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(54) **Laundry drying machine and control method thereof**

(57) Laundry drying machine (1) comprising a rotatable laundry drum (3) which is designed to rotate about an longitudinal axis (6), an electric motor (9), which is mechanically connected with the rotatable laundry drum (3) for rotating said rotatable laundry drum (3) about its longitudinal axis (6); hot-air generator (11) configured to supply a heated airflow to the drum (3) during a drying cycle; an electronic control system (16) configured for: providing a signal (S) indicative of a torque (TE) that said electric motor (9) provides to the rotatable laundry drum (3) during the drying cycle; comparing the sensed signal (S) with a prefixed comparison signal value (THR) associated to a determined laundry moisture corresponding to a desired final moisture (DLM); and stopping the drying cycle based on the outcome of such comparison.

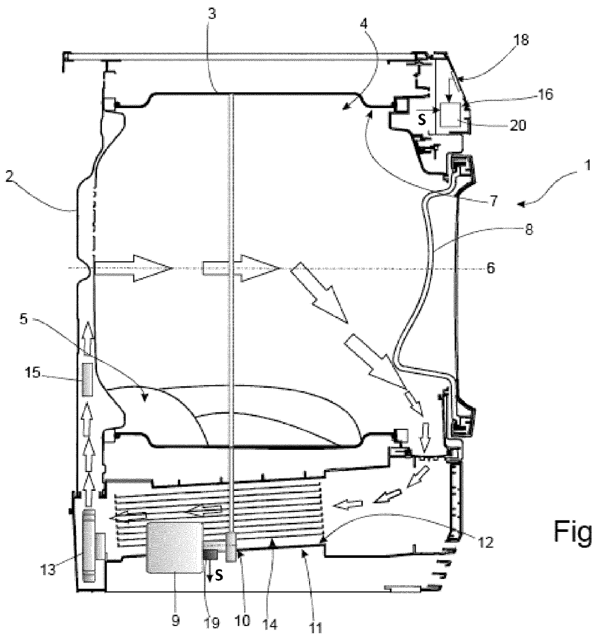

Fig. 1

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Description

[0001] The present invention relates to a laundry drying machine and a method for controlling said machine.

[0002] The present invention further relates to a domestic rotatable drum laundry drying machine which may be embodied as a dryer able to dry clothes, or as a washer-dryer configured to wash and dry clothes.

[0003] Methods for controlling rotatable-drum laundry driers are known, in which: hot air is supplied into the rotating drum so as to flow over the laundry inside the drum; the impedance of the laundry is measured by measuring electrodes positioned inside the drum for contacting the laundry; the moisture of the laundry is determined on the basis of the impedance measurement; and the drying cycle is stopped when the impedance measurement reaches a time-constant comparison threshold associated with a predetermined final moisture.

[0004] Though effective and accurate, the above methods are not suitable to be used in rotatable drum washer-dryers, because the measuring sensors/electrodes cannot be arranged in the drum for contacting the laundry, due to specific architecture of the washer-dryers, and to the fact that the drum is used also for washing operations.

[0005] For such reasons, nowadays, control methods implemented in the washer-dryer are configured to determine the laundry moisture based on control signals available in the washer-dryer, for example temperatures of the airflow measured in some specific positions of the drying circuit, i.e. at the drum inlet and/or the condenser inlet, etc.

[0006] Such control methods continuously measure air-temperatures and stops drying cycles when the air temperature measurement reaches a threshold temperature associated with a predetermined final moisture.

[0007] If the above described control methods are, on the one hand, able to assure acceptable results in terms of drying level of the laundry, on the other hand, they are not enough accurate when a specific drying cycle needs to be performed, such as for example, a so called "iron drying cycle" requiring a high moisture precision because, at the end of the cycle, laundry should be sufficiently humid to facilitate a subsequent ironing.

[0008] In depth research has been carried out by the Applicant to provide a simple and inexpensive solution suitable to be used in a rotatable-drum washer-dryer, and/or a dryer, that will enable guaranteeing the user to achieve a final, accurate moisture value.

[0009] It is therefore an object of the present invention to provide a solution designed to achieve the above goal.

[0010] According to the present invention, there is provided a laundry drying machine as claimed in Claim 1 and preferably, though not necessarily, in any one of the Claims depending directly or indirectly on Claim 1.

[0011] A second aspect of the present invention provides a method to control a laundry drying machine as claimed in Claim 5 and preferably, though not necessarily, in any one of the Claims depending directly or indirectly on Claim 5.

[0012] A third aspect of the present invention provides an electronic control system to control a laundry drying machine as claimed in Claim 9 and preferably, though not necessarily, in any one of the Claims depending directly or indirectly on Claim 9.

[0013] A non limiting embodiment of the present invention will be now described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a laundry drying machine comprising an electronic control system made according to the present invention;
Figure 2 shows a couple of graphs relating to torque changes and moisture changes determined during several drying cycle tests performed through the laundry drying machine shown in Figure 1; whereas
Figure 3 is a flow chart of the operating phases performed through the method for controlling the laundry drying machine shown in Figure 1.

[0014] With reference to Figure 1, referral number 1 indicates as a whole a laundry drying machine, which may be embodied as a rotatable drum laundry dryer, or as a rotatable drum laundry washer-dryer.

[0015] According to the embodiment shown in Figure 1, rotatable-drum laundry drying machine 1 comprises an outer casing 2 that preferably rests on the floor on a number of feet. Casing 2 supports a rotatable laundry drum 3, which defines a washing/ drying chamber 4 for accommodating laundry 5 and rotates about a preferably, though not necessarily, horizontal axis of rotation 6. In an alternative embodiment not shown, axis of rotation 6 may be vertical or inclined. Washing/drying chamber 4 has a front access opening 7 closable by a door 8 preferably hinged to casing 2.

[0016] Rotatable drum 3 may be rotated about the axis of rotation 6 by an electric motor 9 (shown schematically in Figure 1) which is mechanically connected to the rotatable drum 3 through a drive member 10 for transmitting the motion for driving the rotatable drum 3 in rotation about its axis 6.

[0017] Referring to Figure 1, rotatable drum laundry drier 1 also comprises a hot air generator 11 housed inside the casing 2, and designed to circulate through the rotatable drum 3 a stream of hot air having a low moisture level, and which flows over and dries the laundry 5 inside drying chamber 4.

[0018] During the drying cycle, hot air generator 11 provides for gradually drawing air from rotatable drum 3; extracting moisture from the air drawn from rotatable drum 3; heating the dehumidified air to a predetermined temperature, normally higher than the temperature of the air exiting from the rotatable drum 3; and supplying the heated, dehumidified air cyclically back into rotatable drum 3, where it flows over the laundry 5 inside the rotatable drum 3 to dry it.

[0019] Referring to Figure 1, hot air generator 11 provides for continually dehumidifying and heating the air circulating inside rotatable-drum 3 to dry the laundry 5 inside the drum 3/chamber 4, and substantially comprises:

- an air recirculating conduit 12 presenting the two opposite ends connected to the revolving laundry drum 3 on opposite opened sides of the latter;
- a fan 13 located along recirculating conduit 12 to produce inside the latter an airflow which flows into rotatable drum 3 and over the laundry 5 inside the rotatable drum 3;
- preferably, a condensing device 14, which is able to cool the airflow coming out from rotatable drum 3/chamber 4 for condensing the moisture in the airflow; and
- a heating device 15, which is able to heat the airflow returning back into rotatable drum 3, so that the airflow entering into the revolving drum 3 is heated to a temperature higher than or equal to that of the same air flowing out of the drum 3.

[0020] With regard to heating device 15, it may advantageously comprise a number of electric heating components, such as electric resistors (not shown) located inside the air recirculating conduit 12 to dissipate electric power by Joule effect so as to heat the air supplied to rotatable-drum 3.

[0021] Regarding the condensing device 14, it may comprise a heat-exchanger designed to condense the moisture in the airflow through the air recirculating conduit 12. It should be pointed out that condensing device 14 applies, purely by way of example, to one possible embodiment of the present invention, and may be omitted in the case of a vented type rotatable drum laundry drier 1 (i.e. a dryer in which the hot and moisture-laden drying air from the rotatable-drum 3 is expelled directly out of rotatable drum laundry drier 1).

[0022] According to one possible embodiment of the present invention, heating device 15 and condensing device 14 may be replaced with two heat exchangers, i.e. a refrigerant fluid condenser and a refrigerant fluid evaporator respectively, comprised within a heat pump assembly (not shown).

[0023] In actual use, fan 13 blows a stream of drying air, heated by heating device 15 into rotatable drum 3. After contacting laundry 5 inside drum 3, the moisture-laden drying air flows out of rotatable-drum 3 and it is preferably directed to the moisture condensing device 14, which cools the drying air to condense the moisture inside it.

[0024] Rotatable drum laundry drier 1 also comprises an electronic control system 16 configured to control rotatable drum laundry drier 1 preferably on the basis of a drying cycle user-selected through a user control interface 18, according to the control method which will be hereinafter disclosed in detail.

[0025] According to the present invention, the electronic control system 16 comprises a sensing device 19 which outputs a signal S which is indicative of the torque value TE provided to the rotatable drum 3 by the electric motor 9, i.e. a signal which is indicative of the effort made by the drum motor 9 to rotate the drum 3 itself during a laundry drying process. Such signal S may be the motor torque TE itself or, for example, an electrical parameter such as the current (I) through the electric motor, the voltage (V) of the motor, the magnetic flux (Φ) in the electric motor and the like. The electronic control system 16 further comprises an electronic control unit 20 which is configured for: receiving the signal indicative of the torque value TE, comparing such signal S with a prefixed comparison signal value THR associated to a determined laundry moisture corresponding to a desired final moisture, and stopping the drying cycle on the basis of the result of such comparison.

[0026] Preferably, the electronic control unit 20 is configured to stop the drying cycle when the signal S value reaches a value which is lower than, or equal to, a prefixed comparison signal value THR.

[0027] To this end, it should be pointed out that in-depth research carried out by the Applicant has demonstrated that, during the drying cycle, there is a strong correlation between the laundry moisture and the torque value TE, or a signal indicative of such torque, that the electric motor 9 provides to the drum 3. As a matter of the fact, during the drying cycle, the laundry moisture decreases gradually so reducing step by step the total weight of the wet clothes, and the loss in weight affects directly the torque that electric motor 9 has to provide to the drum 3 to maintain a prefixed drum speed.

[0028] In order to clarify the correlation between the laundry moisture and the torque value TE, Figure 2 shows, as an example, some experimental data measured by Applicant during experimental test, wherein it is shown how torque TE provided by the electric motor 9 to the drum 3 decreases during a drying cycle for different laundry loads, i.e. a first laundry load associated to a low weight laundry load (indicated "L1" in Fig 2), a second medium weight laundry load associated to a load weighing about half of the maximum load accepted by the drum chamber 4(indicated "L2" in Figure 2), and, a third high weight laundry load associated to about the maximum load accepted by the drum chamber 4 (indicated "L3" in Figure 2). Through analogous experimental tests, similar graphs may be found representing the correlation between a signal S indicative of the torque TE developed by the electric motor 9 to rotate the drum 3, such as, for example, the current I through the motor 9, the voltage V of the motor, the magnetic flux Φ in the motor, and the like, instead of representing the torque TE itself as shown in Figure 2.

[0029] With reference to Figure 2, experimental data prove that the initial value of torque TE(t1) provided by the drum motor depends on the initial load condition, i.e. laundry weight/quantity and initial laundry moisture, whereas the final value of torque TE(t2) is very similar for a wide ranges of load weights, namely for the first L1, second L2 and third load L3. As mentioned above, even if in Figure 2 it has been represented the drum motor torque on drying process time, other parameters indicative of the torque supplied by the drum motor, such as the current (I), the voltage (V), the magnetic flux (Φ), and the like, could be detected to obtain a similar graph. It is therefore possible to identify a threshold value (THR) of the torque, and, more generally, of a parameter that is indicative of the torque developed by the drum motor 9, wherein such threshold value (THR) is independent on the laundry weight and it can be put in relation to a desired moisture level in the laundry load contained in the drum chamber 4.

[0030] Figure 2 refers to experimental data retrieved by carrying out a laundry drying process through a washer-drier, wherein it can be seen that the same comparison torque value THR for three different laundry load L1, L2 and L3, corresponds substantially to the same final laundry moisture values DFM (Desired Final Moisture). Evidently it is possible to identify the most appropriate threshold (THR) of a signal S indicative of the drum motor torque for each of the drying programs that the machine is able to carry out on a laundry load placed within the drum chamber 4, whatever weight such load has. A set of threshold values corresponding to the user selectable drying programs is therefore stored in a memory support accessible to the electronic control unit 20.

[0031] The effect described above is mainly due to the fact that when the clothes are almost dried they tend to fill completely the drum volume, independently on their weight/quantity, so requiring the drum motor to provide similar torque values for rotating the drum at the same speed. Therefore, it is evident that by monitoring the torque TE values provided to the rotatable drum 3 during the drying cycle, it is possible to have indirectly an indication about the moisture level inside laundry, and consequently determining when stopping the drying cycle.

[0032] Figure 3 shows a flow chart of the operating phases performed by the electronic control system 16 when it carries out the control method according to the present invention.

[0033] At the beginning of the method, electronic control unit 20 starts a drying cycle selected by a user through the user control interface 18 (Block 100). In such operating phase, the electronic control unit 20 controls the electric motor 9 to cause the drum 3 to rotate at pre-set rotation speeds about the axis of rotation 6 according to the drying cycle which user has selected. At the same time, the electronic control unit 20 switches-on the heating device 15 and controls the fan 13 to supply drying air into the rotatable-drum 3 (Block 110).

[0034] During the drying cycle, electronic control unit 20 receives from the sensing device 19 a signal S indicative of the torque provided to the rotatable-drum 3 by the electric motor 9 (Block 120).

[0035] Electronic control unit 20 checks instant by instant, (for example, every a second), whether the signal value S is lower than, or equal to, the prefixed comparison signal value THR associated to the determined laundry moisture corresponding to a desired final moisture (DFM) (Block 130), and if not (NO output from Block 130), it repeats operating-phases disclosed in Blocks 120 and 130 namely, receives from the sensing device 19 a new signal which is indicative of the torque provided to the rotatable drum 3 by the electric motor 9 in a next measuring instant, and performs comparisons between the last detected signal S and the prefixed comparison torque value THR.

[0036] Instead, if the detected signal value S is lower than, or equal to, the prefixed comparison signal value THR, then (YES output from Block 130), electronic control unit 20 determines that laundry moisture has reached the desired final moisture DFM, stops the drying cycle (Block 140), and preferably, though not necessarily, starts a laundry cooling stage (Block 150).

[0037] It should be pointed out that comparison signal value THR can be selected for any drying cycle and that different final moisture (DFM) of the laundry 5 (dryness laundry level) can be advantageously obtained depending on the kind of drying cycle. For example, "cupboard-drying cycle" may preferably be configured to have a specific comparison signal value THR associated with a desired dryness laundry level, which is different to the comparison signal value THR and dryness laundry level of a iron-drying cycle or a damp-drying cycle.

[0038] In addition, the sensing device 19 may be adapted to sense one or more electric parameters of the drum motor 9, such as the current (I), the voltage (V), the magnetic flux (Φ) and the like, or it may be provided with a torque meter so as to provide directly a signal of torque as output. Correspondingly, the electronic control unit 20 may be programmed, i.e. configured, to receive one or more of the above mentioned signals from the sensing device 19 and, if necessary, elaborate them so as to make such signals comparable with the comparison signal values THR stored in a memory support accessible to the electronic control unit 20, so as to carry out the control method disclosed above.

[0039] Stopping the drying cycle may preferably comprise turning off heating device 15. The purpose of the cooling stage is to lower the high temperature (e.g. 70°C) of the laundry 5 to a predetermined low temperature (e.g. 50°C) at which laundry 5 can be handled by the user. At the cooling stage, rotatable drum 3 may be kept turning, and non-heated air fed into rotatable drum 3.

[0040] Rotatable-drum laundry drier 1 has the major advantages of ensuring an accurate desired final moisture for a wide range of drying cycles; ensuring the drying of different load quantity; being suitable to be performed for different kind of laundry textile, i.e. cotton synthetic etc.

[0041] Clearly, changes may be made to the rotatable-drum laundry drier or to the control method as described and illustrated herein without, however, departing from the scope of the present invention.

Claims

1. A laundry drying machine (1) comprising a rotatable laundry drum (3) designed to rotate about an longitudinal axis (6), an electric motor (9), which is mechanically connected with the rotatable laundry drum (3) for rotating said rotatable laundry drum (3) about its axis of rotation (6); hot air generator means (11) configured to supply a heated airflow to the drum (3) during a drying cycle;
the drying machine (1) being **characterized by** comprising:

an electronic control system (16) configured to:

- provide a signal (S) indicative of a torque (TE) that said electric motor (9) provides to the rotatable laundry drum (3) during a drying cycle;
- compare the sensed signal (S) with a prefixed comparison signal value (THR) which is associated to a determined laundry moisture corresponding to a desired final moisture (DLM); and
- stop the drying cycle based on the outcome of such comparison.

2. Laundry drying machine (1) according to Claim 1, wherein said electronic control system (16) is configured to stop the drying cycle, when sensed signal (S) is lower than, or equal to, said prefixed comparison signal value (THR).

3. Laundry drying machine (1) according to Claim 1 or 2 wherein said signal (S) is the current (I) through the electric motor (9) or the voltage (V) of the electric motor (9), or the magnetic flux (Φ) in the motor (9), or the torque (TE) developed by the electric motor (9).

4. Laundry drying machine (1) according to any Claim 1 to 3, wherein hot-air generator means (11) comprises heating means (15) able to heat air to be supplied into drum 3; electronic control system (16) being further configured to switch-off said heating means (15) when drying cycle is stopped and starts a laundry cooling stage, wherein said drum (3) is kept turning, and non-heated air is fed into said drum (3).

5. Method to control a laundry drying machine (1) according to any Claim 1 to 4 the method being **characterized by**:

- providing a signal (S) indicative of a torque (TE) that said electric motor (9) provides to the rotatable laundry drum (3) during a drying cycle;
- comparing the sensed signal (S) with a prefixed comparison signal value (THR) which is associated to a determined laundry moisture corresponding to a desired final moisture (DLM); and
- stopping the drying cycle based on the outcome of such comparison.

6. Method according to Claim 5, comprising the step of stopping the drying cycle, when sensed signal (S) is lower than, or equal to, said prefixed comparison signal value (THR).

7. Method according to Claims 5 or 6 wherein said signal (S) is a current (I) through the electric motor (9) or the voltage (V) of the electric motor (9), or the magnetic flux (Φ) in the motor (9), or the torque (TE) developed by the electric motor (9).

8. Method according to any Claim 5 to 7 wherein said hot-air generator means (11) comprises heating means (15) able to heat air to be supplied into drum (3), the method comprising the steps of switching-off said heating means (15) when drying cycle is stopped and starting a laundry cooling stage, wherein said drum (3) is kept turning, and non-heated air is supplied into said drum (3).

9. Electronic control system (16) configured to control a laundry drying machine (1) according to any claim 1 to 4, said electronic control system (16) being **characterized by** comprising a sensing device (19) adapted to provide a signal (S) indicative of a torque (TE) that said electric motor (9) provides to the rotatable laundry drum (3) during a drying cycle, and an electronic control unit (20) that is configured to compare the sensed signal (S) with a prefixed comparison signal value (THR) associated to a determined laundry moisture corresponding to a desired final moisture (DLM) and to stop the drying cycle based on the outcome of such comparison.

10. Electronic control system according to Claim 9, wherein the electronic control unit (20) stops the drying cycle, when sensed signal (S) is lower than, or equal to, said prefixed comparison signal value (THR).

11. Electronic control system according to claim 9 or 10 wherein said sensing device (9) outputs, as sensed signal (S), a current (I) through the electric motor (9), or a voltage (V) of the electric motor (9), or the magnetic flux (Φ) in the motor (9), or a torque (TE) developed by the electric motor (9).

12. Electronic control system according to any Claim 9 to 11, wherein said hot-air generator means (11) comprise heating means (15) able to heat air to be fed into drum (3) the electronic control system being further configured to switch-off heating means (15) when drying cycle is stopped and starting a laundry cooling stage, wherein said drum (3) is kept turning, and non-heated air is fed into said drum (3).

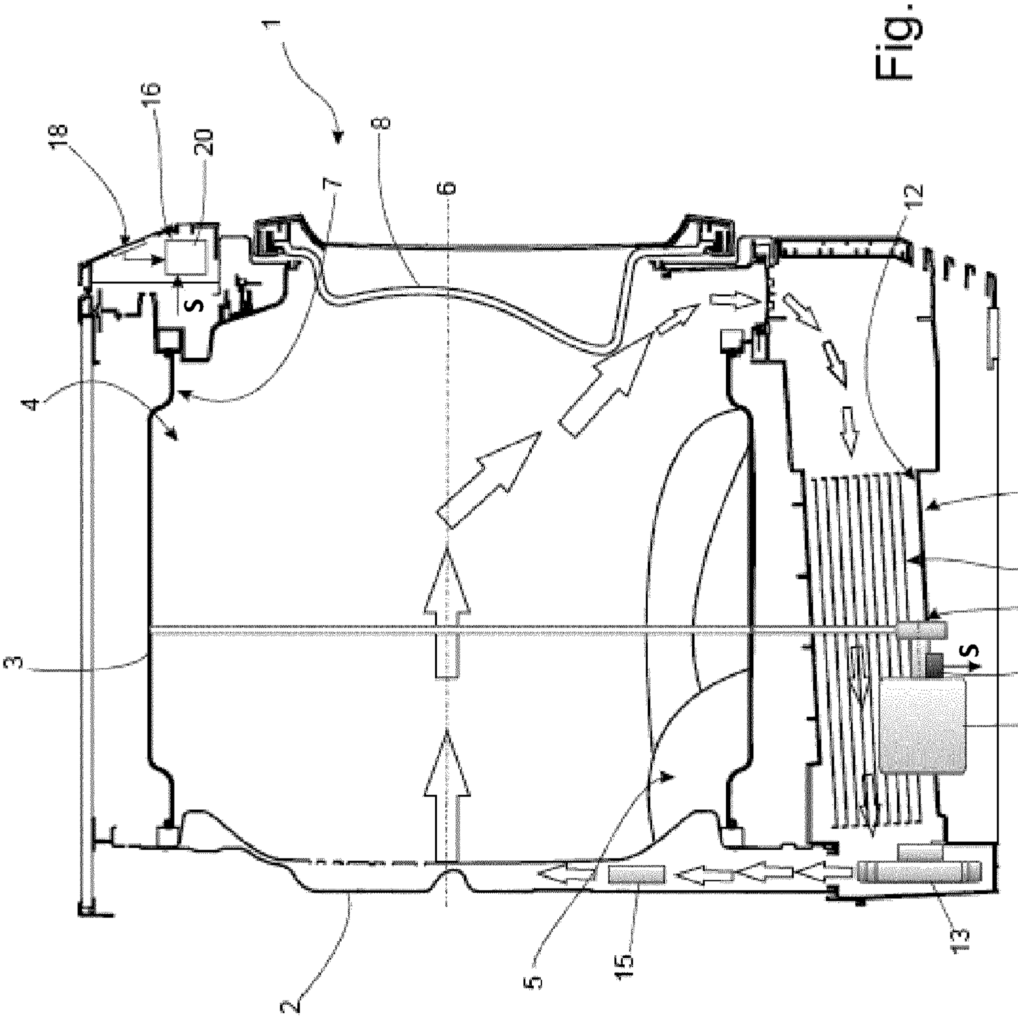
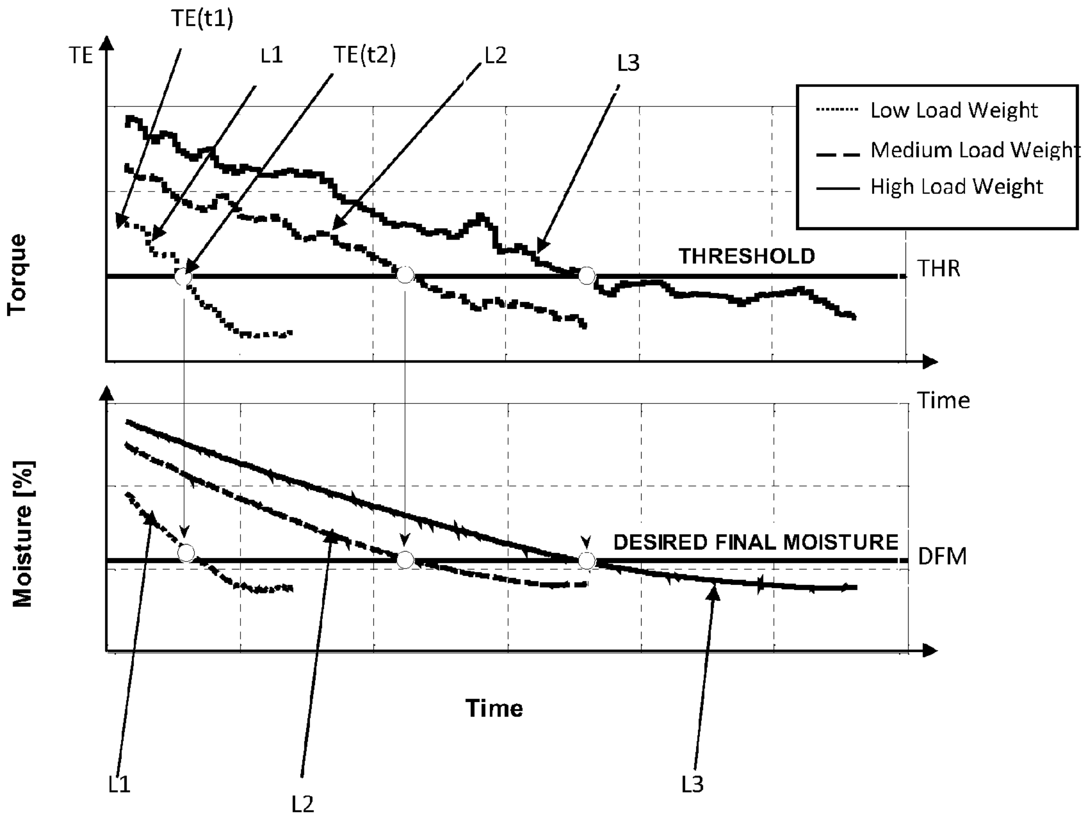


Fig. 1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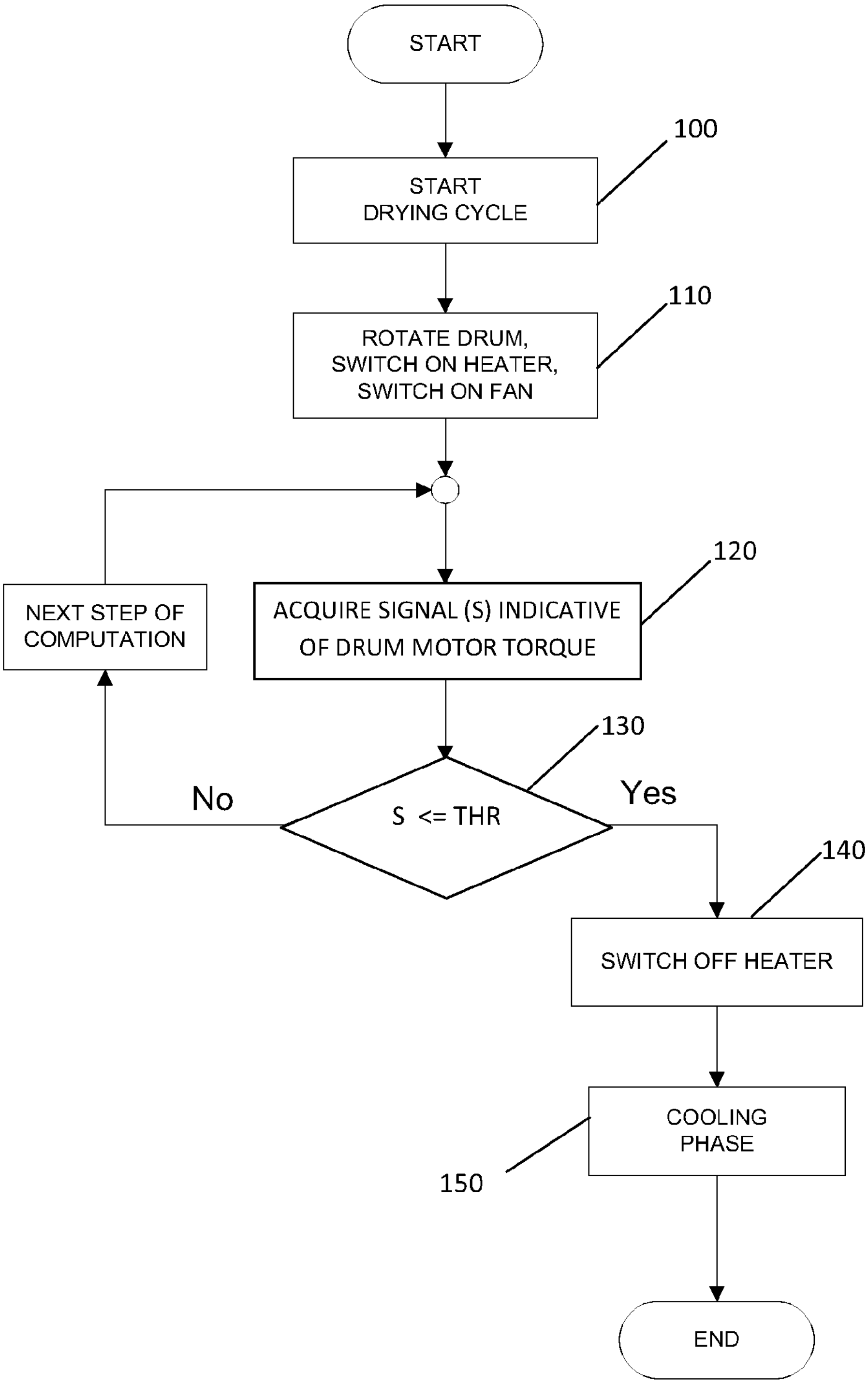
TE
L1
TE(t2)
L2
L3
Low Load Weight
Medium Load Weight
High Load Weight
Torque
THRESHOLD
THR
Time
Moisture [%]
DESIRED FINAL MOISTURE
DFM
Time
L1
L2
L3

Fig.2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100
START
DRYING CYCLE
110
ROTATE DRUM,
SWITCH ON HEATER,
SWITCH ON FAN
120
NEXT STEP OF
COMPUTATION
ACQUIRE SIGNAL (S) INDICATIVE
OF DRUM MOTOR TORQUE
130
No
S <= THR
Yes
140
SWITCH OFF HEATER
COOLING
PHASE
150
END

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 3387

DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 4 481 786 A (BASHARK LARRY T [US]) 13 November 1984 (1984-11-13) * the whole document * -----	1-12	
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TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 March 2012	Spitzer, Bettina

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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27-03-2012

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