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(54) Method of balancing a washing machine drum,and washing machine implementing such a method

(57) A method of balancing the drum (6) of a washing machine (1) wherein the drum (6) is mounted to rotate about its longitudinal axis (A) and houses a variable amount of laundry; the drum (6) having a number of balance tanks (12) spaced angularly on the lateral wall of the drum; and the method including the steps of filling all the balance tanks (12) on the drum (6) with water; rotating the drum (6), and the laundry inside it, at a reference rotation speed (ω_0) high enough to freeze distribution of the laundry on the lateral wall of the drum (6); determining an optimum distribution of the water in the balance tanks (12) to balance the effects of uneven distribution of the laundry on the lateral wall of the drum (6); and selectively draining surplus water from the individual balance tanks (12) to achieve the optimum distribution of the water in the balance tanks (12) and so balance the drum (6) rotating about its longitudinal axis (A).

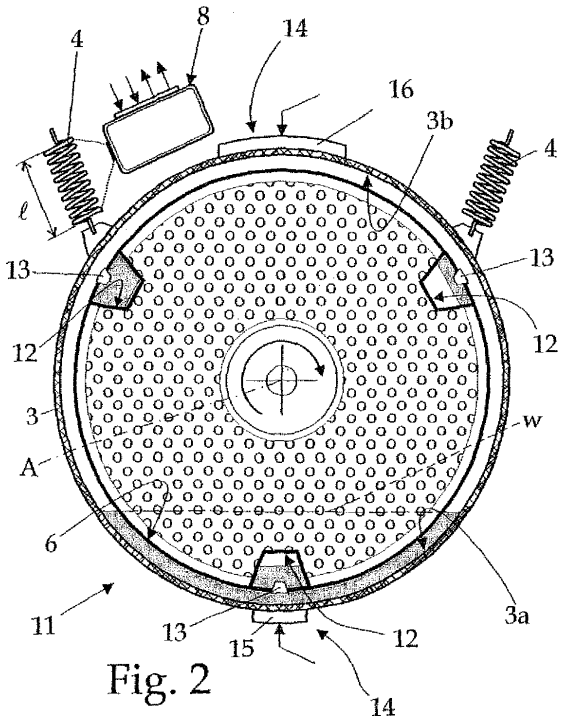


Fig. 2

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Description

[0001] The present invention relates to a method of balancing a washing machine drum, and to a washing machine implementing such a method.

[0002] More specifically, the present invention relates to a method of balancing a loaded drum of a front-loading home washing machine, to which the following description refers purely by way of example.

[0003] As is known, when loaded inside the drum of a front-loading washing machine, the laundry accumulates on the bottom of the cylindrical lateral wall of the drum, and is subsequently distributed dynamically and randomly over the whole lateral wall of the drum during all the stages in the wash cycle in which the drum rotates about its longitudinal axis, with the exception of the spin stage, in which the fast rotation speed of the drum stabilizes and freezes distribution of the laundry on the lateral wall.

[0004] Almost invariably, the laundry is obviously not distributed perfectly evenly over the whole lateral wall of the drum, so that, as the drum rotates, and particularly at the spin stage, mechanical vibration is produced which increases as a function of the extent to which the laundry is distributed unevenly, instant by instant, inside the drum.

[0005] To eliminate this drawback, the entire wash assembly of the machine is normally suspended in floating manner from the machine casing by a system of springs and shock-absorbers designed to absorb at least part of the vibration.

[0006] Since mechanical vibration produced by rotation of the drum is mainly responsible for the noise level of the machine and reaches its peak during the spin stage, over the past few years, motor control strategies have been devised which, by rapidly inverting the rotation direction of the drum at the start of the spin stage, attempt to distribute the laundry evenly inside the drum to further reduce mechanical vibration transmitted to the casing, and so reduce the noise level.

[0007] Unfortunately, in recent years, the maximum rotation speed of the drum during the spin cycle has increased considerably, so that current solutions for reducing mechanical vibration of the drum are now inadequate. In an attempt to solve the problem, washing machine manufacturers have inserted inside the machine casing one or more oscillating-mass vibration dampers designed to reduce mechanical vibration in the most critical machine operating conditions, i.e. during the spin cycle.

[0008] The introduction of oscillating-mass vibration dampers and other devices for reducing mechanical vibration transmitted to the casing has obviously increased the manufacturing cost of washing machines, with all the problems this entails.

[0009] It is an object of the present invention to eliminate at the source mechanical vibration produced by the drum rotating about its longitudinal axis.

[0010] According to the present invention, there is provided a method of balancing a washing machine drum, as claimed in Claim 1 and preferably, though not necessarily, in any one of the dependent Claims.

[0011] According to the present invention, there is also provided a washing machine, as claimed in Claim 8 and preferably, though not necessarily, in any one of the dependent Claims.

[0012] A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a view in perspective, with parts in section and parts removed for clarity, of a washing machine in accordance with the teachings of the present invention;

Figure 2 shows a schematic section of the Figure 1 washing machine, with parts in section and parts removed for clarity;

Figure 3 shows a larger-scale detail of Figure 2;

Figure 4 shows a schematic equivalent kinematic model of the washing machine drum.

[0013] Number 1 in Figure 1 indicates as a whole a washing machine, which is particularly advantageous for home use, and substantially comprises a casing 2 resting on the floor; a preferably, though not necessarily, cylindrical wash tub 3 suspended in floating manner inside casing 2 by means of a number of coil springs 4 (only one shown in Figure 1) preferably, though not necessarily, combined with one or more known shock-absorbers 5; a rotary drum 6 housed, to rotate axially about its longitudinal axis A, inside wash tub 3; and a drive unit 7 connected mechanically to drum 6 to rotate it about its longitudinal axis A inside wash tub 3.

[0014] Wash tub 3, drum 6, and the other component parts of washing machine 1 suspended from casing 2 by coil springs 4 form the wash assembly of the washing machine.

[0015] With reference to Figures 1 and 2, washing machine 1 also comprises a laundry weight detecting device 8 for determining the weight of the laundry currently inside drum 6, and for communicating the weight value to the electronic central control unit 9 of washing machine 1, which in turn optimizes the wash cycle parameters in known manner as a function of the actual weight of the laundry inside drum 6.

[0016] More specifically, laundry weight detecting device 8 determines the instantaneous total weight of the current contents of drum 6, i.e. the total weight m_{tot} of the current amount of laundry inside drum 6. Unlike known solutions, laundry weight detecting device 8 also extrapolates, from the total weight m_{tot} of the current amount of laundry inside drum 6, the balanced component and the unbalanced component of the weight of the laundry inside drum 6. The balanced component represents the weight of the amount of laundry distributed evenly inside drum 6, and the unbalanced component represents the weight of the amount of laundry distributed unevenly, and therefore in unbalanced manner, inside

drum 6.

[0017] According to kinematic physics, in fact, the dynamic behaviour of the laundry distributed randomly on the lateral wall of drum 6 rotating about longitudinal axis A may be represented schematically as a combination of the dynamic behaviour of a balanced mass m_1 and an unbalanced mass m_2, both located inside the rotating drum 6. The balanced mass m_1 is distributed evenly on the lateral wall of drum 6, and, being perfectly balanced, causes no mechanical vibration; whereas, the unbalanced mass m_2 is concentrated at one point on the lateral wall of drum 6, and causes vibration which is absorbed by coil springs 4 and shock-absorbers 5 supporting the wash assembly.

[0018] The weight m_1 of the amount of laundry distributed evenly inside drum 6 obviously corresponds to the balanced mass m_1 of the kinematic model, and the weight m_2 of the amount of laundry distributed unevenly inside drum 6 corresponds to the unbalanced mass m_2 of the kinematic model.

[0019] The same obviously also applies to an empty drum 6 rotating about longitudinal axis A, with the difference that, in this case, the equivalent kinematic model theoretically only contemplates the presence of a sole balanced mass m_0, seeing as the body of drum 6 is intrinsically balanced.

[0020] In the kinematic laundry model, the weight of balanced mass m_1, the weight of unbalanced mass m_2, and the position of unbalanced mass m_2 on the lateral wall of drum 6 obviously vary from one instant to the next as a function of the current distribution of the laundry inside drum 6, and are stabilized or frozen when drum 6 reaches a rotation speed capable of immobilizing the laundry on the lateral wall of drum 6.

[0021] On the basis of the above equivalent kinematic model, laundry weight detecting device 8 is therefore able to determine the total weight m_{tot} of the current contents of drum 6, i.e. the total weight m_{tot} of the current amount of laundry inside drum 6, and also to determine instant by instant the weight of balanced mass m_1 and the weight and position of unbalanced mass m_2 of the equivalent laundry kinematic model, and to transmit these parameters to electronic central control unit 9 of machine 1.

[0022] In the example shown, laundry weight detecting device 8 determines instant by instant the total weight of the wash assembly weighing on coil springs 4, and then determines the weight of balanced mass m_1 and the weight and position of unbalanced mass m_2 corresponding to the kinematic laundry model, by extrapolating them from the time pattern, within a predetermined reference time interval and as drum 6 rotates, of the weight weighing on coil springs 4 supporting the wash assembly. Laundry weight detecting device 8 obviously also determines the total weight m_{tot} of the actual amount of laundry inside drum 6 by summing the weight of balanced mass m_1 and the weight of unbalanced mass m_2.

[0023] With reference to Figures 1 and 2, in the example shown, laundry weight detecting device 8 indirectly determines the instantaneous total weight of the wash assembly weighing on coil springs 4, by determining the instantaneous length l of at least one of coil springs 4 supporting the wash assembly inside casing 2.

[0024] More specifically, laundry weight detecting device 8 statistically processes the time pattern l(t) of length l of coil spring 4 within a predetermined time interval ΔT, in which drum 6 rotates at a predetermined rotation speed ω_0 high enough to freeze distribution of the laundry on the lateral wall of drum 6, so as to determine the mean value l_m of length l of the reference coil spring 4 within the time interval ΔT in which drum 6 rotates at freezing rotation speed ω_0; and then calculates the total weight m_{tot} of the current amount of laundry inside drum 6 on the basis of the mean value l_m of length l of reference coil spring 4, and taking into account the weight of drum 6 and the way the total weight of the wash assembly of machine 1 is distributed between coil springs 4 supporting wash tub 3.

[0025] Laundry weight detecting device 8 also statistically processes the time pattern l(t) of length l of coil spring 4 within time interval ΔT to determine the deviation Δl in the time pattern l(t) of length l of reference coil spring 4, and then extrapolates from deviation Δl the actual weight of the mass of laundry theoretically concentrated in one point on the lateral wall of drum 6, i.e. the weight of unbalanced mass m_2 of the kinematic model.

[0026] Finally, laundry weight detecting device 8 calculates the weight of the mass of laundry theoretically distributed evenly over the whole lateral wall of drum 6, i.e. the weight of balanced mass m_1 of the kinematic model, as the difference between the total weight m_{tot} of the laundry inside drum 6, and the weight of unbalanced mass m_2 of the kinematic model.

[0027] With reference to Figure 1, washing machine 1 also comprises a position sensor 10 for determining a predetermined reference angular position of drum 6 inside wash tub 3, and laundry weight detecting device 8 first compares the signals from position sensor 10 with the time pattern l(t) of length l of reference coil spring 4 within time interval ΔT to determine the time difference between the peaks in the time pattern l(t) of length l of coil spring 4 and the signals from position sensor 10, and then calculates the angular position of the point on the lateral wall of drum 6 at which unbalanced mass m_2 of the kinematic model is theoretically concentrated, on the basis of the freezing rotation speed ω_0 of drum 6 and the above time difference.

[0028] With reference to Figures 1, 2 and 3, washing machine 1 also comprises a drum balancing device 11, which, under control of electronic central control unit 9, dynamically balances the laundry inside drum 6 by temporarily forming inside drum 6 a number of counterweights for compensating the effects of unbalanced mass m_2 of the kinematic model equivalent to the temporary distribution of the laundry on the lateral wall of drum 6.

[0029] In other words, with reference to Figure 4, drum

balancing device 11 temporarily forms inside drum 6 a number of counterweights rotating with drum 6, and the weight and position of which are determined so that the resulting dynamic behaviour can be represented schematically by a kinematic model comprising a balanced mass m_3 and an unbalanced mass m_4, and in which the weight of unbalanced mass m_4 substantially equals the weight of unbalanced mass m_2 of the kinematic laundry model. Moreover, unbalanced mass m_4 and unbalanced mass m_2 of the kinematic laundry model are located at diametrically opposite points on the lateral wall of drum 6.

[0030] More specifically, with reference to Figures 2 and 3, drum balancing device 11 comprises a number of (at least three) wash water storage tanks 12 angularly spaced- preferably, though not necessarily, equally spaced - on the lateral wall of drum 6, and which are filled with a variable quantity of wash water; and a number of regulating valves 13 for controlling wash water flow to and from individual tanks 12.

[0031] Drum balancing device 11 also comprises a valve control assembly 14, which, under control of electronic central control unit 9, opens regulating valves 13 on drum 6 independently of one another to adjust the amount of water inside individual tanks 12.

[0032] More specifically, on the basis of a mathematical model for determining, as a function of the amount of water inside individual tanks 12, the weight of balanced mass m_3 and the weight and position of unbalanced mass m_4 of the kinematic model schematically representing the dynamic behaviour of the counterweights defined by the masses of water inside tanks 12 rotating about longitudinal axis A, electronic central control unit 9 of machine 1 calculates the amount of water required inside each tank 12 to obtain an unbalanced mass m_4 of the same weight as unbalanced mass m_2 of the kinematic laundry model, and positioned diametrically opposite unbalanced mass m_2 on drum 6, i.e. specularly with respect to the axis of rotation of drum 6, and then operates valve control assembly 14 to achieve the calculated optimum distribution of water inside tanks 12.

[0033] In the example shown, drum balancing device 11 comprises three wash water storage tanks 12 defined by three vessels or cavities 12 formed directly, 120° apart, on the lateral wall of drum 6; and each tank or vessel 12 is connected to wash tub 3 by a controlled-release drain valve 13 fitted inside the lateral wall of drum 6 to connect the inside of vessel 12 to the gap between wash tub 3 and drum 6. Controlled-release drain valve 13 is designed to selectively and alternatively assume a first operating configuration, in which it isolates tank 12 from wash tub 3 to prevent water flow to or from tank 12, and a second operating configuration, in which it connects tank 12 to wash tub 3 to allow water flow to or from tank 12, depending on the position of tank 12 inside wash tub 3.

[0034] More specifically, controlled-release drain valve 13 comprises a movable shutter 13a for controlling water flow from wash tub 3 to tank 12, and vice versa, by moving, inside the body of valve 13 and in a direction preferably, though not necessarily, perpendicular to the lateral wall of drum 6, between a closed position cutting off water flow through valve 13, and a fully-open position allowing free water flow through valve 13; and a coil spring 13b, or other elastic member, inserted inside the body of valve 13 to hold movable shutter 13a in the closed position.

[0035] Valve control assembly 14 is designed to selectively open and close regulating valves 13 on command as the corresponding wash water storage tanks 12 travel through the bottom portion 3a of wash tub 3, where the wash water normally accumulates during normal operation of machine 1, or through the top portion of wash tub 3.

[0036] More specifically, in the example shown, movable shutter 13a of each drain valve 13 incorporates a permanent magnet (not shown) oriented with one pole inwards and the other outwards of drum 6. And valve control assembly 14 substantially comprises two coils 15 and 16 of electrically conducting material, which are fixed to the body of wash tub 3, one at the bottom of bottom portion 3a of wash tub 3, and the other at the top of top portion 3b of wash tub 3; and an electric power unit 17 for circulating electric current through coils 15 and 16 independently of each other and under direct control of electronic central control unit 9.

[0037] In the example shown, coil 16 occupies a larger portion of the wall of wash tub 3 than coil 15 underneath.

[0038] Each coil 15, 16 is oriented to generate, when supplied with electric current, a magnetic field which interacts with the magnetic field of the permanent magnet in movable shutter 13a of the valve 13 currently facing coil 15, 16, and moves movable shutter 13a temporarily into the fully-open position in opposition to respective coil spring 13b. Moving movable shutter 13a into the fully-open position obviously allows water flow to or from tank 12, depending on the rotation speed of drum 6 about longitudinal axis A and the position of coil 15, 16 on wash tub 3.

[0039] Operation of washing machine 1 will now be described, assuming wash tub 3 is filled with water to a predetermined level W high enough to completely immerse tanks 12 moving past coil 15, and that the selected wash cycle has finished the various stages preceding the spin stage.

[0040] At this point, before rotating drum 6 at the maximum rotation speed of the selected wash cycle, electronic central control unit 9 of washing machine 1 operates drive unit 7 to move all of tanks 12 of drum balancing device 11 successively to the bottom portion 3a of wash tub 3 and into position facing coil 15, and simultaneously activates electric power unit 17 to power coil 15 and open the regulating valve 13 of the tank 12 stopped directly over coil 15.

[0041] Since the water level w inside wash tub 3 is high enough to completely immerse the tank 12 stopped directly over coil 15, opening valve 13 allows wash water

to flow freely into and completely fill tank 12.

[0042] Once all the tanks 12 of drum balancing device 11 are filled, electronic central control unit 9 operates drive unit 7 to rotate drum 6 at freezing rotation speed ω_0 and so freeze distribution of the laundry on the lateral wall of drum 6.

[0043] When drum 6 reaches freezing rotation speed ω_0, electronic central control unit 9 activates laundry weight detecting device 8, which, by analysing the time pattern l(t) of length l of reference coil spring 4, determines the weights of balanced mass m_1 and unbalanced mass m_2 corresponding to the actual distribution of the laundry inside drum 6, and the angular position on the lateral wall of drum 6 of the point at which the whole unbalanced mass m_2 of the kinematic laundry model is assumed to be concentrated.

[0044] More specifically, by analysing the time pattern l(t) of length l of reference coil spring 4 and the signals from position sensor 10, laundry weight detecting device 8 calculates the weights of the balanced mass m_1' and unbalanced mass m_2' corresponding to the kinematic model of drum 6 rotating at rotation speed ω_0 together with the laundry and the masses of water stored in tanks 12.

[0045] In this connection, it should be pointed out that, in theory, the weight of drum 6 is defined at the design stage, and drum 6 is balanced at the production stage and so forms no part of the unbalanced mass of the kinematic model of drum 6.

[0046] On acquiring the parameters of the kinematic model of the laundry distributed inside drum 6 rotating at rotation speed ω_0 - or, rather, the parameters of the kinematic model of the system comprising the laundry and the water inside tanks 12 - electronic central control unit 9 calculates the amount of wash water required in each tank 12 of drum balancing device 11 to compensate the unbalanced mass m_2' formed by the laundry and the water in tanks 12 (as stated, drum 6 is balanced at the production stage and forms no part of the unbalanced mass of the kinematic model of drum 6), and then operates electric power unit 17 to power coil 16 synchronously with the passage of individual tanks 12 past coil 16, and so selectively open regulating valves 13 to drain surplus water from individual tanks 12.

[0047] If drum 6 is not perfectly balanced, by analysing the time pattern l(t) of length l of reference coil spring 4 and the signals from position sensor 10, laundry weight detecting device 8 calculates the weights of the balanced mass m_1' and unbalanced mass m_2' corresponding to the kinematic model of a mass system rotating at rotation speed ω_0, wherein the mass system comprises drum 6 as it is, all the water inside drum 6 (both inside and outside of tanks 12), and all laundry inside drum 6.

[0048] In this case, on acquiring the parameters of the kinematic model of the mass system comprising drum 6 as it is, the laundry, and the water inside drum 6 (tanks 12 included), electronic central control unit 9 calculates the amount of wash water required in each tank 12 of the drum balancing device 11 to compensate the unbalanced mass m_2' formed by drum 6, the laundry and the water inside drum 6(tanks 12 included); and then operates electric power unit 17 to power coil 16 synchronously with the passage of individual tanks 12 past coil 16, and so selectively open regulating valves 13 to drain surplus water from individual tanks 12.

[0049] In both situations, the amount of wash water to be drained from each tank 12 of drum balancing device 11 is calculated on the basis of the mathematical model, which, as a function of the amount of water inside individual tanks 12, provides for determining the weight of balanced mass m_3 and the weight and position of unbalanced mass m_4 of the kinematic model schematically representing the dynamic behaviour of the counterweights defined by the masses of water inside tanks 12, assuming tanks 12 are all originally filled completely with wash water, and therefore perfectly balanced, and so form no part of unbalanced mass m_2'.

[0050] In other words, electronic central control unit 9 assumes the parameters of unbalanced mass m_2' from laundry weight detecting device 8 depend solely on the uneven distribution of the laundry on the lateral wall of drum 6 (i.e. unbalanced mass m_2' coincides with unbalanced mass m_2), and regulates the amount of water inside tanks 12 so that the unbalanced mass m_4 produced by optimum distribution of the water in tanks 12 of drum balancing device 11 compensates, and eliminates the effects of, the unbalanced mass m_2' of the kinematic model of drum 6 (i.e. the unbalanced mass m_2 produced by the laundry distributed randomly inside drum 6).

[0051] More specifically, on the basis of the mathematical model for determining the weight of balanced mass m_3 and the weight and position of unbalanced mass m_4 on the basis of the water distribution inside tanks 12, electronic central control unit 9 of washing machine 1 calculates the optimum distribution of water required inside tanks 12 of drum balancing device 11 to obtain an unbalanced mass m_4 of the same weight as unbalanced mass m_2' and located diametrically opposite unbalanced mass m_2' on drum 6, and then operates regulating valves 13 to drain surplus water from individual tanks 12 to achieve the calculated optimum distribution.

[0052] In the event the mathematical model supplies a number of possible optimum distributions of water inside tanks 12 of drum balancing device 11, electronic central control unit 9 selects the optimum distribution resulting preferably, though not necessarily, in the lightest balanced mass m_3, and then operates regulating valves 13 to drain surplus water from individual tanks 12 to achieve the selected optimum distribution.

[0053] To safeguard against calculating errors caused by unequal filling of tanks 12 at the start of the balancing process or by an unbalanced drum 6- which would result in the water inside tanks 12 and/or in drum 6 forming part of unbalanced mass m_2' of the kinematic model of mass system -, electronic central control unit 9 of washing machine 1 may keep track of the changes in individual pa-

rameters of the kinematic model of the mass system as water is drained from tanks 12 of drum balancing device 11, and perform an interactive balancing process for reaching the minimum value of the unbalanced component of the overall weight of drum 6 and its load.

[0054] In fact, due to the continuous variation of geometrical and constructive parameters of the washing machine 1 and to non-accurate filling up and draining of the water from tanks 12, electronic central control unit 9 can provide, at the beginning, a rough distribution of the wash water in tanks 12. Then control unit 9 performs an interactive "fine tuning" of the distribution of the wash water in tanks 12, regulating step by step the water amount inside one or, maybe, two tanks 12 while monitoring the evolution of the unbalanced component value. In other words, during the interactive "fine tuning" control unit 9 repeats many times the calculation of the weights of the balanced mass m_1' and unbalanced mass m_2' of the kinematic model, and the calculation of the optimum distribution of water required inside tanks 12.

[0055] Obviously, electronic central control unit 9 of washing machine 1 discontinues the interactive balancing process in the event of failure to gradually reduce the unbalanced component of the overall weight of drum 6 and its load.

[0056] Dynamic balancing of drum 6 is terminated when electronic central control unit 9 succeeds in regulating the water inside individual tanks 12 of drum balancing device 11 to achieve the calculated/selected optimum distribution. The masses of water stored inside tanks 12, in fact, define counterweights 12, which rotate about longitudinal axis A integrally with drum 6, and which have a dynamic behaviour equivalent to the sum of a balanced mass m_3 distributed evenly on the lateral wall of drum 6, and an unbalanced mass m_4 concentrated at a precise point on the lateral wall of drum 6, at which the weight of unbalanced mass m_4 substantially equals the weight of unbalanced mass m_2' produced by the laundry distributed inside drum 6, and at which unbalanced mass m_4 is located, on the lateral wall of drum 6, diametrically opposite the location point of unbalanced mass m_2'.

[0057] Once drum 6 is balanced dynamically, and seeing as the distribution of the laundry inside drum 6 remains unchanged as long as the centripetal force immobilizes the laundry on the lateral wall of drum 6, electronic central control unit 9 of washing machine 1 operates drive unit 7 to increase the rotation speed of drum 6 gradually to the maximum speed of the spin cycle, with no mechanical vibration being caused by rotation of drum 6.

[0058] The advantages of the drum balancing method described are obvious: perfectly balancing drum 6 at the spin stage eliminates the need for sophisticated, high-cost vibration-damping systems, which have a far from negligible effect on the manufacturing cost of the machine.

[0059] By eliminating mechanical vibration at the spin stage, the wash assembly suspension system, i.e. coil springs 4 and shock-absorbers 5, can be designed to simply absorb minor mechanical vibration produced by low-speed rotation of drum 6.

[0060] Clearly, changes may be made to the method of balancing drum 6 and to washing machine 1 implementing such a method, without, however, departing from the scope of the present invention.

[0061] For example, drain valves 13 may be conventional controlled-open-close solenoid valves. In which case, valve control assembly 14 may comprise a central control unit fixed to the casing; and wiring for electrically powering the solenoid valves on the lateral wall of drum 6. In this case, the solenoid valve central control unit may obviously be integrated in electronic central control unit 9 of washing machine 1.

[0062] In a further non-shown embodiment, valve control assembly 14 comprises only bottom coil 15 which, in moving the movable shutter 13a into the fully-open position, can selectively fill up tanks 12 with water, or drain surplus water from tanks 12. In fact, when drum 6 reaches freezing rotation speed ω_0, the centrifugal force is high enough to push the water out of each tank 12 even if said tank 12 faces the bottom portion 3a of wash tub 3 and is submerged in the wash water.

Claims

1. A method of balancing the drum (6) of a washing machine (1) wherein said drum (6) rotates about its longitudinal axis (A) and houses a variable amount of laundry distributed randomly on its lateral wall; said drum (6) comprising a number of balance tanks (12) spaced angularly on the lateral wall of the drum and for storing a variable amount of water; and the method being **characterized by** comprising the steps of:

   - filling each of the balance tanks (12) on said drum (6) with water;
   - rotating the drum (6), and the laundry inside it, at a reference rotation speed (ω_0) high enough to freeze distribution of the laundry on the lateral wall of the drum (6);
   - determining at least once, as the drum (6) rotates at said reference rotation speed (ω_0), an optimum distribution of the water in the balance tanks (12) to balance the effects of uneven distribution of the laundry on the lateral wall of the drum (6); and
   - selectively draining surplus water from the individual balance tanks (12), as the drum (6) rotates at said reference rotation speed (ω_0), to achieve said optimum distribution of the water in the balance tanks (12) and so balance the drum (6) rotating about its longitudinal axis (A).

2. A method of balancing the drum of a washing machine, as claimed in Claim 1, **characterized in that**

determining said optimum distribution of the water in the balance tanks (12) comprises the steps of:

- determining, as the drum (6) rotates at said reference rotation speed (ω_0), at least the parameters of the unbalanced mass (m_2, m_2') of a kinematic model of the dynamic behaviour of the rotating drum (6) and its contents; said kinematic model describing the dynamic behaviour of the drum (6) by combining the dynamic behaviour of a first balanced mass (m_1') distributed evenly on the lateral wall of the drum (6), and of a first unbalanced mass (m_2, m_2') concentrated at a specific point on the lateral wall of the drum (6); and
- calculating at least once, by means of a predetermined mathematical model, the amount of water required in the individual balance tanks (12) to obtain a number of balance counterweights (12) equivalent to a second balanced mass (m_3) distributed evenly on the lateral wall of the drum (6), and to a second unbalanced mass (m_4) concentrated at a specific point on the lateral wall of the drum (6); the weight of the second unbalanced mass (m_4) being substantially equal to the weight of said first unbalanced mass (m_2); the point on the lateral wall of the drum (6) at which the second unbalanced mass (m_4) is located being substantially diametrically opposite the point at which the first unbalanced mass (m_2) of the kinematic model of the drum (6) is located; and optimum distribution of the water in the balance tanks (12) being defined by the distribution of the water required to obtain said number of balance counterweights (12).

3. A method of balancing the drum of a washing machine, as claimed in Claim 2, **characterized in that** the step of calculating the amount of water required in the individual balance tanks (12) to obtain said number of balance counterweights (12) supplies a number of possible optimum distributions of the water in the balance tanks (12); and determining said optimum distribution of the water in said balance tanks (12) comprises the step of selecting, from all the possible optimum distributions of the water in the balance tanks (12), the optimum distribution resulting in the number of balance counterweights (12) capable of producing the lightest second balanced mass (m_3) of all those calculated.

4. A method of balancing the drum of a washing machine, as claimed in Claim 2 or 3, **characterized in that** determining the parameters of said first unbalanced mass (m_2, m_2') comprises the step of determining the weight of said first unbalanced mass (m_2, m_2').

5. A method of balancing the drum of a washing machine, as claimed in Claim 4, **characterized in that** determining the weight of said first unbalanced mass (m_2, m_2') comprises the step of determining, within a predetermined reference time interval (ΔT) and as the drum (6) rotates at said reference rotation speed (ω_0), the time pattern (l(t)) of the length (l) of an elastic member (4) supporting the wash tub (3) in which said drum (6) rotates; the step of statistically calculating the deviation (Δl) in the time pattern (l(t)) of the length (l) of the elastic member (4) within said reference time interval (ΔT); and the step of extrapolating the weight of said first unbalanced mass (m_2, m_2') of the kinematic model of the drum (6) from the deviation (Δl) in the time pattern (l(t)) of the length (l) of said elastic member (4).

6. A method of balancing the drum of a washing machine, as claimed in Claim 4 or 5, **characterized in that** determining the parameters of said first unbalanced mass (m_2, m_2') comprises the step of determining the position of the point on the lateral wall of the drum (6) at which said first unbalanced mass (m_2, m_2') is concentrated.

7. A method of balancing the drum of a washing machine, as claimed in Claim 6, **characterized in that** determining the position of said first unbalanced mass (m_2, m_2') on the lateral wall of the drum (6) comprises the step of determining the time difference between the time pattern (l(t)) of the length (l) of said elastic member (4) within said reference time interval (ΔT), and the signals from a position sensor (10) for determining a predetermined angular position of the drum (6); and the step of calculating the position of the first unbalanced mass (m_2, m_2') on the lateral wall of the drum (6) on the basis of the value of said reference rotation speed (ω_0) and the value of said time difference.

8. A washing machine (1) comprising a drum (6) mounted to rotate about its longitudinal axis (A) and for housing a variable amount of laundry distributed randomly on the lateral wall of the drum; and a drive unit (7) for rotating the drum (6) about its longitudinal axis (A); said washing machine (1) being **characterized by** also comprising:

- a number of balance tanks (12) spaced angularly on the lateral wall of the drum (6) and for storing a variable amount of water;
- acquisition means (8, 9, 10) for determining, as the drum (6) rotates at a given reference rotation speed (ω_0), an optimum distribution of the water in said balance tanks (12) to balance the effects of uneven distribution of the laundry on the lateral wall of the drum (6); and
- balance tank fill level regulating means (13, 14)

for regulating the amount of water in each said balance tank (12) to achieve said optimum distribution of the water in the balance tanks (12) and so balance the drum (6) rotating about its longitudinal axis (A).

9. A washing machine as claimed in Claim 8, **characterized in that** the acquisition means (8, 9, 10) determine the parameters of the unbalanced mass (m_2, m_2') of a kinematic model of the dynamic behaviour of the drum (6) rotating at said reference rotation speed (ω_0); said kinematic model describing the dynamic behaviour of the drum (6) by combining the dynamic behaviour of a first balanced mass (m_1') distributed evenly on the lateral wall of the drum (6), and of a first unbalanced mass (m_2, m_2') concentrated at a specific point on the lateral wall of the drum (6).

10. A washing machine as claimed in Claim 9, **characterized in that** said acquisition means (8, 9, 10) calculate the optimum distribution of the water in the balance tanks (12) as a function of the parameters of said unbalanced mass (m_2, m_2') of the kinematic model, and then control said balance tank fill level regulating means (13, 14) so that each balance tank (12) contains the amount of water required to achieve said optimum distribution of the water in the balance tanks (12).

11. A washing machine as claimed in Claim 8, 9 or 10, **characterized by** comprising fill means (7, 9, 13) for filling each of said balance tanks (12) completely with wash water; said balance tank fill level regulating means (13, 14) selectively draining surplus wash water from each balance tank (12) as the drum (6) rotates about its longitudinal axis (A).

12. A washing machine as claimed in Claim 10 or 11, **characterized by** also comprising a casing (2), and a wash tub (3) suspended in floating manner from said casing (2) by means of at least one elastic connecting member (4); said drum being mounted to rotate axially inside said wash tub (3); and said acquisition means (8, 9, 10) comprising a first detecting device (8) for determining the instantaneous length (l) of said at least one elastic connecting member (4), and a first processing device (9) which calculates the deviation (Δl) in the time pattern (l(t)) of the length (l) of the elastic connecting member (4) within a reference time interval (ΔT).

13. A washing machine as claimed in Claim 12, **characterized in that** said acquisition means (8, 9, 10) also comprise a second detecting device (10) for determining a predetermined angular position of the drum (6); and a second processing device (9) which compares the time pattern (l(t)) of the length (l) of the elastic connecting member (4) within said reference time interval (ΔT) with the signals from said second detecting device (10).

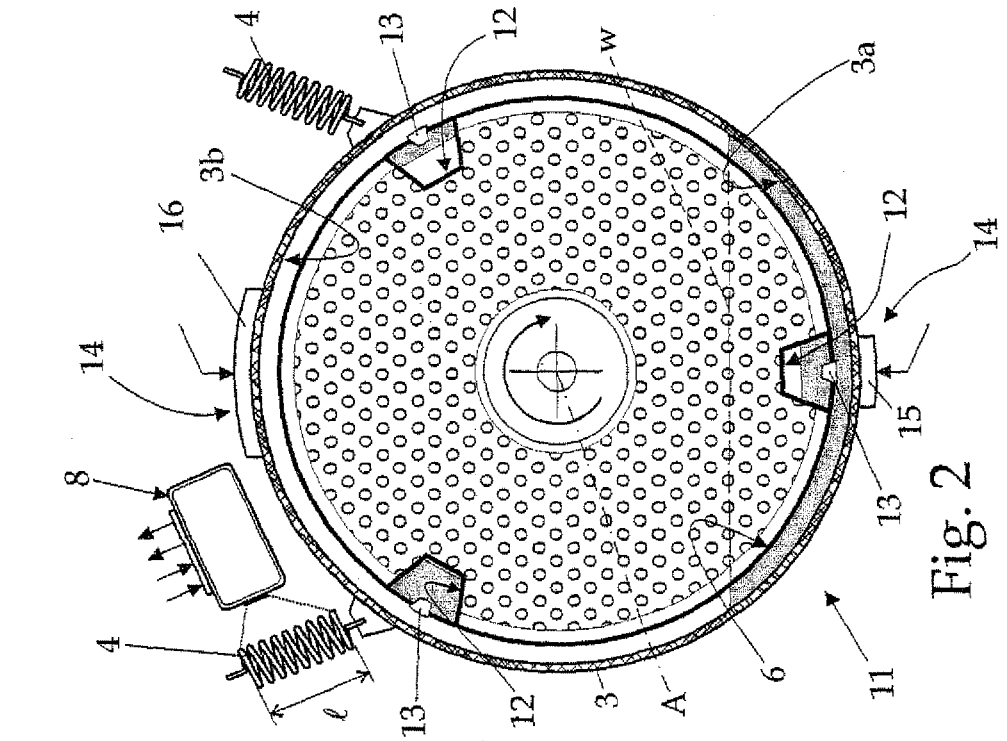

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Fig. 2

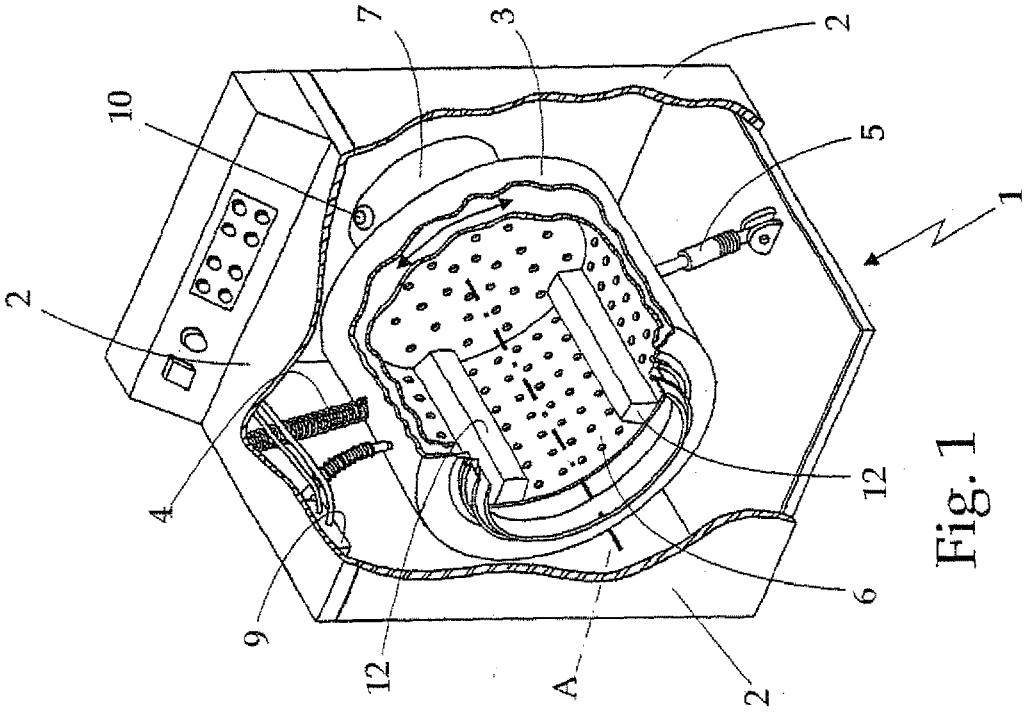

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Fig. 1

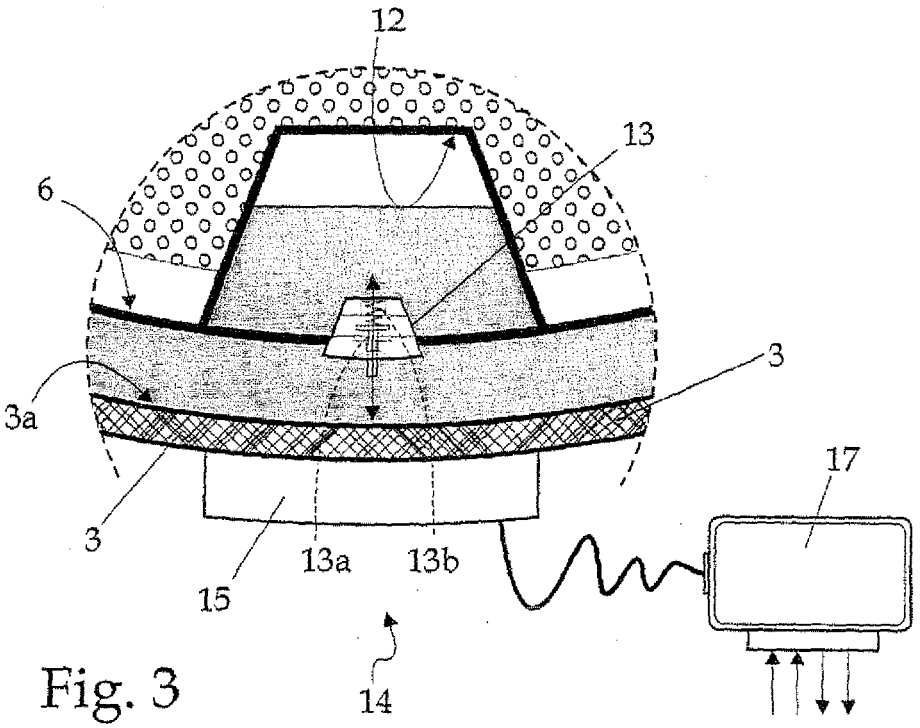


Fig. 3

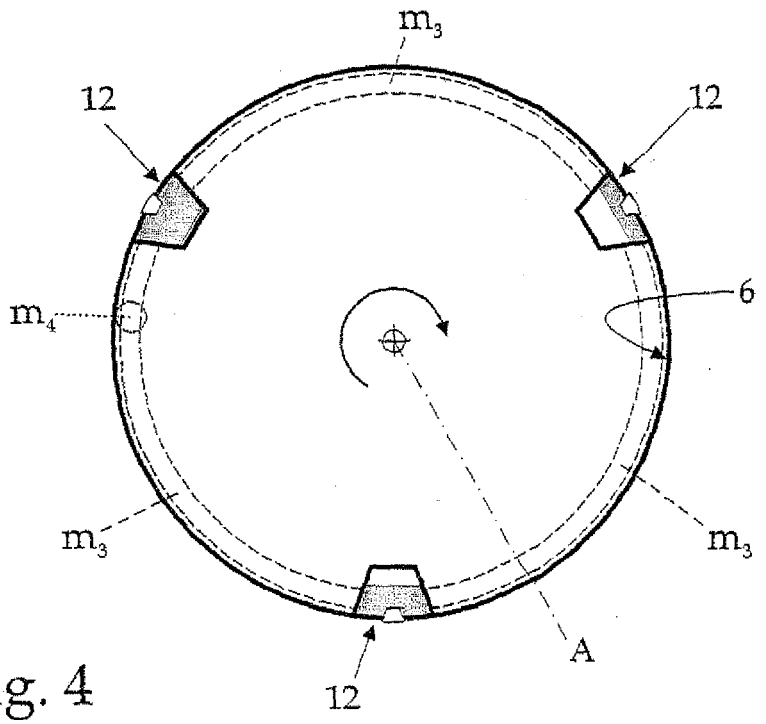


Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 4573

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	BE 1 012 788 A6 (LENFANT THEO [BE]; ROGERSON PETER [BE]) 6 March 2001 (2001-03-06) * the whole document * -----	1,8,11	INV. D06F37/22

TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 January 2008	Ureta, Rolando

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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3

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 4573

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22-01-2008

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BE 1012788 A6	06-03-2001	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82