributions related to the heat exchanger module 3, the latent power can be calculated or approximated as a function of four parameters:

$$LP = func(P_{AIR}, P_{DRY\_POWER\_IN}, P_{SYS\_TRANS}, P_{LOSS}) \quad (5)$$

[0106] P_{SYS_TRANS} represents the thermal transient contribution of the system;
The air contribution (P_{AIR}) depends on T_{in}, T_{out}, and the flow rate of the process air. Note, that T_{in} in the present case represents the temperature of the process air at the heat exchanger module output and Tout represents the temperature of the process air at the heat exchanger module input, as indicated in FIG. 1.

[0107] In case that the heat exchanger module 3 comprises and uses a heat pump system, $P_{DRY\_POWER\_IN}$ is related to the compressor power consumption during the drying operation. In case that the heat exchanger module 3 uses an electric heating element for heating the process air, $P_{DRY\_POWER\_IN}$ corresponds to the electric power consumption of the electric heater.

[0108] In general, the latent power LP can be expresses as a function of T_{in}, T_{out}, $P_{DRY\_POWER\_IN}$, speed of the fan 10, and the structure and/or operation of the appliance 1, such as for example geometry, used materials and the like.

[0109] For the heat exchanger module 3, the contribution of the thermal transient can be neglected in the final or end phase of a drying cycle. Hence, the latent power for the heat exchanger module 3 can be approximated in a linear combination as follows:

$$LP \cong K_4 \cdot T_{IN} + K_5 \cdot T_{OUT} + K_6 \cdot P_{DRY\_POWER\_IN} \quad (6).$$

[0110] In the formula (6), K_4 to K_6 are weighting or calibration factors for the parameters as mentioned above.

[0111] The weighting factors K_1, K_2, K_3, K_4, K_5, and K_6 may be experimentally calibrated. They may be dependent on the structure and/or operation of the appliance 1, in particular the drum module 2 and/or heat exchanger module 3. As an example, the mass flow of the process air, corresponding or relating to the speed of the fan 10, as well as the drying circuit geometry may affect K_1 to K_6. It shall be noted that K_1 to K_6, in more detail at least one of the weighting factors K_1 to K_6, may vary or change during time and may be adapted or corrected accordingly.

[0112] Once the values of the weighting factors K_1 to K_6 are defined, known or determined they can be stored in a memory of the electronic control unit 4 in order to be available for determining, calculating and/or approximating the latent power LP during subsequent drying cycles.

[0113] Based on the latent power LP calculated in particular according to formulae (4) or (6), the electronic control unit 4 can determine an end or halt condition in which the drying cycle has to be stopped or halted. For determining or identifying the end or halt condition, a latent power threshold LP_{THR} may be used. The latent power threshold LP_{THR} may be stored in the memory of the electronic control unit 4.

[0114] In general, the latent power threshold LP_{THR} can be determined or calculated from a plurality of values and/or parameters relating or corresponding to for example the:

- laundry quantity;
- initial dryer temperature;
- type of drying program;
- laundry weight;
- fabric type of the laundry;
- desired residual humidity at the end of the drying cycle;
- ambient temperature;
- inner temperature of the laundry drying machine;
- working parameters of a heat pump system used for drying and/or heating drying air;
- working parameters of a heater used for drying and/or heating drying air;
- amount of condensed moisture;
- machine alarm conditions;
- slope of a graph representing the time course of the latent power during a drying cycle;

[0115] In particular, the latent power threshold LP_{THR} can be selected or determined in dependence of the laundry quantity and/or the initial dryer temperature and/or a drying program selected by a user.

[0116] Table 1 gives an example of the selection of latent power thresholds LP_{THR1} to LP_{THR6} in dependence of laundry quantity and drying program selection. Two different drying programs, one for obtaining laundry suitable for being ironed, in which a residual humidity of laundry is about 12%, and one for obtaining laundry suitable to be immediately put into a wardrobe, in which a residual humidity of laundry is 0% or at least close to 0%. Further, three different categories for laundry quantity, i.e. load levels, are provided.

Table 1: Example of threshold selection for latent power.

LOAD LEVEL	LOAD QUANTITY	LATENT POWER THRESHOLD (LP_{THR})	
		IRONING PROGRAM (res. humidity 12%)	WARDROBE PROGRAM (res. humidity 0%)
1	$0 \leq L \leq 3Kg$	LP_{THR1}	LP_{THR4}
2	$3Kg < L \leq 6Kg$	LP_{THR2}	LP_{THR5}
3	$6Kg < L \leq 9Kg$	LP_{THR3}	LP_{THR6}

[0117] In case that the latent power LP will reach or fall below the latent power threshold LP_{THR}, the drying cycle or drying program will be automatically stopped. Since the latent power threshold LP_{THR} for determining the drying cycle or drying program stop may be defined in an initial stage of the drying process, i.e. when the course of the drying process is in the phase A depicted in FIG. 2, and it is used in the last part of the process, the activation of comparison between the actual latent power LP and the determined threshold LP_{THR} is operated once it can be reasonably assumed that the course of the drying process is in phase B or C shown in FIG. 2, i.e. in a phase where the drying rate DR, or the actual latent power LP, is expected to decrease over time. In this way, it can be ensured that a premature stop of a drying cycle or drying program does not occur; in particular, it is ensured that a drying stop does not occur during phase A of the drying course. In order to be sure that drying process is stopped only during a phase wherein the actual latent power decreases over time, the comparison between the actual latent power LP and the determined threshold LP_{THR} may be activated only after the actual latent power has been found to be greater than the determined threshold LP_{THR} since the beginning of the drying process, or after a predetermined time from said beginning of the drying process, or after a parameter indicating the status of the laundry drum within the drum 6 has reached or passed a predetermined value. Such parameter indicating the laundry status may be, for example, an electrical or electro-mechanical parameter of the drum motor 5, such as the motor power consumption, the current and/or voltage supplied to the motor, the motor torque or a combination thereof. Termination of the drying program may be executed or carried out by the electronic control unit 4.

[0118] FIG. 3 shows in a flowchart of an exemplary drying algorithm, which will be described in more detail below.

[0119] After starting and initializing the drying program or drying cycle, which may be part of a higher-level process, in particular drying process, the appliance 1, for example the electronic control unit 4, starts to evaluate the laundry quantity. This may for example be done by using a weight sensor, a weight determining algorithm, or based on a user input.

[0120] Thereafter, a latent power threshold LP_{THR} is selected or determined. The latent power threshold LP_{THR} in the present example is selected as a function of the laundry quantity and the drying program selected.

[0121] In a subsequent step, the electronic control unit 4 activates the components and subsystems of the appliance 1 that are needed for conducting the drying cycle. In particular, the heating system is switched on and rotation of the drying drum is started.

[0122] After activation of the drying components, the system, in particular the electronic control unit 4, acquires the operational parameters T_{in}, T_{out}, and $P_{DRY\_POWER\_IN}$ which have been described in more detail further above. The parameters may be acquired by suitable sensors provided, or already available, at respective locations of the appliance 1.

[0123] In a next step, the latent power LP is calculated from the parameters acquired in the preceding step. In the example given in FIG. 3, the latent power LP is calculated according to formula (6).

[0124] The weighting factors K_4, K_5, and K_6 are retrieved from a memory of the electronic control unit 4, where they had been stored beforehand. The weighting factors K_4, K_5, and K_6 may be determined as set out further above.

[0125] In a next step, the calculated latent power LP is compared with the latent power threshold LP_{THR}. As described above the comparison between the calculated latent power LP and the latent power threshold LP_{THR} is enabled only when it can be assumed that the laundry drying course is in phase B or C as depicted in FIG. 2. For example, the comparison between the actual LP value and the threshold LP_{THR} can be enabled after the actual latent power has been found to be greater than the determined threshold LP_{THR} since the beginning of the drying process. Further conditions to enable the comparison between the actual LP value and the threshold LP_{THR} the have been disclosed above. If the latent power LP is still larger than the latent power threshold LP_{THR}, the algorithm will continue to a subsequent loop and re-acquire the parameters T_{in}, T_{out}, and $P_{DRY\_POWER\_IN}$, re-compute the latent power LP and so on.

[0126] If in the step of comparing the calculated latent power LP with the latent power threshold LP_{THR} it is determined that the latent power LP is smaller or equals the latent power threshold LP_{THR}, which is indicative of the end of the drying cycle, the algorithm exits the loop and in a next step causes the drying process, in particular the heating system, drying fan, drum rotation and others to be stopped. In this state, the algorithm has reached the end and the drying cycle is finished.

[0127] As can be seen, the proposed method allows in a comparatively easy and reliable way to control end conditions of drying cycles in laundry dryers.

[0128] The algorithm as described in connection with FIG. 3 is representative for a heat pump based heat exchange module 3. A similar algorithm may be set up for a heater based heat exchange module, in particular by using the adequate formula for calculating the latent power LP.

[0129] The algorithm as shown and described in connection with FIG. 3 may be extended or broadened and in general is not restricted to the steps and actions as described further above. For example, a modified algorithm may provide recalculating the latent power threshold during the drying cycle, in particular during the drying loop. In addition, other, additional or alternative parameters, and formulas may be used for calculating, determining or approximating the latent power LP. Further modifications are conceivable, in particular according to any embodiment and variant mentioned in the description above and further above.

[0130] The proposed method and in particular the described algorithm in particular have the following advantages:

- the proposed control method is suitable for comparatively accurately obtaining final or residual laundry moisture levels;
- complicated or extra humidity and/or moisture sensors can dispensed with;
- the method and algorithm can be applied to different dryer topologies, in particular based on electric heaters, heatpump systems, washer-dryer and so on;
- a favourable uniformity of drying can be obtained even for different and varying load quantities;
- the drying algorithm and method can be applied to different types of laundry and textiles, e.g. cotton, synthetic, etc.

[0131] Favourable characteristics that may contribute to the benefits or quality of the proposed method and algorithm may be summarized as follows:

- usage of the latent power LP for controlling the drying process;
- determination, in particular approximation, of the latent power as a function of drying drum input and/or output temperatures (T_{in}, Tout), power consumption required for heating process air at the hot exchanger ($P_{DPY\_POWER\_IN}$), and/or motor power (P_{MOTOR}) ;
- utilization of weighting factors K_i for determination of the latent power, which may be dependent on process air flow rate, in particular fan speed, and on geometry and/or operational data of the appliance;
- possibility to determine or extract the latent power LP based on data from the drying drum module (2) and/or the heat exchanger module (3);
- providing a latent power threshold LP_{THR} that may be selected or determined as a function of load quantity, drying program and/or initial dryer temperature;
- automated stop or halt of the drying process or drying cycle in case that the latent power reaches and/or drops below the latent power threshold;

List of reference numerals

[0132]

1	laundry treating machine
2	drum module
3	heat exchanger module
4	electronic control unit
5	driving motor
6	drying drum
7	laundry
8	condenser
9	tank
10	fan
11	heater
DR	drying rate
MC	moisture content
A-D	drying phases

Claims

1. Method of conducting a drying cycle for drying wet laundry (7) in a laundry treating machine (1), wherein at least one operational condition of the drying cycle is controlled in a function of latent power (LP) corresponding to the power factually needed for evaporating residual moisture from the laundry (7).

2. Method according to claim 1, wherein the latent power (LP) is used for controlling a stop condition in which the drying cycle is stopped.

3. Method according to at least one of claims 1 and 2, wherein the latent power (LP) is calculated from at least one operational parameter and/or operating parameter of the laundry treating machine (1), preferably selected from the following group: process air temperature at a dryer input (T_{in}), process air temperature of a dryer output (T_{out}), power consumption needed for heating drying air ($P_{DPY\_POWER\_IN}$), power consumption of driving motors (P_{MOTOR}), temperature, heat and/or power transfer characteristics of the dryer, power loss (P_{LOSS}) of the dryer, power transfer and transfer characteristics of the drying airflow, drying drum speed (ω), drying drum torque (τ), speed of a drying air fan, structural data of the laundry drying components of the laundry treating machine, power consumption of a heat pump compressor ($P_{DRY\_POWER\_IN}$), power consumption of a drying air heating element ($P_{DRY\_POWER\_IN}$).

4. Method according to at least one of claims 1 to 3, wherein the latent power (LP) is calculated based on operating and/or operational parameters of a drying drum module (2) of the laundry treating machine (1), wherein the operating and/or operational parameter is at least one of power transfer and power transfer characteristics of the drying airflow, in particular a drying air temperature (T_{in}) at an input of a drying drum (6) of the drying drum module (2), a process air temperature (Tout) at the drying drum output, a flow rate of drying air through the drying drum, the power consumption of a drying drum driving motor (P_{MOTOR}), thermal transient contributions of the drying drum module (2), in particular of the drying drum (6), power losses (P_{LOSS}) in or at the drying drum module (2), structural data of the laundry drying components of the laundry treating machine (1).

5. Method according to claim 4, wherein the latent power (LP) is approximated based on operational and operating parameters of the drying drum module (2) according to the following formula:

$$LP \cong K_1 \cdot T_{in} + K_2 \cdot T_{out} + K_3 \cdot \omega \cdot \tau ,$$

wherein LP is the latent power, T_{in} is the temperature of drying air entering the drying drum (6), T_{out} is the temperature of drying air leaving the drying drum (6), ω is the drying drum speed, τ is the drying drum torque, and K_1, K_2 and K_3 represent a first group of weighting factors or coefficients.

6. Method according to at least one of claims 1 to 5, wherein the latent power (LP) is calculated based on operating and/or operational parameters of a heating or heat exchanging module (3) of the laundry treating machine (1), wherein the operating and/or operational parameter is at least one of a power transfer and transfer characteristic of the drying airflow, an input power ($P_{DRY\_POWER\_IN}$) of a heating element (11) for heating drying air, an input power of a heat exchanger ($P_{DPY\_POWER\_IN}$), power losses (P_{LOSS}) in or at the heating or heat exchanging module (3), a process air temperature (T_{out}, T_{in}) at an input and/or output of the heating or heat exchanging module (3), speed and/or power consumption of a drying air fan, thermal transient contributions of the heating or heat exchanging module (3), power losses (P_{LOSS}) in or at the heating or heat exchanging module (3), structural data of the laundry drying components of the laundry treating machine (1).

7. Method according to claim 6, wherein the latent power (LP) is approximated based on operational and operating parameters of heating or heat exchanging module (3) according to the following formula:

$$LP \cong K_4 \cdot T_{in} + K_5 \cdot T_{out} + K_6 \cdot P_{dry\_power\_in},$$

wherein LP is the latent power, T_{in} is the temperature of drying air exiting the heating or heat exchanging module (3), T_{out} is the temperature of drying air entering the heating or heat exchanging module (3), $P_{DRY\_POWER\_IN}$ is either related to the power consumption of a heater (11) of the heat exchanging module (3) or to the power consumption of a compressor of the heat exchanging module (3), and K_4, K_5 and K_6 represent a second group of weighting factors or coefficients.

8. Method according to claim 5 or 7, wherein the first and second group of weighting factors (K_1, K_2, K_3, K_4, K_5, K_6)

are experimentally calibrated, and are stored in a memory related to an electronic controller unit (4) of the laundry treating machine (1).

9. Method according to at least one of claims 1 to 8, wherein a latent power threshold (LP_{THR}) is used as a parameter for stopping the drying cycle, preferably in case that the latent power (LP) falls below or reaches the latent power threshold (LP_{THR}).

10. Method according to claim 9, wherein the latent power threshold (LP_{THR}) is defined or calculated prior to or during the drying cycle, and wherein the latent power threshold (LP_{THR}) preferably is recalculated or updated during the laundry drying operation.

11. Method according to one of claims 9 and 10, wherein the latent power threshold (LP_{THR}) is determined, calculated, adapted and/or updated based on at least one of the following parameters: laundry quantity (L), initial dryer temperature, type of drying program, laundry weight, fabric type of the laundry, desired residual humidity at the end of the drying cycle, ambient temperature, an inner temperature of the laundry drying machine, working parameters of a heat pump system used for drying and/or heating drying air, working parameters of a heater used for drying and/or heating drying air, amount of condensed moisture, machine alarm conditions, slope of a graph representing the time course of the latent power (LP) during a drying cycle.

12. Method according to at least one of claims 1 to 11, comprising the steps of:

a.starting a drying program;
b.evaluating laundry to be dried,
c. selecting a latent power threshold (LP_{THR}),
d.activating laundry drying modules (2, 3) of the laundry treating machine (1),
e.acquiring operational and/or operating parameters of the laundry treating machine (1), in particular laundry drying modules (2, 3), required for calculating the actual latent power (LP) or approximated latent power (LP),
f.calculating the actual latent power (LP) or approximated latent power (LP),
g.comparing the actual latent power (LP) or approximated latent power (LP) with the latent power threshold (LP_{THR}), and
h.α) stopping the drying cycle if the actual latent power (LP) is smaller or corresponds to the latent power threshold (LP_{THR}) or
h.β) returning to step e) in case that the actual latent power (LP) lies above the latent power threshold (LP_{THR}).

13. Method according to claim 12, wherein in step c) the latent power threshold (LP_{THR}) is calculated from operational and/or operating parameters of the laundry treating machine (1), and wherein step c) is preferably repeated several times during a drying cycle in order to update the latent power threshold (LP_{THR}).

14. Laundry treating machine (1) comprising a laundry drying unit (2, 3) which comprises an electronic controller unit (4) configured to operate the laundry drying unit (2, 3) by a method according to at least one of claims 1 to 13.

15. Electronic controller unit (4) adapted to control a laundry treating machine (1), wherein the electronic controller unit (4) comprises a memory in which a program is stored, which is configured to carry out in a laundry treating apparatus (1) a method according to at least one of claims 1 to 13.

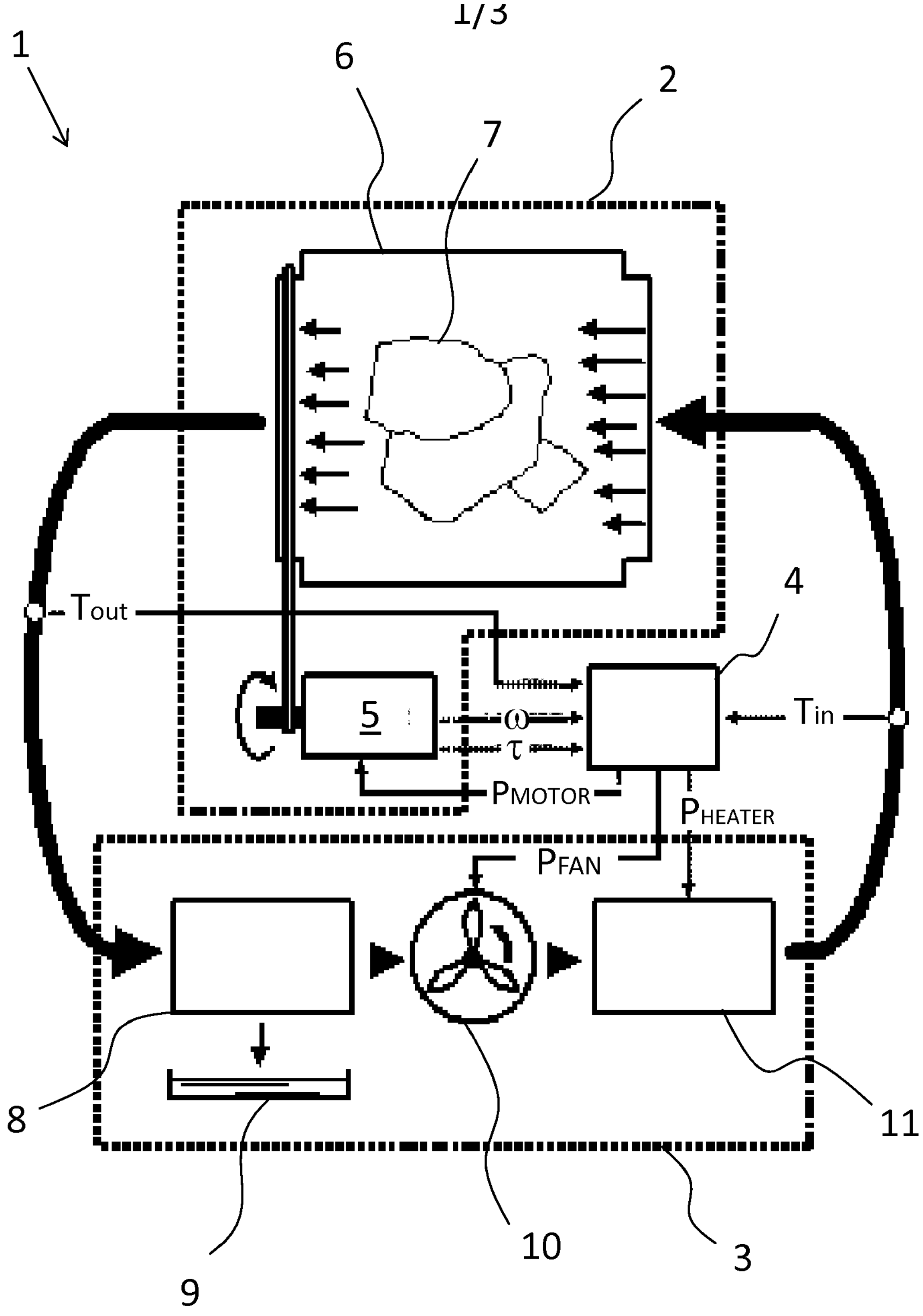

FIG. 1

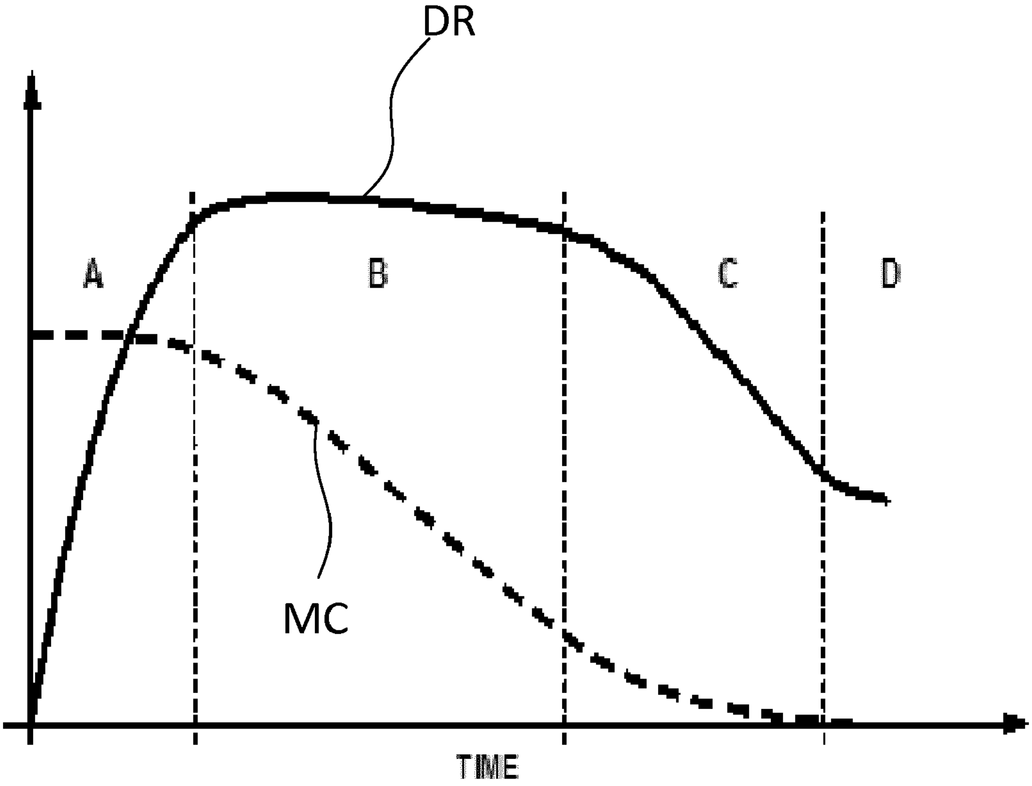

FIG. 2

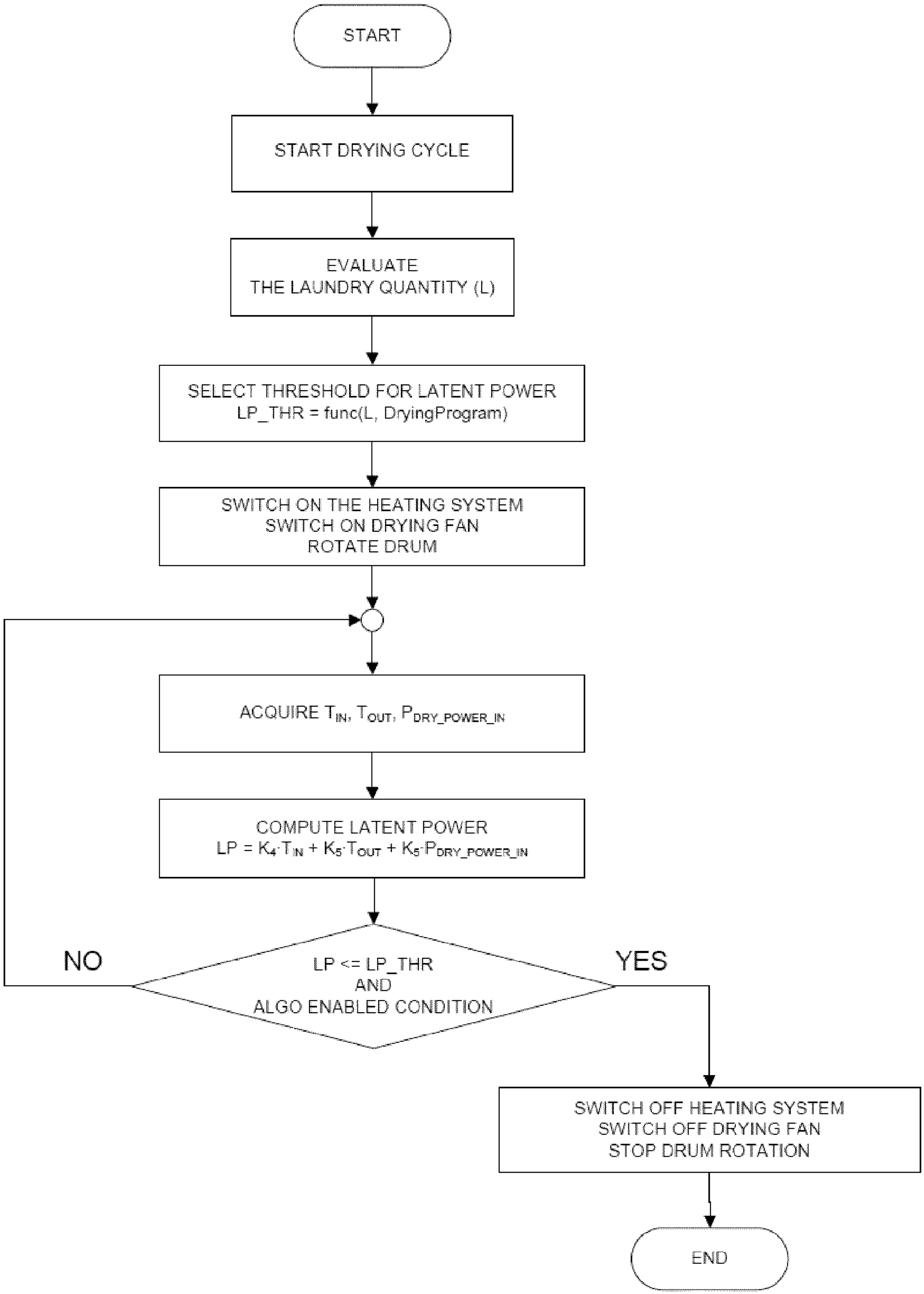
START
START DRYING CYCLE
EVALUATE THE LAUNDRY QUANTITY (L)
SELECT THRESHOLD FOR LATENT POWER
LP_THR = func(L, DryingProgram)
SWITCH ON THE HEATING SYSTEM
SWITCH ON DRYING FAN
ROTATE DRUM
ACQUIRE T_{IN}, T_{OUT}, $P_{DRY\_POWER\_IN}$
COMPUTE LATENT POWER
$LP = K_4 \cdot T_{IN} + K_5 \cdot T_{OUT} + K_5 \cdot P_{DRY\_POWER\_IN}$
NO
LP <= LP_THR
AND
ALGO ENABLED CONDITION
YES
SWITCH OFF HEATING SYSTEM
SWITCH OFF DRYING FAN
STOP DRUM ROTATION
END

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 2966

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	14 October 2014	Spitzer, Bettina

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 16 2966

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