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(54) Laundry machine with adaptive spinning cycle and method for controlling thereof

(57) A method of controlling a spinning phase of a laundry machine (**100**) for treating laundry items is proposed. The laundry machine (**100**) comprises a drum (**110**) adapted to house the laundry items to be treated, a motor (**120**) arranged for rotating the drum (**110**). The method comprises the following steps: obtaining an indication of an unbalance mass (um_s, um_d) associated with the laundry items housed in the drum (**110**), determining a maximum rotating speed (w_M) at which the drum (**110**) is rotated by the motor (**120**) on the basis of said unbalance indication, rotating the drum (**110**) at the maximum rotating speed (w_M) for a time interval having a time duration. In the solution according to an embodiment of the present invention, the method further comprises determining said time duration (T_{SL}) for which the motor (**120**) rotates the drum (**110**) at the maximum rotating speed (w_M) on the basis of a non-linear polynomial function of a variable (*rpm*) related to the maximum rotating speed.

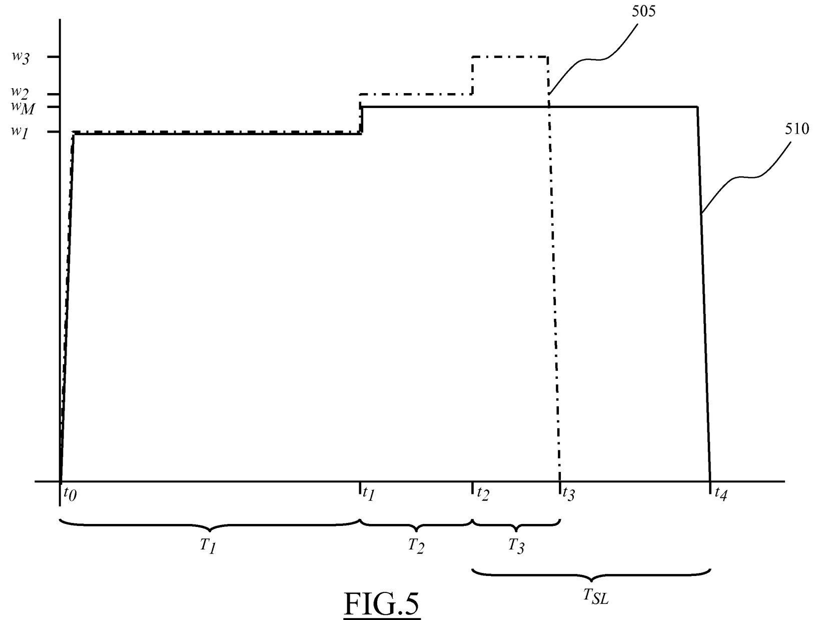

FIG.5

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Description

[0001] The present invention relates to laundry treatment appliances or machines. In more detail, the present invention refers to appliances for washing laundry and/or washing and drying laundry comprising a rotating drum, both for domestic and professional use. More particularly, the present invention relates to an adaptive spinning cycle.

[0002] Washing and washing/drying laundry machines - which will be referred to simply as laundry machine in the following - typically comprise a casing substantially parallepiped-shaped. The casing accommodates a laundry-treating chamber, comprising a drum, generally rotatable, apt to contain the laundry to be washed (and dried in the case of washing/drying laundry machines). The laundry-treating chamber further comprises a tub in which the drum is rotatably contained. The tub is suspended inside the casing by means of suspension elements (such as extension springs) and damping elements. A front panel of the casing may be provided with a loading opening to access the treating chamber for loading/unloading the laundry, and a door is provided for closing the loading opening, particularly during the laundry machine operation; in such case the laundry machine is defined as front-loading laundry machine. Alternatively, a top panel of the casing may be provided with a loading opening to access the treating chamber for loading/unloading the laundry, and a door is provided for closing the loading opening, particularly during the laundry machine operation; in such case the laundry machine is defined as top-loading laundry machine. The casing also accommodates the electrical, electronic, mechanical (e.g., a motor for rotating the drum and an electronic control system for managing the laundry machine operation *etc.),* and hydraulic components necessary for the operation of the laundry machine (e.g., inlet and outlet hydraulic systems, treating agent dispenser *etc.).*

[0003] The operation of the laundry machine comprises various operation phases. For example, in a washing phase, washing liquid (e.g., water or water mixed with washing products) is introduced in the tub of the laundry machine by means of an inlet hydraulic system fluidly connected to the tub and is heated up to a predetermined temperature. The laundry previously loaded into the rotatable drum is washed thanks to the chemical reactions exerted by the washing liquid, supported by the tumbling action caused by the rotation of the drum. At the end of the washing phase the washing liquid is drained from the tub into an outlet hydraulic system and then a spinning phase may be performed for removing washing liquid from the laundry. One or more rinsing phases may follow, in which water is introduced into the tub for rinsing the laundry just washed. At the end of each rinsing phase the water is drained from the tub and a further spinning phase may be performed for removing water from the laundry. Anyway, after the last rinsing phase, a final spinning phase is typically performed, during which water is removed from the laundry (i.e., the laundry is de-watered) in order to obtain a desired final humidity (or rest humidity) for the laundry. Preferably, one or more operating parameters (e.g., washing liquid temperatures) of the operating phases may be set by a user through a user interface, provided for this purpose, in the laundry machine. In the final spinning phase the drum is typically rotated at the maximum rotating spin compatible with the kind of loaded laundry, so as to remove as much water as possible from the latter.

[0004] During the spinning phases, the laundry may distribute unevenly within the drum causing unbalance - mainly, static unbalance, when the laundry mass/inertia is distributed along an axis parallel to a rotation axis of a driving shaft that rotatably connects the drum and a motor, and dynamic unbalance, when the laundry mass/inertia is distributed along an axis that do not intersect with the rotation axis of the driving shaft - that lead to substantial oscillation of the drum within the tub that are detrimental for the laundry machine operation (i.e., may reduce a power efficiency of the laundry machine) and may cause a damage and/or a faster wear-out of laundry machine component parts (e.g., deformation/wear-out of the drum, wear-out of a bellows connected to the drum *etc.).*

[0005] Therefore, spinning phases of the laundry machine operation has to be carefully controlled in order prevent the above mentioned drawbacks. In the art some expedients have been proposed for controlling the spinning phases of the laundry machine operation, in which a rotating maximum speed is reduced below a maximum available rotating speed in order to avoid oscillations of the drum and, at the same time a duration of the spinning phase is prolonged.

[0006] For example, DE 19531656 discloses a process for regulating the spinning speed of a laundry drum. The process involves executing a first spinning process during a period of time at a first speed. Subsequently, the drum is brought into the tolerance range of a second speed and an imbalance measurement is carried out. A revolution speed profile is established for the further spinning process in accordance with the measured imbalance and on the basis of preset speed/time data.

[0007] The process disclosed in DE 19531656 is said to select a speed-time combination for a spinning phase according to a measured unbalance and to a set of curves based on "empirical data" but there are no teaching about how the curves and the empirical data are calculated nor about how the measured unbalance is associated with a speed-time combination.

[0008] FR 2577949 discloses means provided for automatically making the spinning time, during rinsing and/or during final spinning, dependent on at least one of the following parameters: the quantity of laundry introduced into the drum, the type of this laundry and the rotational speed of the drum. The spinning time is, for example, proportional to the quantity of laundry contained in the drum, the coefficient of proportionality depending on the type of laundry.

[0009] The means disclosed requires the knowledge of the composition (in terms of types of cloth such as cotton cloth, synthetic cloth *etc.)* of the laundry in order to properly select the spinning speed and the spinning time.

[0010] The aim of this invention is devising a laundry machine in which a time-duration of each spinning phase is effectively and simply determined in order to prevent the drawbacks mentioned above and, at the same time providing laundry with a desired final humidity at the end of the spinning cycle.

[0011] Applicant has found that it is possible to effectively and simply controlling a spinning phase of a laundry machine by determining, for the maximum rotating speed permitted by the detected unbalance of the drum, the time duration of the spinning phase allowing obtaining laundry with a desired final humidity at the end of the spinning cycle, on the basis of a non-linear polynomial function of a variable related to the maximum rotating speed. Preferably the non-linear polynomial function has at least a coefficient empirically determined.

[0012] One aspect of the present invention proposes a method of controlling a spinning phase of a laundry machine for treating laundry items. The laundry machine comprises a drum adapted to house the laundry items to be treated, a motor arranged for rotating the drum. The method comprises the following steps: obtaining an indication of an unbalance mass associated with the laundry items housed in the drum, determining a maximum rotating speed at which the drum is rotated by the motor on the basis of said unbalance indication, rotating the drum at the maximum rotating speed for a time interval having a time duration. In the solution according to an embodiment of the present invention, the method further comprises determining said time duration for which the motor rotates the drum at the maximum rotating speed on the basis of a non-linear polynomial function of a variable related to the maximum rotating speed.

[0013] Preferably the non-linear polynomial function has at least a coefficient empirically related to the specific geometry of the laundry machine.

[0014] In an embodiment of the invention, the coefficient is empirically determined by detecting the time required to obtain a prefixed final humidity of the laundry items housed in the drum when rotating the drum at a prefixed maximum rotating speed.

[0015] In an embodiment of the invention, said polynomial function is a quadratic polynomial function.

[0016] In an embodiment of the invention, said polynomial function is a quadratic polynomial function of the form:

$$T_{spin} = a \times rpm^2 + b \times rpm + c\,,$$

wherein T_{SL} is the time duration, *rpm* is the variable and *a, b* and c are the coefficients of the terms $a \times rpm^2$, $b \times rpm$ and c, respectively.

[0017] In an embodiment of the invention, wherein the step of obtaining an indication of an unbalance mass comprises: determining a static unbalance mass associated with the laundry items housed in the drum, and wherein determining the maximum rotating speed comprises: determining a calculated maximum rotating speed on the basis of following equation:

$$w_{Mc} = \sqrt{\frac{f}{um_s \times r}}\,,$$

wherein w_{Mc} is the calculated maximum rotating speed, *f* is a maximum allowable centrifugal force sustainable by the drum, *r* is the drum radius and um_s is the static unbalance.

[0018] In an embodiment of the invention, wherein the step of determining a static unbalance mass comprises: measuring a inertia moment of the drum housing the laundry items; measuring a torque of the motor, and computing said static unbalance mass on the basis of said inertia moment and said motor torque.

[0019] In an embodiment of the invention, wherein the step of obtaining an indication of an unbalance mass comprises: measuring a dynamic unbalance mass associated with the laundry items housed in the drum; comparing the dynamic unbalance mass with a dynamic unbalance mass threshold, and wherein determining the calculated maximum rotating speed comprises, if the measured dynamic unbalance mass is greater than the dynamic unbalance mass threshold: comparing the calculated maximum rotating speed with a predetermined maximum rotating speed, and selecting as the maximum rotating speed the lowest between the calculated maximum rotating speed and the predetermined maximum rotating speed.

[0020] In an embodiment of the invention, the laundry machine further comprises a user interface adapted to receive inputs provided by a user, and wherein the method further comprises: receiving, through the user interface, an indication about the type of laundry items to be treated by the laundry machine and/or a weight of the laundry items.

[0021] In an embodiment of the invention, the method further comprises the step of rotating the drum in order to distribute uniformly the laundry items housed inside the drum before obtaining an indication of an unbalance mass.

[0022] In an embodiment of the invention, the method further comprises the step of rotating the drum at a lower rotation speed lower than said maximum rotation speed for at least one further time interval preceding said time interval having said time duration.

[0023] In an embodiment of the invention, the time interval that has said time duration is a last time interval of a plurality of time intervals during which the drum is rotated at a respective rotating speed.

[0024] In an embodiment of the invention, the method further comprises repeating at least twice, during a laundry-treating cycle, the steps of: obtaining an indication of an unbalance mass associated with the laundry items housed in the drum; determining a maximum rotating speed at which the drum is rotated by the motor on the basis of said unbalance indication; rotating the drum at the maximum rotating speed for a time interval having a time duration, and determining said time duration for which the motor rotates the drum at the maximum rotating speed.

[0025] Another aspect of the present invention proposes a laundry machine for treating laundry items comprising a drum adapted to house the laundry items to be treated, a motor arranged for rotating the drum, a control system for managing the operation of the laundry machine. In the solution according to an embodiment of the present invention, the control system is configured to perform the method mentioned above.

[0026] In an embodiment of the invention, the control system comprises a calculating unit configured for calculating said non-linear polynomial function based on the maximum rotating speed and a memory element adapted to store the coefficient, the maximum allowable centrifugal force, the measured static unbalance, the dynamic unbalance mass threshold and the predetermined maximum rotating speed.

[0027] In an embodiment of the invention, the control system comprises a look-up table storing a set of stored maximum rotating speeds, and for each stored maximum rotating speed, at least one corresponding time duration for which the motor have to rotate the drum calculated through said non-linear polynomial function, and wherein the control system is configured for selecting the time duration corresponding to a maximum rotating speed selected from the set of stored maximum rotating speeds on the basis of said unbalance indication.

[0028] These, and others, features and advantages of the solution according to the present invention will be better understood with reference to the following detailed description of some embodiments thereof, provided for illustrative and not restrictive purposes, to be read in conjunction with the attached drawings. In this regard, it is expressly intended that the drawings are not necessarily to scale and that, unless specified otherwise, they simply aim to conceptually illustrate the structures and procedures. In particular:

- **Figure 1A** is an isometric view of a laundry machine in which the present invention may be implemented;
- **Figure 1B** is a schematic cross-sectional view of the laundry machine of **Figure 1A;**
- **Figure 2** is a schematic block diagram of a control system for controlling the operation of a laundry machine according to an embodiment of the present invention;
- **Figures 3A** and **3B** are two portions of a schematic flowchart of a method for controlling a spinning phase of the washing machine according to an embodiment of the present invention;
- **Figure 4** is a schematic block diagram of a control system for controlling the operation of a laundry machine according to another embodiment of the present invention, and
- **Figure 5** is a schematic diagram showing a controlled spinning phase according to an embodiment of the present invention compared with a known spinning phase.

[0029] With reference to the drawings, **Figures 1A** and **1B** are isometric and cross-sectional views, respectively, of a laundry machine **100** in which the present invention may be implemented.

[0030] The laundry machine **100** is a machine for treating laundry (such as for example a laundry washing machine or a laundry washing/drying machine) of the front-loading type. Anyway, it should be apparent from the following description that laundry machines of the top-loading type may also benefit from the solution according to the present invention.

[0031] In the example at issue, the laundry machine **100** comprises a casing or cabinet **105** preferably substantially parallelepiped-shaped, which encloses a washing tub, or simply tub, **107** (as shown in **Figure 1B)** preferably substantially cylindrically-shaped, wherein the laundry is treated, along with any other component of the laundry machine **100** necessary for its operation (e.g., hydraulic, electronic and electromechanical apparatuses as described in the following).

[0032] The tub **107** houses a rotatable drum **110** preferably substantially cylindrically shaped, which, in operation, rotates about an axis **A** in order to tumble the laundry to be washed. Typically, the tub **107** comprises, in a backside or backwall **107a** thereof, a shaft opening **107b,** in which a drum rotor shaft **110a** is inserted. The rotor shaft **110a** is attached to the drum **110** and rotatably connected by means of a transmission apparatus **115** to a drum motor **120,** preferably electric, comprised in the laundry machine **100** in order to rotate the drum **110** during operation. The drum motor **120** is preferably, although not limitatively, positioned in a bottom position with respect to the casing **105.** The transmission apparatus **115** may comprise a transmission belt or chain **115a** coupled with a pair of pulleys **115b** and **115c,** of which a first pulley **115b** is mounted to the drum rotor shaft **110a** while a second pulley **115c** is mounted to a motor shaft **120a.** Alternatively, in other embodiments according to the present invention (not shown in the Figures), the rotating movement may be transferred to the drum in any known manner; for example, a motor may be directly connected to the drum (so called "direct drive"), with the motor shaft coinciding to the drum shaft.

[0033] In order to allow a user to access the tub **107** and the inside of the drum **110** (for loading/unloading the laundry), a loading/unloading opening **125** is advantageously provided on a front side of the laundry machine **100.** The tub **107** is provided with a tub opening **107c,** and the drum **110** is provided with a drum opening **110b.** The tub opening **107c** is adapted to be aligned with the loading/unloading opening **125** provided in the casing **105,** and with the drum opening **110b** of the drum **110.**

[0034] Preferably, in order to achieve a watertight connection between the loading/unloading opening **125** and the tub opening **107b** (in order to avoid leakages of washing liquid into the casing **105),** a bellows **130,** preferably made of an elastomeric and waterproof material, is mounted in a watertight manner (such as by gluing, by welding, by interference fitting, *etc.*) to a border of the loading/unloading opening **125** and is coupled with a border of the tub opening **107c.**

[0035] The loading/unloading opening **125** is closable by a door **135,** which is hinged, preferably, to the casing **105** by means of a hinge (not shown in the figures).

[0036] The tub **107** is fluidly connected to a hydraulic apparatus (not shown in the drawings) adapted to provide washing liquids (*e.g.*, water mixed with detergents) in the washing tub **107** for treating the laundry therein, and to exhaust such liquids once used. The laundry machine **100** may possibly comprise also a drying air apparatus (not shown) fluidly connected with the tub **107** adapted to heat up and blow drying air into the tub and draw therefrom moisturized cool air.

[0037] In addition, a user interface **140** is advantageously provided, preferably, although not limitatively, on a top portion **105t** of the casing **105.** Preferably, the user interface **140** may comprise a control panel **140a** for selecting laundry treatment cycles (*e.g.,* a set of operations and parameters designed for treating peculiar fabrics, such as wool items) to be carried out by the laundry machine **100,** and a drawer **140b** for loading laundry-treating products (*e.g.,* detergents, softeners, bleachers, *etc.).*

[0038] The laundry machine **100** is advantageously provided with a control system **150** (*e.g.,* comprising one or more microcontroller and/or other electronic devices) adapted to control the laundry machine **100** operation, which is preferably, although not necessarily, placed in a top position inside the casing in order to be less prone to contacts with liquids or humidity possibly leaking from the tub **107.**

[0039] In one embodiment of the invention, the control system **150** is advantageously configured to control spinning phases performed by the laundry machine **100** during operation in an adaptive way.

[0040] Turning to **Figure 2,** it is a schematic block diagram of the control system **150** for controlling the operation of a laundry machine **100** according to an advantageous embodiment of the present invention.

[0041] In one advantageous embodiment of the invention, in order to control spinning phases, the control system **150** comprises a calculating unit **205** configured to perform mathematic operation (as described in greater detail below) and a memory element **210** adapted to store operating parameters and data (as described in greater detail below).

[0042] Moreover, the control system **150** can advantageously comprise one or more operating sensors **215** (e.g., comprising one or more angular speed sensor and torque sensors) adapted to acquire information about the laundry machine **100** operation; for example, the operating sensors **215** can measure a rotating speed w, and a torque associated with the drum **110.**

[0043] With reference to **Figures 3A** and **3B,** which are two portions of a schematic flowchart of a method of controlling a spinning phase of the washing machine **100** according to an advantageous embodiment of the present invention, a spinning phase control performed by the control system **150** is now described.

[0044] The method of controlling a spinning phase of the laundry machine **100** according to an advantageous embodiment of the present invention is adapted to determine a reduced maximum rotating speed w_{Mr}, generally reduced with respect to a default maximum rotating speed w_{Md} at which the drum **110** can be rotated if the unbalance of the drum is low enough, which is set by default during the laundry machine manufacturing and, more preferably, reduced with respect to a laundry-treatment maximum rotating speeds w_{Mlt} (in its turn lower than, or equal to, the default maximum rotating speed w_{Md}) at which the drum **110** can be rotated if the unbalance of the drum is low enough, each laundry-treatment maximum rotating speed w_{Mlt} being associated with a corresponding laundry-treating program (e.g., selectable by a user through the user interface **140).** The determined reduced maximum rotating speed w_{Mr} is used as maximum rotating speed w_M at which the drum 110 can be rotated without causing oscillations of the drum **110** within the tub 107 to become detrimental for the laundry machine **100** operation, as well as without provoking a damage and/or a faster wear-out of laundry machine **100** component parts (e.g., deformation/wear-out of the drum **110** and/or the tub **107,** wear-out of a bellows 130 coupled with the drum 110 *etc.).*

[0045] In addition, the method further determines a time interval T_{SL} for which the drum 110 has to be rotated at the reduced maximum rotating speed w_{Mr} in order to obtain a desired final humidity of the laundry treated. Preferably, such a desired final humidity corresponds to the final humidity that would be achieved at the end of a selected laundry-treating program comprising a rotation at the laundry-treatment maximum rotating speeds w_{Mlt}. The time interval T_{SL} is determined on the basis of a non-linear polynomial function of at least one variable related to the reduced maximum rotating speed w_{Mr} achievable by the drum 110 during the spinning phase. Preferably non-linear polynomial function has at least a coefficient empirically determined (as described in the following).

[0046] In one advantageous embodiment of the invention, initially the program maximum rotating speed w_{Mp} associated with the laundry-treating program selected by the user is identified (block **305).** Preferably, although not limitatively, the user may modify the laundry-treatment maximum rotating speed w_{Mlt} during a selection of the laundry-treating program (e.g., by means of the user interface **140).** For example, the user has the possibility to reduce a value of the laundry-treatment maximum rotating speed w_{Mlt} in order to obtain a different, higher, final humidity for the laundry or to reduce mechanical stresses suffered by the fabric thereof. Having identified the program maximum rotating speed w_{Mp} also a desired final humidity of the laundry items at the end of the spinning cycle is defined. For example, such desired final humidity may be predetermined and stored in the memory element **210,** in such a way that any predefined washing program selectable by the user has its specific final desired humidity stored within. In addition, or alternatively, a user may directly input through the user interface **140** the desired final humidity value and/or may select the desired final humidity value out of a set of final humidity values through the user interface **140.**

[0047] In a further preferred embodiment, a user may also input through the user interface **140** an indication about the type of laundry to be treated by the laundry machine **100** and/or the weight of the laundry in order to achieve a more accurate determination of the reduced maximum rotating speed w_{Mr} (dashed block **310).** Alternatively or in addition, the operating sensors **215** may comprise one or more weight sensor adapted to automatically determine the weight of the laundry inside the drum **110.**

[0048] Subsequently, a reduced maximum rotating speed w_{Mr} is determined.

[0049] Preferably, the control system **150** first actuates the drum motor **120** for rotating the drum **110** in order to distribute uniformly the laundry items housed inside the drum **110** (block **315).**

[0050] Afterwards, thanks to the operating sensors **215** an indication of an unbalance mass associated with laundry items distributed unevenly within the drum **110** is obtained.

[0051] In one advantageous embodiment of the invention, a static unbalance mass um_s is determined as follows. An inertia moment of the drum **110** housing the laundry items is measured according to any suitable known manner (e.g., by means of the operating sensors **215;** block **320**). In addition, a torque of the drum motor **120** is measured (e.g., by means of the operating sensors **215;** block **325).**

[0052] The static unbalance mass um_s is then computed by the calculating unit **205,** preferably on the basis of a combination of the measured inertia moment and the measured motor torque in any known way (block **330).** The static unbalance mass um_s thus computed may be stored in the memory element **210** of the control system **150.**

[0053] Afterwards, a calculated maximum rotating speed w_{Mc} is calculated by the calculating unit **205** that combines the static unbalance mass um_s with data stored in the memory element **210.**

[0054] In one advantageous embodiment of the invention, the calculating unit **205** determines a calculated maximum rotating speed w_{Mc} (block **335)** on the basis of the following equation:

$$w_{Mc} = \sqrt{\frac{f}{um_s \times r}}, \qquad (1)$$

wherein the datum f is a maximum allowable centrifugal force sustainable by the drum **110** (e.g., experimentally or theoretically defined during a design/prototyping phase of the manufacture of the laundry machine **100**) and the datum *r* is a radius of the drum **110.** As mentioned above, the data *f* and *r* (or their ratio) may be (permanently) stored in the memory element **210.**

[0055] Preferably, although not limitatively, a dynamic unbalance mass um_d is further determined for taking into account also its contribution to oscillations of the drum **110** within the tub **107** that are detrimental for the laundry machine **100** in determining of the reduced maximum rotating speed w_{Mr}.

[0056] In one embodiment of the invention, the dynamic unbalance mass um_d associated with the laundry items housed in the drum **110** is measured in a known manner (e.g., by means of the measurements performed by operating sensors **215;** block **340).**

[0057] The measured dynamic unbalance mass um_d is compared with a dynamic unbalance mass threshold $um_{d|th}$ (e.g., stored in the memory element **210;** decision block **345**). If the measured dynamic unbalance mass um_d is lower than the dynamic unbalance mass threshold $um_{d|th}$ (exit branch **N** of decision block **345**), the effects associated with the dynamic unbalance mass um_d are deemed substantially to not negatively affect the spinning phase. Thus, the calculated maximum rotating speed w_{Mc} is selected as the reduced maximum rotating speed w_{Mr} (block **350**) and the method proceeds to decision block **355** (described below).

[0058] Conversely, if the measured dynamic unbalance mass um_d is greater than the dynamic unbalance mass threshold $um_{d|th}$ (exit branch **Y** of decision block **345**), the calculated maximum rotating speed w_{Mc} is compared with a predetermined maximum rotating speed w_{Mp} (decision block **360**).

[0059] The predetermined maximum rotating speed w_{Mp} is experimentally (or theoretically) defined during a design/prototyping phase of the manufacture of the laundry machine **100** in order to ensure avoiding any detrimental effects on the laundry machine **100** (i.e., the predetermined maximum rotating speed w_{Mp} is sized to avoid detrimental effects associated with the measured dynamic unbalance mass um_d greater than the dynamic unbalance mass threshold $um_{d|th}$). If the calculated maximum rotating speed w_{Mc} is lower than the predetermined maximum rotating speed w_{Mp} (exit branch **N** of decision block **360**), the calculated maximum rotating speed w_{Mc} is selected as the reduced maximum rotating speed w_{Mr} for the spinning phase of the laundry machine **100** (block **350**). Instead, if the calculated maximum rotating speed w_{Mc} is greater than the predetermined maximum rotating speed w_{Mp} (exit branch **Y** of decision block **360**), the predetermined maximum rotating speed w_{Mp} is selected as the reduced maximum rotating speed w_{Mr} for the spinning phase of the laundry machine **100** (block **365**), thus ensuring to avoid any detrimental effects to the laundry machine **100** associated with the measured dynamic unbalance mass um_d.

[0060] Then, the reduced maximum rotating speed w_{Mr} thus obtained is compared with the laundry-treatment maximum rotating speed w_{Mlt} (identified at block **305**), i.e. the maximum rotating speed preset by factory default for spinning phases (decision block **355**). If the reduced maximum rotating speed w_{Mr} is greater than the laundry-treatment maximum rotating speed w_{Mlt} (exit branch **Y** of decision block **355**), a speed profile of the spinning phase needs not to be modified, i.e. the laundry-treatment maximum rotating speed w_{Mlt} is confirmed as the maximum rotating speed w_M of the spinning phase (block **370**), and the laundry machine **100** performs the spinning phase operation (block **375**) with parameters preset by default (e.g., the laundry-treatment maximum rotating speed w_{Mlt}).

[0061] Conversely, if the reduced maximum rotating speed w_{Mr} is lower than the laundry-treatment maximum rotating speed w_{Mlt} (exit branch **N** of decision block **355**), the speed profile of the spinning needs to be modified, i.e. the reduced maximum rotating speed w_{Mr} is set as the maximum rotating speed w_M for the spinning phase (block **380**).

[0062] Indeed, a spinning phase of the laundry machine **100** generally comprises a plurality of intervals, and each interval has a respective time duration during which the drum **110** is rotated at a respective rotating speed (usually, different from a rotating speed of the other intervals). For example, each the interval of the spinning phase is designed in such a way to have a respective rotating speed greater than the rotating speed of the previous interval.

[0063] In an advantageous embodiment of the present invention the rotating speeds of all the intervals spinning phase are checked and maintained lower, or equal to, the reduced maximum rotating speed w_{Mr} if selected as the maximum rotating speed w_M (in order to prevent detrimental effects on the laundry machine **100**) by the control system **150.**

[0064] After the reduced maximum rotating speed w_{Mr} for the spinning phase has been determined, it is defined for how long the drum **110** has to be rotated at such reduced maximum rotating speed w_{Mr} in order to obtain the desired final humidity for the laundry treated by the laundry machine **100.**

[0065] In an embodiment of the invention, the method defines a time duration T_{SL} of the last interval of the spinning phase of the laundry machine **100** (in order to obtain a desired final humidity for the laundry treated by the laundry machine **100**) during which the drum **110** is rotated at the reduced maximum rotating speed w_M.

[0066] In an embodiment of the invention, the time duration T_{SL} is calculated on the basis of a non-linear polynomial function (step **385**).

[0067] For example, the polynomial function is a quadratic non-linear polynomial function of the form:

$$T_{SL} = a \times rpm^2 + b \times rpm + c \, , \qquad (2)$$

where *rpm* is a variable associated with the reduced maximum rotating speed w_{Mr} and *a, b* and c are (empirically determined) coefficients of the terms $a \times rpm^2$, $b \times rpm$ and c mentioned above, respectively.

[0068] In one embodiment of the invention, the variable *rpm* is derived from the reduced maximum rotating speed w_{Mr} (e.g. operation performed by the calculating unit **205);** preferably, the variable *rpm* is a number of rounds per minute performed by the drum **110** while rotating at the reduced maximum rotating speed w_{Mr}.

[0069] The coefficients *a, b* and c (stored in the memory element **210)** are empirically determined in order to define a final humidity for the laundry items housed in the rotating drum **110** at the end of the time duration T_{SL} for which the drum **110** is rotated at the reduced maximum rotating speed w_{Mr}. Therefore, the memory element **210** stores a plurality of sets of three coefficients *a, b* and c, each set being associated with a corresponding desired final humidity.

[0070] In one advantageous embodiment of the invention, the sets of coefficients *a, b* and c are experimentally defined during a design/prototyping phase of the manufacture of the laundry machine 100. For example, for a given desired final humidity value, the coefficients *a, b* and c of the corresponding set may be defined by solving a corresponding system of three equation (2), wherein in each of the three equations (2) the variables *rpm* and T_{SL} are respectively the detected value of the variable related to the reduced maximum rotating speed w_{Mr} of the drum speed, and the corresponding time duration required for obtaining a prefixed final humidity (with a different prefixed final humidity for each equation (2) of the system) for the laundry items housed in the rotating drum **110,** while the coefficients a, b and c are the unknowns which value can be easily obtained by solving the system of the three equations (2).

[0071] Once the time duration T_{SL} is defined (i.e., at block **385**) the parameters (i.e., the reduced maximum rotating speed w_{Mr} and the time duration T_{SL}) of the spinning phase are determined and the method performs the spinning phase operation (block **375**) according to the parameters just determined.

[0072] It should be noted that the method just described may be implemented several times during a laundry-treating cycle of the laundry machine **100,** i.e. each time a spinning phase is performed during the same laundry-treating cycle.

[0073] It should be noted that the method described above may undergo several modification, e.g. similar steps with the same functions may substitute several steps or portions thereof, some non-essential steps may be removed, or additional optional steps may be added, the steps may be performed in different order, in parallel or overlapped (at least in part), without departing from the scope of the present invention.

[0074] Turning now to **Figure 4,** it is a schematic block diagram of an alternative control system **150'** for controlling the operation of a laundry machine **100** according to another embodiment of the present invention.

[0075] The control system 150' differs from the control system 150 in what follows. The control system 150' comprises a look-up table 405 (instead of the calculating unit 205 previously described). In one embodiment of the invention, the look-up table 405 is adapted to store a plurality of reduced maximum rotating speeds. Preferably, each stored (reduced) maximum rotating speed w_{Ms} stored in the look-up table 405 ensures that detrimental effects on the laundry machine 100 operation are avoided for corresponding measurements (e.g., torque, weight measurements), or for a corresponding range of measurements, provided by the operating sensors 215.

[0076] In one embodiment of the invention, each stored maximum rotating speed w_{Ms} of the plurality of the stored reduced maximum rotating speeds is (pre)calculated (e.g., during a designing/prototyping phase of the laundry machine **100**), for example by means of equation (1) described above.

[0077] In addition, for each stored maximum rotating speed w_{Ms}, the look-up table **405** comprises a set of stored time durations for which the motor have to rotate the drum **110** at the stored maximum rotating speed w_{Ms}, each for obtaining a corresponding final humidity of the laundry to be treated.

[0078] In one embodiment of the invention, each stored time duration T_{SLs} of the sets of stored time durations stored in the look-up table **405** is (pre)determined (e.g., during a designing/prototyping phase of the laundry machine **100)** by means of a non-linear polynomial function such as the quadratic non-linear polynomial function (2) described above.

[0079] In operation, once the laundry-treatment maximum rotating speed w_{Mlt} is defined (and also the desired final humidity of the laundry items at the end of the spinning cycle, as described above), a stored (reduced) maximum rotating speed w_{Ms} to be used as reduced maximum rotating speed w_{Mr} is determined.

[0080] Preferably, the control system **150'** first actuates the drum motor **120** for rotating the drum **110** in order to distribute uniformly the laundry items housed inside the drum **110.**

[0081] Afterwards, the operating sensors **215** perform measurements (e.g., torque measurements) on the drum **110** containing the laundry to be treated. The control system **150'** selects a stored maximum rotating speed w_{Ms} stored in the look-up table **405** as the reduced maximum rotating speed w_{Mr} according to the measurements performed by the operating sensors **215.** In other words, the control system **150'** is configured to select the stored maximum rotating speed w_{Ms} among the stored maximum rotating speeds stored in the look-up table **405** more similar to a calculated maximum rotating speed adapted to prevent detrimental effects on the laundry machine **100** associated with the static unbalance mass um_s and/or the dynamic unbalance mass um_d indicated (i.e., inferable) by means of the measurements performed by the operating sensors **215** (e.g., the reduced maximum rotating speed that will be obtained by implementing equation (1)).

[0082] As in the previous example, the reduced maximum rotating speed w_{Mr} is compared with the laundry-treatment maximum rotating speed w_{Mlt} (i.e., it is verified if it is needed to reduce the maximum rotating speed w_M of the spinning phase).

[0083] Subsequently, if the reduced maximum rotating speed w_{Mr} is selected as the maximum rotating speed w_M, on the basis of the reduced maximum rotating speed w_{Mr} and on the basis of the desired final humidity (determined together with the laundry-treatment maximum rotating speed w_{Mlt}) the time duration T_{SL} is selected. Preferably, from the set of stored time durations associated with the reduced maximum rotating speed w_{Mr} (i.e., the stored maximum rotating speed w_{Ms} selected among the stored maximum rotating speeds stored in the look-up table **405)** is selected as time duration T_{SL} the stored time duration T_{SLs} that substantially provides the desired final humidity at the reduced maximum rotating speed w_{Mr}

[0084] Once the time duration T_{SL} is defined, the spinning phase is performed with the parameters (i.e., the maximum rotating speed w_M and the time duration T_{SL}) just determined.

[0085] Therefore, also with the control system **150'** it is possible to modify the spinning phase of the laundry machine **100** in such a way to automatically prevent detrimental effects on the laundry machine **100** (e.g., lowering the operating performance and/or provoking a damage and/or a faster wear-out thereof) and, at the same time, providing treated laundry items having the desired final humidity.

[0086] Turning now to **Figure 5,** it is a schematic diagram showing a controlled spinning phase according to an embodiment of the present invention compared with a known spinning phase.

[0087] A first spinning phase curve **505** illustrates a spinning phase for which the respective reduced maximum rotating speed w_{Mr} is equal to or greater than the laundry-treatment maximum rotating speed w_{Mlt}, and therefore the laundry-treatment maximum rotating speed w_{Mlt} is selected as the maximum rotating speed w_M. The first spinning phase curve **505** comprises a first portion featuring a first rotating speed w_1 and having a first fixed time duration T_1 (extending from an initial spinning time instant t_0 to a first portion final time instant t_1, and defined by default), a second portion featuring a second rotating speed w_2 (greater than the first rotating speed w_1) and having a second fixed time duration T_2 (extending from first portion final time instant t_1 to a second portion final time instant t_2, and defined by default) and a third portion featuring the default maximum rotating speed w_{Md} and having a third time duration T_3 (extending from second portion final time instant t_2 to a final spinning time instant t_3, and defined by default).

[0088] A second spinning phase curve **510** illustrates a spinning phase for which the respective reduced maximum rotating speed w_{Mr} is lower than the laundry-treatment maximum rotating speed w_{Mlt}, and therefore the reduced maximum rotating speed w_{Mr} is selected as the maximum rotating speed w_M. The second spinning phase curve **510** comprises a first portion substantially corresponding to the first portion of the first spinning phase curve **505** (i.e., features the first rotating speed w_1 and has the first fixed duration T_1, defined by default). In the example of **Figure 5** the second rotating speed w_2 results to be greater than the reduced maximum rotating speed w_{Mr}, therefore during a second portion of the second spinning phase curve **510** the rotating speed of the drum **110** is limited to the value of the maximum rotating speed w_M (i.e., in order to prevent detrimental effects on the laundry machine **100)** for a whole time duration of such second portion of the second spinning phase curve **510** (equal to the second fixed duration T_2, defined by default). Eventually, a third portion of the second spinning phase curve **510** features the maximum rotating speed w_M (i.e., in order to prevent detrimental effects on the laundry machine **100**) and has the time duration T_{SL} (computed by means of the non-linear polynomial function (2) and extending from second portion final time instant t_2 to a final spinning time instant t_4), longer than the third time duration T_3, in order to ensure a desired final humidity of the laundry being treated by the laundry machine **100** with the drum rotated at the maximum rotating speed w_M.

[0089] By comparing the first spinning phase curve **505** with second spinning phase curve **510,** it should be apparent to those skilled in the art that the laundry machine **100** according to an embodiment of the present invention is configured to automatically limit the maximum rotating speed achievable by the drum **110** to a value that prevents detrimental effects on the laundry machine **100.** At the same time, the laundry machine **100** is further configured to adjust a time duration of a last portion (i.e., the third portion in the example of **Figure 5**) of its spinning phase curve in order to obtain a desired final humidity of the laundry being treated by the laundry machine **100.**

[0090] It should be noted that the embodiments of the invention described above may be combined or modified without departing from the scope of the present invention. For example, in a further embodiment a further control system comprises a simplified calculating unit configured for calculating only the reduced maximum rotating speed on the basis of the measurements provided by the operating sensors and a look-up table storing only a plurality of time durations each one associable with a corresponding one (or more) reduced maximum rotating speed.

Claims

1. A method of controlling a spinning phase of a laundry machine **(100)** for treating laundry items which comprises a drum **(110)** adapted to house the laundry items to be treated, a motor **(120)** arranged for rotating the drum **(110),** the method comprising

   - obtaining an indication of the unbalance associated with the laundry items housed in the drum **(110),**
   - determining a maximum rotating speed (w_M) at which the drum **(110)** can be rotated by the motor **(120)** on the basis of said unbalance indication,
   - rotating the drum **(110)** at the maximum rotating speed (w_M) for a time interval having a time duration,

   characterized by

   - determining said time duration (T_{SL}) for which the motor **(120)** rotates the drum **(110)** at the maximum rotating speed (w_M) on the basis of a non-linear polynomial function of a variable (*rpm*) related to said maximum rotating speed (w_M).

2. The method according to claim 1, wherein said non-linear polynomial function has at least one coefficient (*a*, *b, c*)

related to the specific geometry of the laundry machine **(100).**

3. The method according to claim 2, wherein said at least one coefficient (*a, b, c*) is empirically determined by detecting the time (T_{SL}) required to obtain a prefixed final humidity of the laundry items housed in the drum **(110)** when rotating the drum at a prefixed maximum rotating speed (w_M).

4. The method according to any one of the claims 1 to 3, wherein said polynomial function is a quadratic polynomial function of the form:

$$T_{spin} = a \times rpm^2 + b \times rpm + c\,,$$

wherein T_{SL} is the time duration (T_{SL}), *rpm* is the variable and *a, b* and c are the coefficients of the terms $a \times rpm^2$, $b \times rpm$ and c, respectively.

5. The method according to any one of the preceding claims, wherein obtaining an indication of unbalance associated with the laundry items housed in the drum **(110)** comprises:

- determining a static unbalance mass (um_s) associated with the laundry items housed in the drum **(110),** and

wherein determining the maximum rotating speed (w_M) comprises

- determining a calculated maximum rotating speed (w_{Mc}) on the basis of following equation:

$$w_{Mc} = \sqrt{\frac{f}{um_s \times r}}\,,$$

wherein w_{Mc} is the calculated maximum rotating speed (w_{Mc}), *f* is a maximum allowable centrifugal force sustainable by the drum, *r* is the drum radius and um_s is the static unbalance (um_s).

6. The method according to claim 5, wherein determining a static unbalance mass (um_s) comprises:

- measuring an inertia moment of the drum **(110)** housing the laundry items;
- measuring a torque of the motor **(120),** and
- computing said static unbalance mass (um_s) on the basis of said inertia moment and said motor torque.

7. The method according to any one of the preceding claims, wherein obtaining an indication of unbalance associated with the laundry items housed in the drum **(110)** comprises:

- measuring a dynamic unbalance mass (um_d) associated with the laundry items housed in the drum **(110);**
- comparing the dynamic unbalance mass (um_d) with a dynamic unbalance mass threshold ($um_{d|th}$), and

wherein determining the calculated maximum rotating speed (w_M) comprises, if the measured dynamic unbalance mass (um_d) is greater than the dynamic unbalance mass threshold ($um_{d|th}$):

- comparing the calculated maximum rotating speed (wM_c) with a predetermined maximum rotating speed (w_{Mp}), and
- selecting as the maximum rotating speed (w_M) the lowest between the calculated maximum rotating speed (w_{Mc}) and the predetermined maximum rotating speed (w_{Mp}).

8. The method according to any one of the preceding claims, wherein the laundry machine **(100)** further comprises a user interface **(140)** adapted to receive inputs provided by a user, and wherein the method further comprises:

- receiving, through the user interface **(140)** an indication about the type of laundry items to be treated by the laundry machine **(100)** and/or a weight of the laundry items.

9. The method according to any one of the preceding claims, further comprising:

- rotating the drum **(110)** in order to distribute uniformly the laundry items housed inside the drum **(110)** before obtaining an indication of unbalance associated with the laundry items housed in the drum **(110).**

10. The method according to any one of the preceding claims, further comprising:

- rotating the drum **(110)** at a lower rotation speed lower (w_1) than said maximum rotation speed (w_M) for at least one further time interval preceding said time interval having said time duration.

11. The method according to claim 10, wherein the time interval having said time duration (T_{SL}) is a last time interval of a plurality of time intervals (T_1, T_2, T_{SL}) during which the drum **(110)** is rotated at a respective rotating speed (w_1, w_M).

12. The method according to any one of the preceding claims, further comprising repeating at least twice, during a laundry-treating cycle, the steps of:

- obtaining an indication of the unbalance associated with the laundry items housed in the drum **(110);**
- determining a maximum rotating speed (w_M) at which the drum is rotated by the motor (120) on the basis of said unbalance indication;
- rotating the drum (110) at the maximum rotating speed (w_M) for a time interval having a time duration (T_{SL}), and
- determining said time duration (T_{SL}) for which the motor **(120)** rotates the drum **(110)** at the maximum rotating speed (w_M).

13. A laundry machine **(100)** for treating laundry items comprising a drum **(110)** adapted to house the laundry items to be treated, a motor **(120)** arranged for rotating the drum, a control system **(150; 150')** for managing the operation of the laundry machine **(100),**
characterized in that
the control system **(150; 150')** is configured to perform the method according to any one of the claims 1 to 12.

14. The laundry machine **(100)** according to claim 13, wherein the control system **(150)** comprises a calculating unit **(205)** configured for calculating said non-linear polynomial function based on the maximum rotating speed (w_M) and a memory element **(210)** adapted to store the coefficient (*a*, *b*, *c*), the maximum allowable centrifugal force (*f*), the measured static unbalance (um_s), the dynamic unbalance mass threshold ($um_{d|th}$) and the predetermined maximum rotating speed (w_{Mp}).

15. The laundry machine **(100)** according to claim 13, wherein the control system **(150')** comprises a look-up table **(405)** storing:

- a set of stored maximum rotating speeds (w_{Ms}), and
- for each stored maximum rotating speed (w_{Ms}), at least one corresponding time duration (T_{SL}) for which the motor **(120)** have to rotate the drum **(110)** calculated through said non-linear polynomial function, and

wherein the control system **(150')** is configured for selecting the time duration (T_{SL}) corresponding to a maximum rotating speed (w_M) selected from the set of stored maximum rotating speeds on the basis of said unbalance indication.

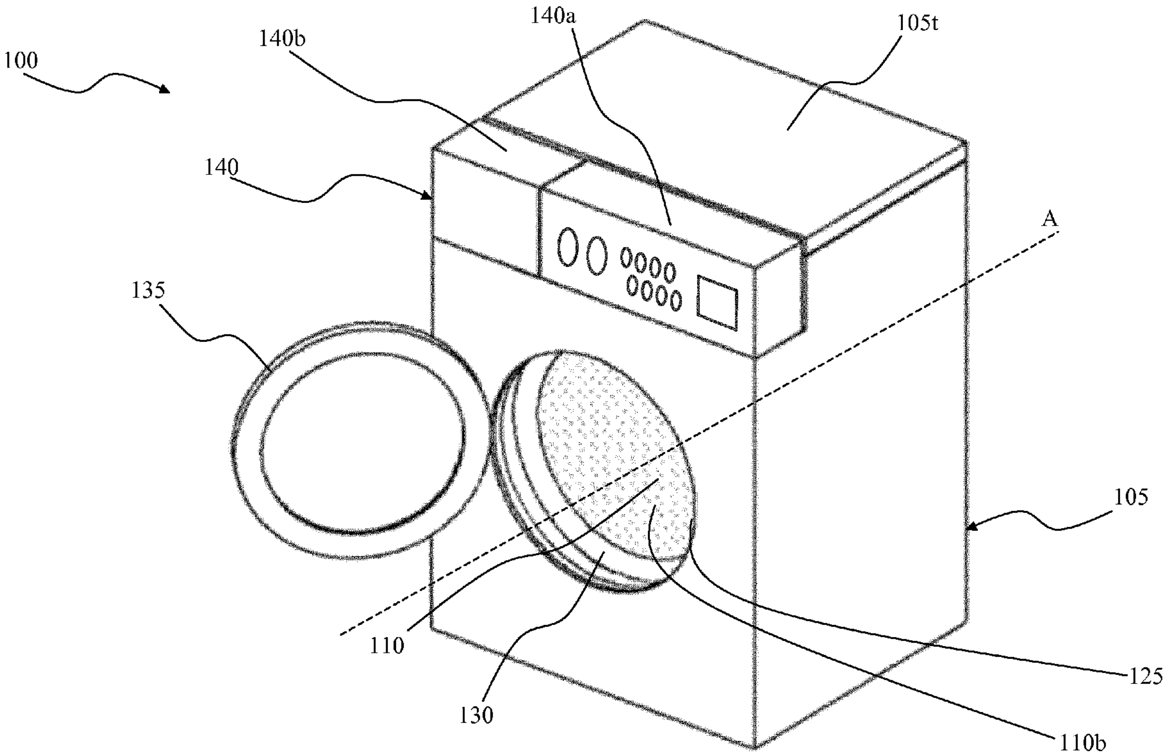


FIG.1A

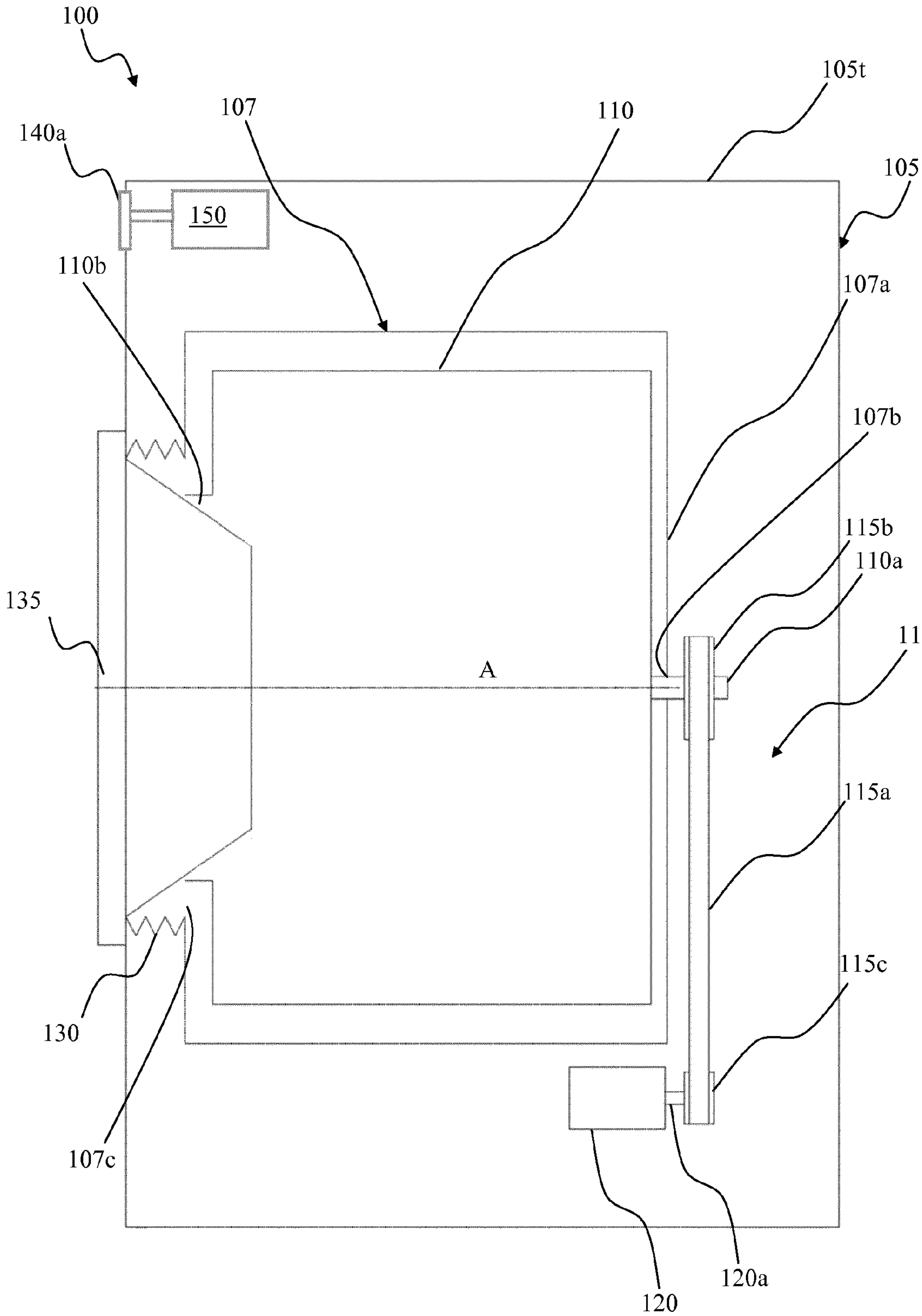

100
107
110
105t
105
140a
150
110b
107a
107b
115b
110a
135
A
115
115a
115c
130
107c
120
120a

FIG.1B

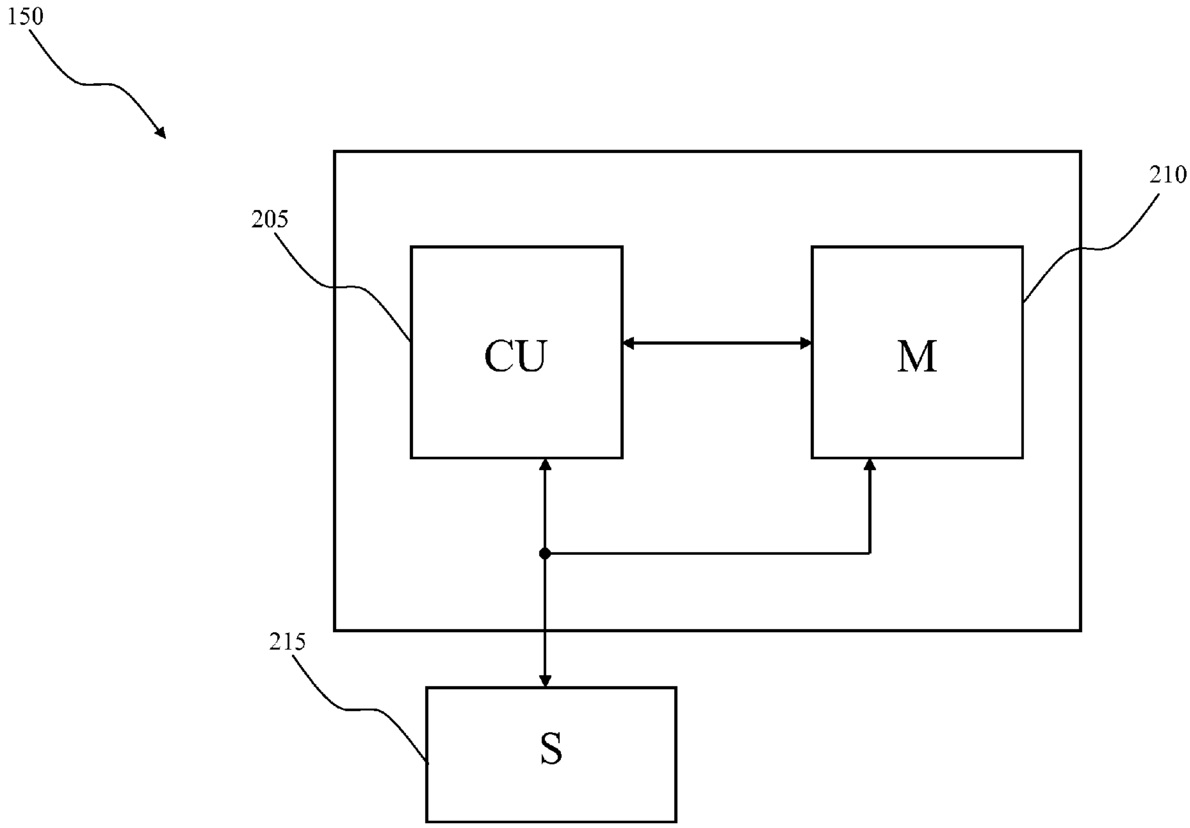
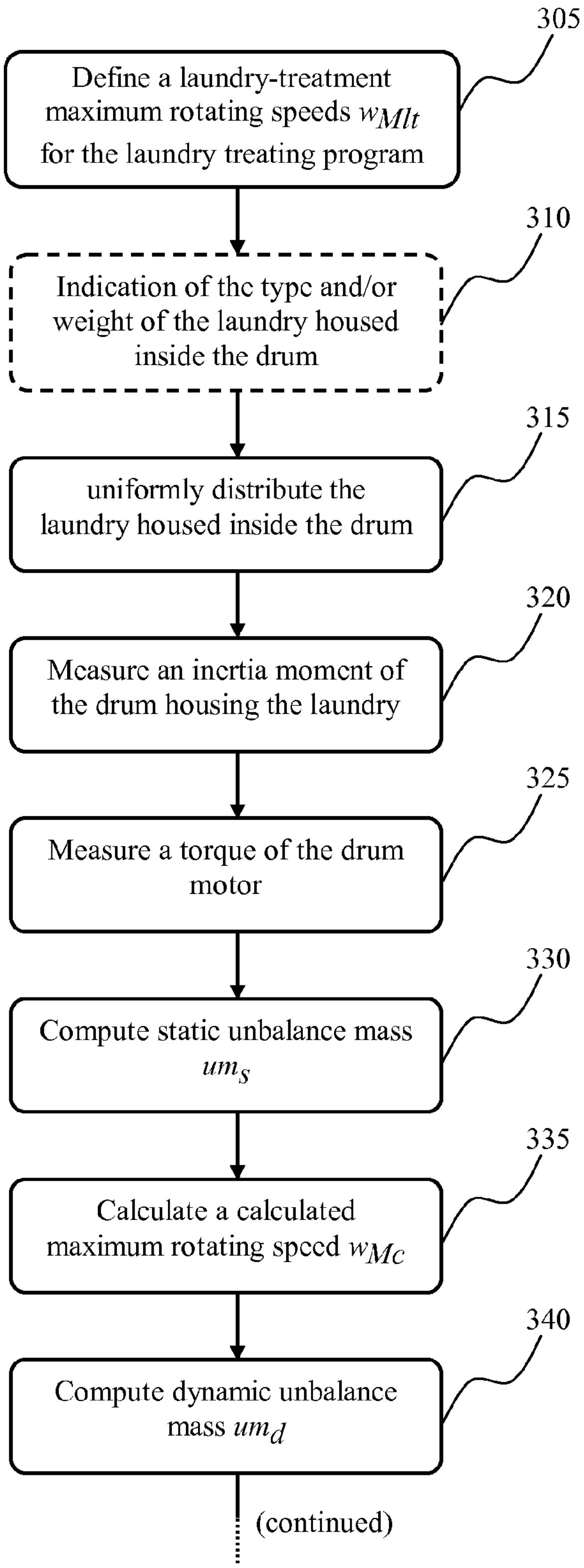


FIG.2



305
Define a laundry-treatment maximum rotating speeds w_{Mlt} for the laundry treating program
310
Indication of the type and/or weight of the laundry housed inside the drum
315
uniformly distribute the laundry housed inside the drum
320
Measure an inertia moment of the drum housing the laundry
325
Measure a torque of the drum motor
330
Compute static unbalance mass um_s
335
Calculate a calculated maximum rotating speed w_{Mc}
340
Compute dynamic unbalance mass um_d
(continued)

FIG.3A

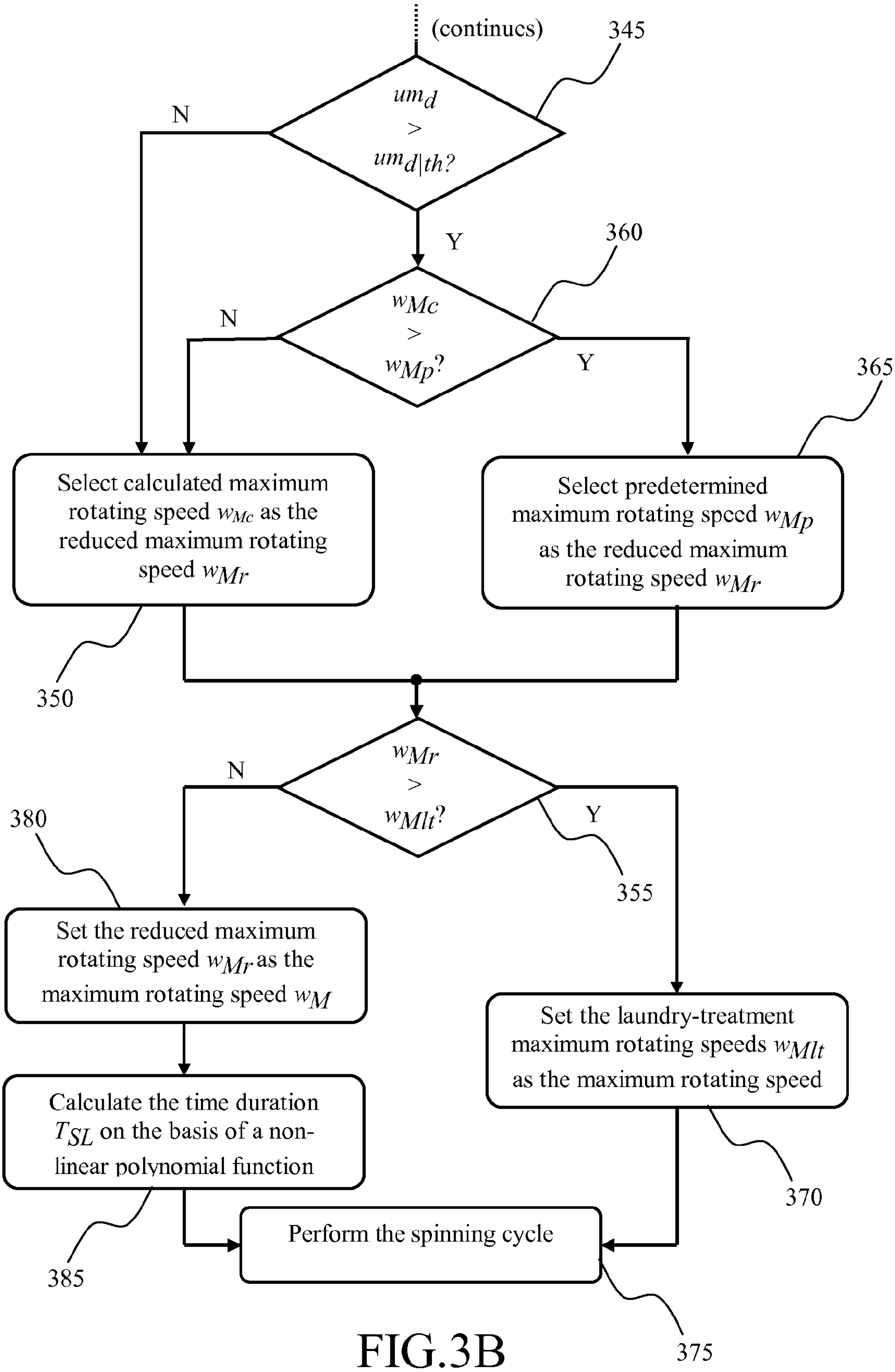

(continues)
345
$um_d > um_{d|th}$?
N
Y
360
$w_{Mc} > w_{Mp}$?
N
Y
365
Select calculated maximum rotating speed w_{Mc} as the reduced maximum rotating speed w_{Mr}
Select predetermined maximum rotating speed w_{Mp} as the reduced maximum rotating speed w_{Mr}
350
$w_{Mr} > w_{Mlt}$?
N
Y
380
355
Set the reduced maximum rotating speed w_{Mr} as the maximum rotating speed w_M
Set the laundry-treatment maximum rotating speeds w_{Mlt} as the maximum rotating speed
Calculate the time duration T_{SL} on the basis of a non-linear polynomial function
370
Perform the spinning cycle
385
375

FIG.3B

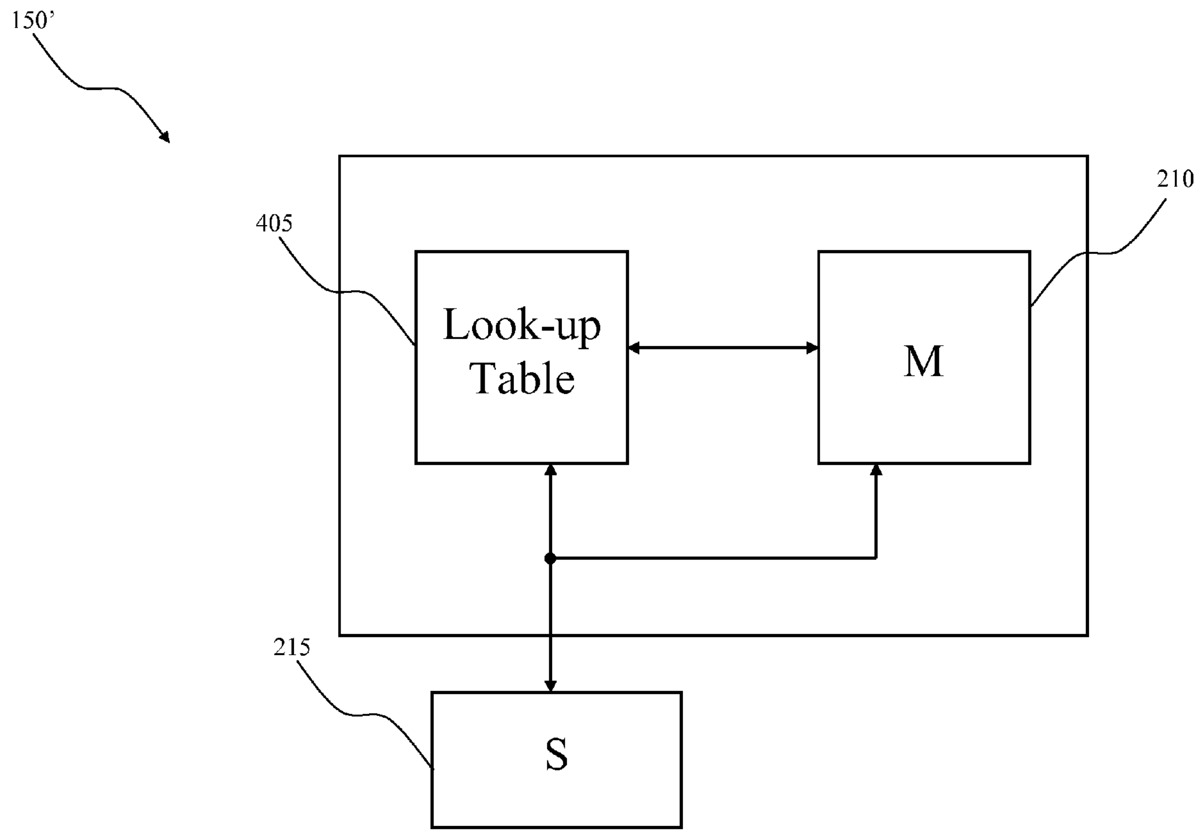


FIG.4

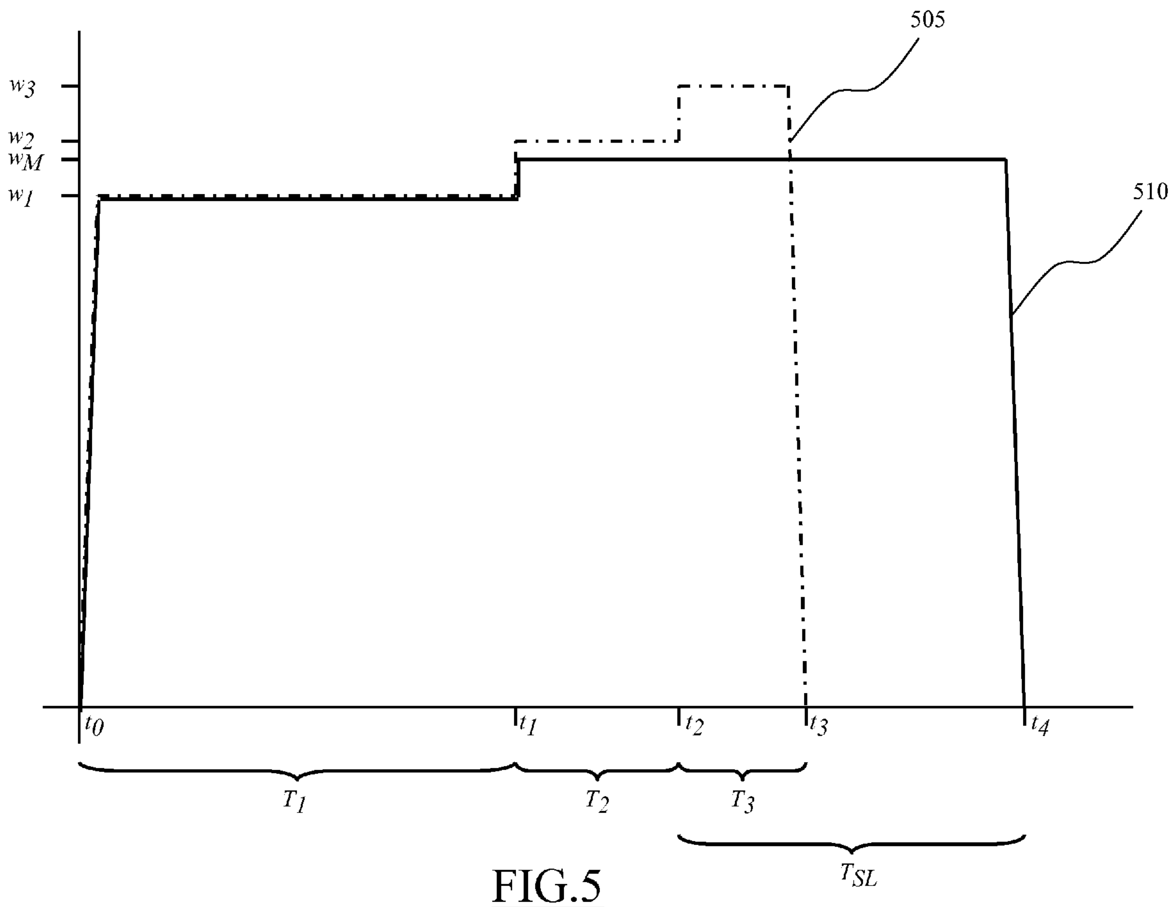


FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 14 17 7877

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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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	23 October 2014	Bermejo Pasetti, M

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 17 7877

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