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(54) **System to determine the duration of a drying cycle in a rotatable-drum laundry dryer**

(57) Electronic control system (12) configured to calculate an estimated duration (TDE) of a drying cycle performed by a rotatable-drum drier (1) comprising a casing (2) and a rotatable drum (3) structured for housing the laundry to be dried and is fixed in axially rotating manner inside the casing (2); the system being further configured to measure at least a parameter in said rotatable-drum drier, which is indicative of the moment of inertia (JE) of the laundry loaded in the drum (3); and estimate the duration of a drying cycle (TDE) based on the calculated moment of inertia of the laundry loaded in the drum (3).

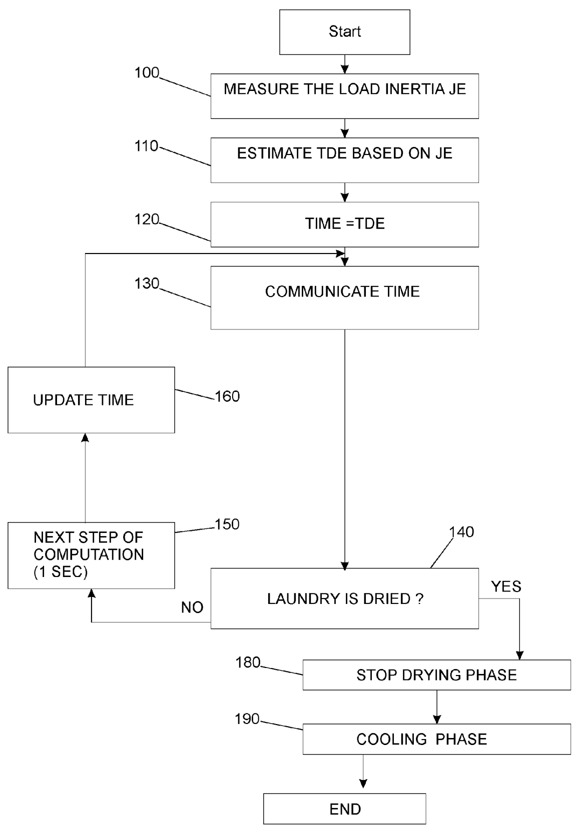

Fig. 3

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Description

[0001] The present invention relates to a system to determine the duration of a drying cycle in a rotatable-drum laundry dryer.

[0002] More specifically, the present invention relates to a system calculating an estimated duration, i.e. an estimated end of cycle time of a drying cycle performed by means of a rotatable-drum laundry drying machine or by a washer-dryer configured to wash and dry clothes, to which the following description refers purely by way of example without implying any loss of generality.

[0003] As it is known, most of domestic washer-dryer currently on the market, generally comprise: a substantially parallelepiped-shaped, boxlike outer casing structured for resting on the floor; a substantially cylindrical revolving drum which is structured for housing the laundry to be washed/dried and is housed in axially rotating manner inside the casing to rotate about a longitudinal reference axis, directly facing a laundry loading/unloading opening formed in the front wall of the casing; a porthole door hinged to the front wall of the casing to rotate to and from a closing position in which the door rests completely against the front wall of the casing to close the laundry loading/unloading opening and airtight seal the revolving drum; an electrically-powered motor assembly which is housed inside the casing and is structured for driving into rotation the revolving drum about its longitudinal reference axis during washing/drying cycles; a drying circuit which is housed inside the casing and is structured to circulate inside the revolving drum a stream of hot air which has a very low moisture content and flows through the revolving drum and over the laundry inside the drum to dry the laundry; and finally, an electronic control system which controls both the motor assembly and the drying circuit to perform, on command, one of the user-selectable washing and/or drying cycles stored in a central control unit of the system.

[0004] The electronic control system of the washer-dryer of the kind above disclosed is usually configured to detect some specific drying conditions based on several control parameters measured during the drying cycle, namely laundry moisture, and determines the end of cycle time, when said specific drying conditions are met, for example when the laundry moisture, measured through a couple of conductimetric sensors, reaches a prefixed moisture threshold stored in the control system memory.

[0005] However, in the recent times, there has arisen the need on the part of dryer- user to have available also an estimation of the drying cycle in the first instants after a user selected drying program has been started in order to have a visual indication of the end of the cycle time, already at the very beginning of the drying cycle.

[0006] An aim of the present invention is to provide an extremely simple system able to calculate/estimate the drying cycle duration at the beginning of drying cycle in order to determine the end of drying cycle time.

[0007] In compliance with the above aim, according to the present invention there is provided an electronic control system and a method configured to calculate an estimated duration of a drying cycle performed by a rotatable-drum drier comprising a casing and a rotatable drum structured for housing the laundry to be dried and is fixed in axially rotating manner inside the casing; wherein the system/method is configured to measure at least a parameter in said rotatable-drum drier, which is indicative of the moment of inertia of the laundry loaded in the drum; and estimate the duration of a drying cycle based on the calculated moment of inertia of the laundry loaded in the drum.

[0008] Preferably, the electronic control system/method is configured to measure said parameter in the rotatable-drum drier which is indicative of the moment of inertia of the laundry loaded in the drum at the beginning of the drying cycle to be performed, i.e. in the very first period of a drying cycle.

[0009] Preferably the electronic control system/method is configured to calculate the duration of the drying cycle by implementing a linear combination of the measured moment of inertia, according to the following equation: $TDE=F(JE)=A*JE-B$ wherein A and B are linear parameters associated with the drier and the laundry load.

[0010] Preferably, the electronic control system/method is configured to stop the drying cycle after estimated duration.

[0011] A non-limiting embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a washer-dryer configured to estimate the duration of a drying cycle, according to the present invention;

Figure 2 is an example of a graph showing the variation in duration of the drying cycle based on the moment of inertia; whereas

Figure 3 is a flow chart of the steps performed by the system/method to estimate duration of a drying cycle in a washer-dryer shown in Figure 1.

[0012] With reference to Figure 1, referral number 1 indicates as a whole a laundry dryer corresponding to a rotatable-drum laundry dryer or a rotatable-drum laundry washer-dryer.

[0013] According to the embodiment shown in Figure 1, rotatable-drum laundry dryer 1 comprises an outer casing 2 that preferably rests on the floor on a number of feet. A rotatable laundry drum 3 is mounted within the casing 2 and the drum 3 defines a washing/ drying chamber 4 for 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.

[0014] Drum 3 may be rotated about axis of rotation 6 by an electric motor 9 (shown schematically in Figure 1), and is fed with hot air heated by a heating device 10 and supplied into drum 3 preferably by a fan 11. Fan 11 may preferably, though not necessarily, be driven by the electric motor 9 or, in an alternative embodiment (not shown), by an auxiliary electric motor (not shown) independent of electric motor 9. Heating device 10 may advantageously comprise one or more electric heating components, such as electric resistors (not shown), or in an alternative embodiment a refrigerant fluid condensing element of a heat pump circuit.

[0015] In actual use, fan 11 blows into the drum 3 a stream of drying air, heated by heating device 10 into drum 3. After contacting laundry 5 inside drum 3, the moisture-laden drying air flows out of drum 3 and it is preferably directed to a moisture condensing device 14, which cools the drying air to condense the moisture inside it. For this purpose, condensing device 14 may be an air/air heat exchanger supplied with cold air taken from outside the drier or a refrigerant fluid evaporating element of a heat pump circuit. After being passed through the moisture condensing device 14, the moisture-free air is led again towards the drum 3 by fan 11 to pass cyclically inside the chamber 4. It should be pointed out that condensing device 14 as described above 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 laundry drum 3 is expelled directly out of rotatable-drum laundry drier 1).

[0016] Rotatable-drum laundry drier 1 also comprises an electronic control system 12 configured to control rotatable-drum laundry drier 1 preferably on the basis of a drying cycle user-selected by using a user control interface 13.

[0017] According to a preferable embodiment of the present invention, the electronic control system 12 is configured to estimate, after a user-selected drying cycle has begun running, a duration of the drying cycle, and preferably, though not necessarily calculate the end of cycle time based on the estimated duration.

[0018] In the instant of time subsequent to the start of the user-selected drying cycle, the electronic control system 12 determines the moment of inertia JE of the "rotating load" of the drier 1, which is associated to the mass of the rotatable laundry drum 3 plus the mass of the laundry 5 housed inside the rotatable laundry drum 3.

[0019] In other words, after user has selected the drying cycle, the electronic control system 12 performs a "starting drying phase", wherein the drum is conveniently rotated to cause the laundry load to be uniformly arranged on the cylindrical inner wall of the drum 3. In such starting drying phase of the drying cycle, the electronic control system 12 determines the moment of inertia JE of the rotating load of the drier 1.

[0020] Preferably, the electronic control system 12 measures one or more parameters associated with the moment of inertia JE of the "rotating load" of the drier 1, and calculate the moment of inertia JE based on measured parameters according to known inertia calculating method. For example, electronic control system 12 may be configured to calculate the moment of inertia JE of the rotating load of the drier 1 according to the method disclosed in EP 2107151 A1 filed by the Applicant, wherein the measured parameters used to calculate the moment of inertia JE are the torque values provided to the rotatable drum 3 by the electric motor 9 and/or the drum speed. However, it should be pointed out that moment of inertia JE may be calculated by implementing any other kind of known inertia calculating method.

[0021] According to a possible embodiment of the present invention, electronic control system 12 may be configured to determine the moment of inertia JE based on one or more electrical parameters of the electrical motor 9, which may be measured during the starting phase of the drying cycle by means of appropriate sensors.

[0022] The electronic control system 12 is further configured to determine/estimate the cycle duration TDE, i.e. the cycling time of the drying cycle based on the moment of inertia JE calculated at the starting phase of the drying cycle, i.e. at the first instants of time after the motor has begun to rotate the drum 3.

[0023] To this end, it should be pointed out that research made by the Applicant, shows that the time TDE taken from the drier 1 to dry the clothes is practically proportional to the moment of inertia JE measured during the starting phase of the drying cycle.

[0024] Figure 2 shown, as an example, some experimental data measured by Applicant during experimental test, wherein it is shown that cycle time, namely the duration of a cotton drying cycle TDE (axis Y) to dry a cotton-laundry-load having a prefixed beginning moisture, is substantially a linear function of the moment of inertia JE (axis X).

[0025] More specifically, electronic control system 12 may be configured to calculate the duration of the drying cycle TDE by implementing a linear combination of the calculated moment of inertia JE, according, for example, to the following equation:

$$\text{a)}\quad TDE=F(JE)=A*JE - B$$

wherein A and B are experimental values, i.e. linear parameters, associated with the drier 1 architecture, that is the dryer geometry and mass distribution of mechanical operation devices to drive the drum 3, and further associated to laundry load characteristics like the fiber type, the drying cycle profile (i.e. temperature profile, air flow rate, and so on) and the drying circuit design (sections area, circuit length, and the like).

[0026] Said A and B experimental values may be associated with respective drying cycle and be stored in a database of the electronic control system 12.

[0027] In other words, linear parameters A and B characterizing the above linear equation used to estimate the time to end TDE, may change their values according to the selected drying cycle.

[0028] The linear parameters A and B can be estimated experimentally through laboratory tests in which there are measured the real end of the drying cycle time TDE of a specific kind of drying cycle in pre-set starting drying conditions such as: predetermined kind of laundry load (i.e. cotton, synthetic fibers), predetermined weight of laundry moisture/load (and, as a consequences, pre-set starting moment of inertia JE). The calibration of the parameters A end B may be done, for example, by collecting data with different kinds of laundry loads (starting from the minimum up to the maximum load) and performing several test cycles with the specific drying program selected for the drier machine under analysis.

[0029] In the case in point, it is possible to determine linear parameters A, B through an estimation method, preferably, but not necessarily, the least-squares method. The least-squares method is a known optimization technique, which enables a linear combination of specific functions to be found that, by means of linear parameters, approaches as closely as possible an interpolation of a set of data, which, in this case, are constituted by the duration of the drying cycle measured at the various laundry-load/moment of inertia JE.

[0030] Figure 3 shows a flow chart of the operating-phases performed to a preferable control method implemented by electronic control system 12 to control rotatable-drum laundry drier 1 and determine/estimate the duration TDE of the drying cycle.

[0031] At the beginning of the method, namely before starting a drying cycle selected by user, the electronic control system 12 provides the linear parameters A and B to be used for estimating the duration TDE of the drying cycle, such parameters A, B are taken from those stored in a database of the electronic control system 12, based on the selected drying cycle. Then the electronic control system 12 performs the starting drying phase of the drying cycle, wherein the drum 3 is conveniently rotated to cause the laundry load 5, and consequently the moisture, to be uniformly distributed among laundry in the drum 3. In such starting drying phase of the drying cycle, the electronic control system 12 determines/measures the moment of inertia JE (Block 100) of the load of the drier 1. As above disclosed, in this phase, electronic control system 12 may measure some parameters associated with the drier load, i.e. the torque provided to the rotatable drum 3 and/or the drum speed, and calculate the moment of inertia JE according to the measured torque/speed.

[0032] The electronic control system 12 estimates the duration of the drying cycle TDE based on the calculated moment of inertia JE according to the linear function a) TDE=F(JE)=A*JE-B (Block 110), wherein A end B are the linear parameters associated with the selected drying cycle.

[0033] The electronic control system 12 assigns the estimated drying cycle TDE to a time control variable TIME (TIME=TDE) (Block 120) and communicates the time control variable TIME, namely the estimated drying cycle TDE, to the user by means of the user control interface 13 (Block 130).

[0034] The electronic control system 12 starts the drying cycle. In detail, in such operating-phase, the electronic control system 12 switches-on the heating device 10, controls the fan 11 to feed drying air into the rotatable drum 3 and, at the same time, 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 selected drying cycle.

[0035] During the drying cycle, the electronic control system 12 checks instant by instant, (for example, every a second), whether the TIME variable has reached a zero value (Block 140) and, if not (NO output from Block 140), updates the TIME variable, i.e. decrements the TIME variable by interval dt, i.e. one second, (TIME =TIME-dt; Blocks 150,160), and communicates the updated time control variable TIME corresponding to the remaining cycle time, to the user by means of the user control interface 13 (Block 130), for example through a display.

[0036] If the TIME variable has reached a zero value (YES output from Block 140), the electronic control system 12 detect that laundry is dried, interrupts the drying cycle (Block 180) and starts a laundry cooling stage (Block 190).

[0037] Stopping the drying cycle may preferably comprise turning off heating device 10. The purpose of the cooling stage is to lower the high temperature (e.g. 70°C) of the laundry to a predetermined low temperature (e.g. 50°C) at which laundry 5 can be handled by the user. At the cooling stage, drum 3 may be kept turning, and non-heated air fed into drum 3.

[0038] It should be pointed out that according to a possible embodiment of the present invention, after the starting phase, i.e. during the subsequent drying phase of the drying cycle, the electronic control system 12 may repeat one or more time, the estimation of the duration of drying cycle TDE as above disclosed (Blocks 100 and 110) and updating the remaining cycle time to be shown through the user control interface 13.

[0039] Moreover, according to a further possible embodiment of the present invention, the electronic control system 12 may be configured to estimate the duration of the drying cycle TDE by implementing operations above disclosed (Blocks 100 and 110), and calculate and show to the user the remaining cycle time/estimated duration at any instant of the drying cycle, in response, for example, to an user command supplied to the electronic control system 12 by means of the user control interface 13.

[0040] In other words, the estimation of the duration of the drying cycle TDE may be performed during the starting phase as above disclosed, and/or one or more times during the subsequent drying cycle to advantageously provide, at any new estimation phase, a more accurate remaining cycle time to the user. This allows to avoid the unpleasant situation for a user, expecting to have his/her selected drying cycle ended when the user interface shows a cycle time duration equal to zero, to see that the cycle continues running over the estimated time because moisture in the laundry load is detected as still too high to stop the drying process.

[0041] In addition, it should be pointed out that according to a possible embodiment of the present invention, the estimated drying cycle TDE information may be used only to inform the user about the remaining cycle time and not as control variable for interrupting the drying cycle.

[0042] In other words, according to such possible embodiment, the electronic control systems may be configured to: estimate the cycle duration TDE by means of linear function a) on the basis of calculated/determined moment of inertia JE; determine remaining cycle time based on estimated cycle duration TDE; communicate the estimated cycle duration TDE and/or the remaining cycle time to the user; stop the drying cycle when specific drying conditions are met, for example when the measured laundry moisture reaches a prefixed moisture threshold.

[0043] Rotatable-drum laundry drier 1 has the major advantages of:

- estimating of the remaining cycle time at the beginning of the drying cycle execution;
- informing continuously the end-user about the end of cycle time;
- being simple to perform.

[0044] Clearly, changes may be made to the rotatable-drum laundry drier as described and illustrated herein without, however, departing from the scope of the present invention.

Claims

1. Electronic control system (12) configured to calculate an estimated duration (TDE) of a drying cycle performed by a rotatable-drum drier (1) comprising a casing (2) and a rotatable drum (3) structured for housing the laundry to be dried and is fixed in axially rotating manner inside the casing (2);
the system being **characterized by** being further configured to:

- measure at least a parameter in said rotatable-drum drier, which is indicative of the moment of inertia (JE) of the laundry loaded in the drum (3), and determine the moment of inertia (JE) based on measured parameter; and
- estimate the duration of a drying cycle (TDE) based on the determined moment of inertia of the laundry loaded in the drum (3).

2. Electronic control system according to Claim 1, configured to measure said parameter in said rotatable-drum drier (1) and estimate the duration of a drying cycle (TDE), during a starting phase of the drying cycle.

3. Electronic control system according to Claims 1 or 2, configured to measure said parameter in said rotatable-drum drier (1) and estimate the duration of a drying cycle (TDE), one or more time during the drying cycle.

4. Electronic control system according to any of the previous Claims, configured to estimate the duration of the drying cycle (TDE) by implementing a linear combination of the determined moment of inertia (JE), according to the following equation: TDE=F(JE) =A*JE-B wherein A and B are linear parameters associated with the selected drying cycle.

5. Electronic control system according to any of the previous Claims, configured to stop the drying cycle on the basis of the estimated duration (TDE).

6. Electronic control system according to any of the previous Claims, configured to communicate the estimated duration (TDE to the user.

7. Electronic control system according to any of the previous Claims, configured to estimate the duration of a drying cycle (TDE) and/or communicate to the user the estimated duration (TDE), in response to an user command.

8. Method to calculate an estimated duration (TDE) of a drying cycle performed by a rotatable-drum drier (1) comprising a casing (2) and a rotatable drum (3) structured for housing the laundry to be dried and is fixed in axially rotating manner inside the casing (2); the method being **characterized by**: measuring at least a parameter in said rotatable-drum drier, which is indicative of the moment of inertia (JE) of the laundry loaded in the drum (3); determining the moment of inertia (JE) based on measured parameter; and estimating the duration of a drying cycle (TDE) based on the determined moment of inertia(JE) of the laundry loaded in the drum (3).

9. Method according to Claim 8, comprising the step of measuring said parameter in said rotatable-drum drier (1) and estimating the duration of the drying cycle (TDE), during a starting phase of the drying cycle.

10. Method according to Claims 8 or 9, comprising the step of measuring said parameter in said rotatable-drum drier (1) and estimating the duration of the drying cycle (TDE), one or more time during the drying cycle.

11. Method according to any of the previous Claims from 8 to 10, comprising the step of estimating the duration of the drying cycle (TDE) by implementing a linear combination of the measured moment of inertia (JE), according to the following equation: TDE=F(JE) =A*JE-B wherein A and B are linear parameters associated with the selected drying cycle.

12. Method according to any of the previous Claims from 8 to 11, comprising the step of stopping the drying cycle on the basis of the estimated duration (TDE).

13. Method according to any of the previous Claims from 8 to 12, comprising the step of communicating the estimated duration (TDE) to the user.

14. Method according to any of the previous Claims from 8 to 13, comprising the step of estimating the duration of a drying cycle (TDE) and/or communicating the estimated duration (TDE) to the user in response to a user command.

15. Rotatable-drum drier (1) comprising a casing (2), a rotatable drum (3) structured for housing the laundry (5) to be dried and is fixed in axially rotating manner inside the casing (2); and an electronic control system (12) configured to calculate an estimated duration (TDE) of a drying cycle according to any of the Claims from 1 to 7.

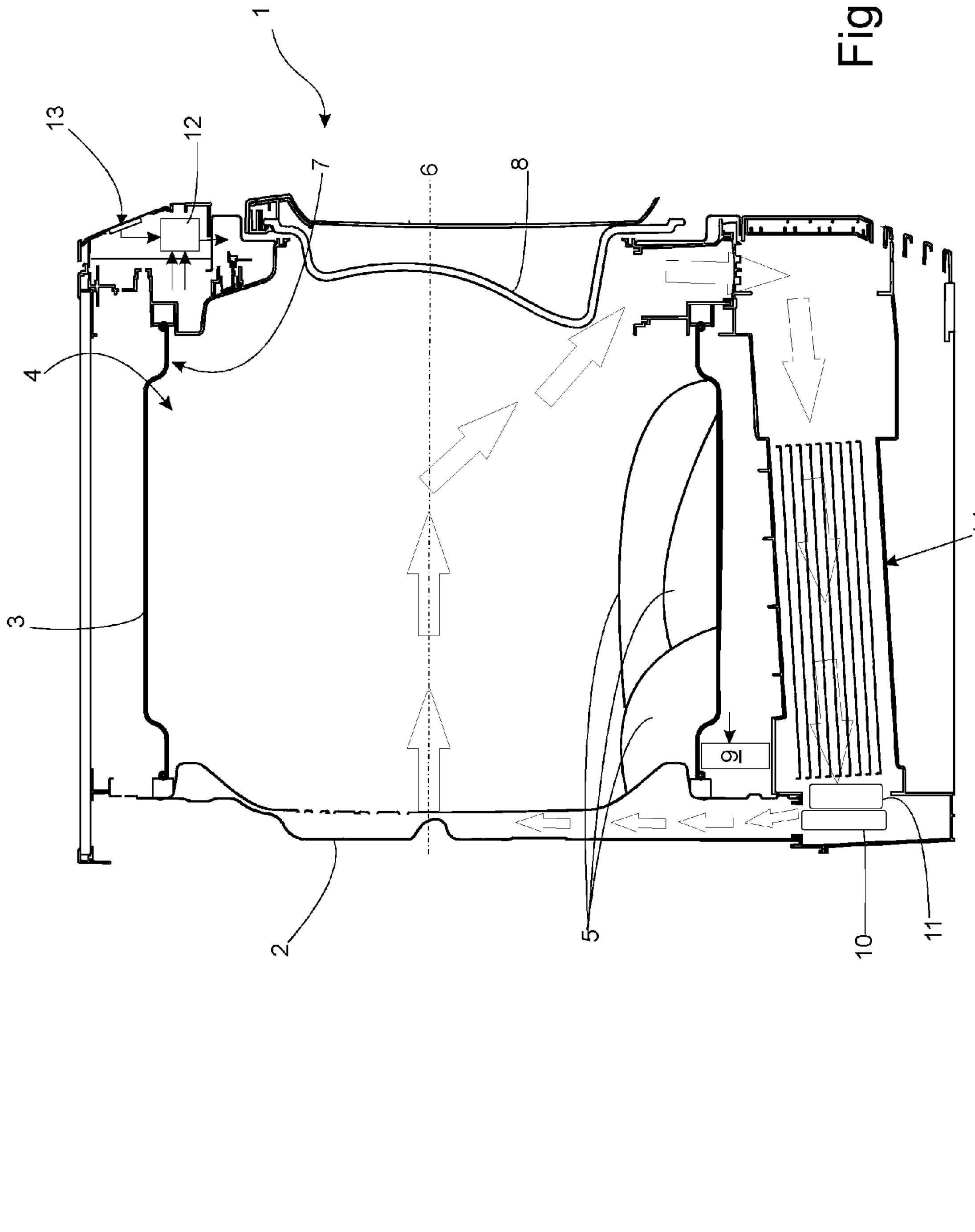

Fig. 1

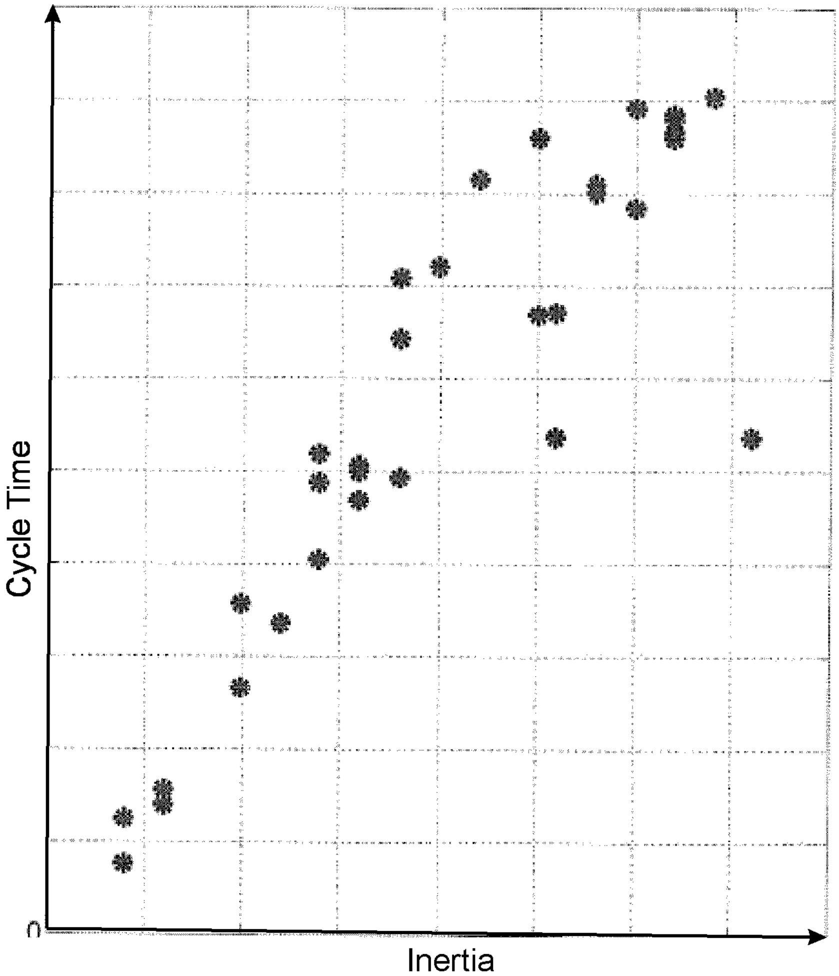

Fig. 2

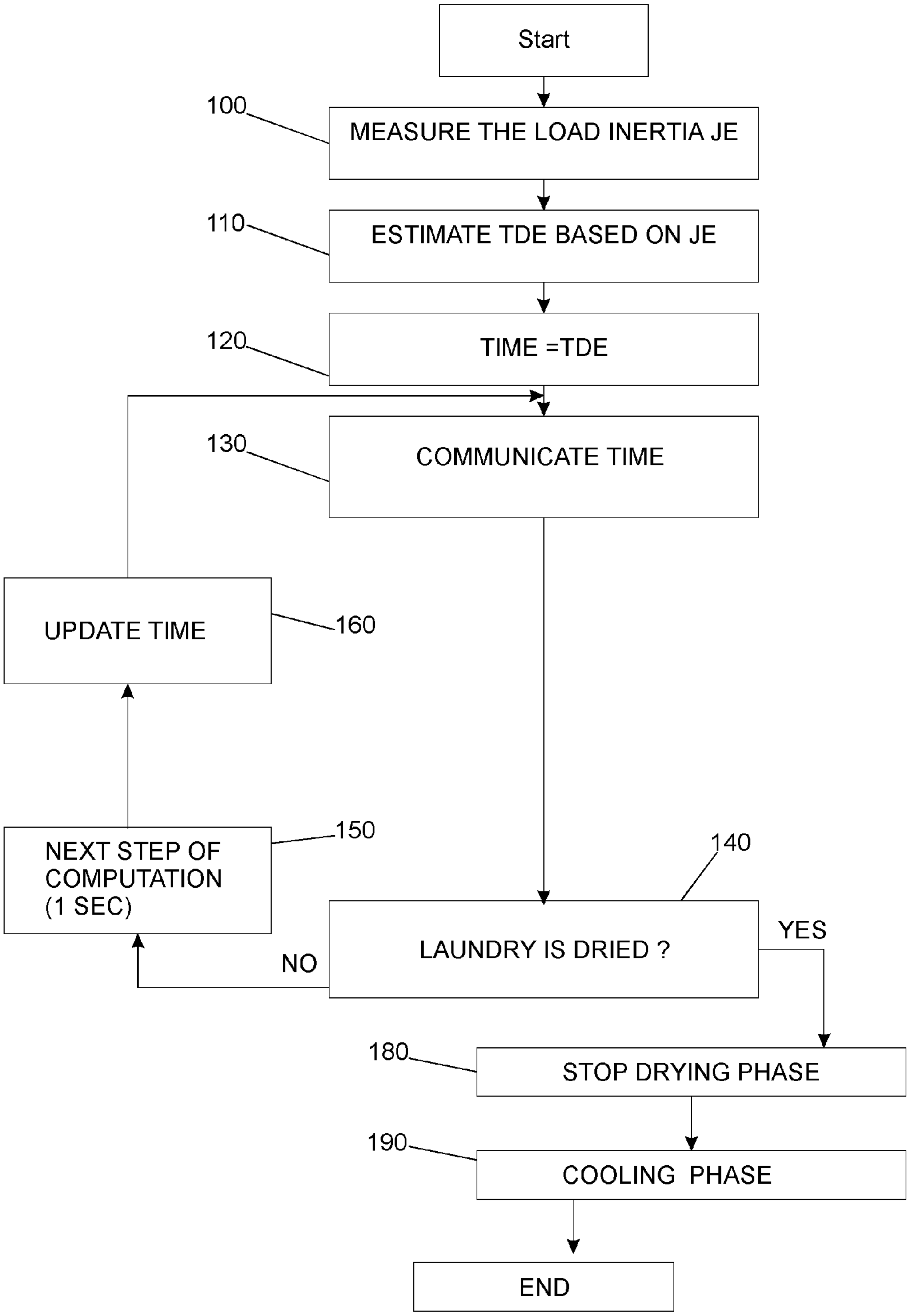
Start
100
MEASURE THE LOAD INERTIA JE
110
ESTIMATE TDE BASED ON JE
120
TIME =TDE
130
COMMUNICATE TIME
UPDATE TIME
160
NEXT STEP OF COMPUTATION (1 SEC)
150
140
LAUNDRY IS DRIED ?
NO
YES
180
STOP DRYING PHASE
190
COOLING PHASE
END

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 1247

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D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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