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(71) Applicant: **Panasonic Corporation**
Kadoma-shi
Osaka 571-8501 (JP)

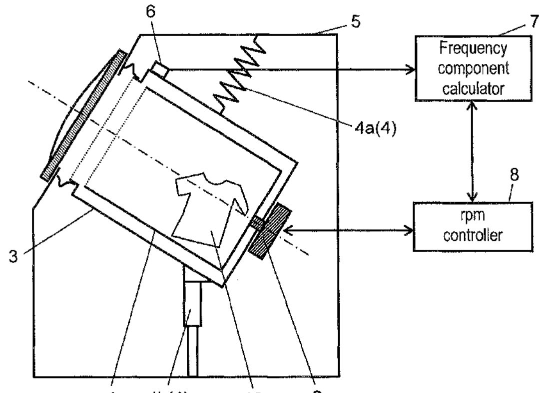
(72) Inventors:
- **NOMURA, Hiroyoshi**
  Osaka-shi, Osaka 540-6207 (JP)
- **TSUJIMURA, Satoshi**
  Osaka-shi, Osaka 540-6207 (JP)
- **SARADA, Kiyoshi**
  Osaka-shi, Osaka 540-6207 (JP)
- **FUJII, Hiroyuki**
  Osaka-shi, Osaka 540-6207 (JP)
- **TERAI, Kenji**
  Osaka-shi, Osaka 540-6207 (JP)
- **YABUUCHI, Hidetaka**
  Osaka-shi, Osaka 540-6207 (JP)

(74) Representative: **Schwabe - Sandmair - Marx**
Patentanwälte
Stuntzstraße 16
81677 München (DE)

(54) WASHING MACHINE, AND METHOD AND PROGRAM FOR CONTROLLING DRUM ROTATION SPEED

(57) A washing machine includes a drum (1) for being rotated with laundry (10) loaded therein, a drum container (3) for accommodating the drum (1), and supported from a housing (5) by a resilient supporting mechanism (4), a motor (2) for rotating the drum (1), a vibration sensor (6) for sensing a vibration of the drum container (3), a frequency component calculator (7) for calculating a frequency component value of a vibration sensed by the vibration sensor (6), and an rpm controller (8) for varying an rpm of the motor (2) in response to the frequency component value. The foregoing structure allows preventing the laundry (10) from sticking to the inner wall of drum (1), thereby improving washing power of the washing machine.

FIG. 1



EP 2 169 102 A1

Description

Technical Field

[0001] The present invention relates to a drum-type washing machine, a method for controlling an rpm of a drum of the washing machine, and a program of the control method.

Background Art

[0002] A conventional washing machine has monitored the behavior of the drum and the laundry therein, and then anticipated the behavior of the laundry for changing an rpm of the drum. For instance, Patent Literature 1 discloses a washing machine including a drum container equipped with an acceleration sensor. The washing machine includes a controller for anticipating the behavior of the laundry based on a change in an output from the acceleration sensor and a change in a torque current component of the motor, thereby changing an rpm of the motor which rotates the drum.

[0003] The foregoing conventional structure, however, cannot always properly control the rpm of the drum. To be more specific, a variety of vibrations is loaded to the drum container, so that the behavior of the laundry cannot be monitored accurately based on a simple change in an acceleration output. For instance, vibrations of the motor per se or vibrations of the housing of the washing machine are loaded to the drum container. The drum container generates different vibrations depending on an amount, weight, quality of the laundry. The behavior of the drum thus cannot be determined accurately based on the simple change in the acceleration output. A similar situation to what is discussed above can be expected to an electric current value indicating the torque component of the motor. For instance, a greater amount of water is used when the washing machine is in the washing mode, and when the clothes made of chemical fiber are washed, no relation sometimes can be found between a moving amount of the clothes and the torque.

[0004] The conventional washing machine thus cannot detect the drum rotating eccentrically with the laundry sticking on the inner wall of the drum. In the case where the laundry sticks on the inner wall of the drum and rotates together with the drum, the laundry is hardly washed. The conventional washing machine thus does not have enough washing power.

Patent Literature 1: Unexamined Japanese Patent Application Publication No. 2006 - 346270

Disclosure of Invention

[0005] The present invention detects the laundry sticking on an inner wall of a drum of a washing machine, and then controls an rpm of the drum, thereby preventing the laundry from sticking on the inner wall, thereby increasing washing power of the washing machine.

[0006] The washing machine of the present invention comprises the following structural elements

a drum for accommodating a laundry and being rotated;
a drum container supported from a housing by a resilient supporting mechanism and accommodating the drum;
a motor for driving the drum;
a vibration sensor for sensing vibrations of the drum container;
a frequency component calculator for calculating a frequency component of the vibrations sensed with the vibration sensor; and
an rpm controller for changing an rpm of the motor in response to the frequency component.

[0007] The structure discussed above allows extracting a frequency component corresponding to an rpm of the drum from the vibrations of the drum container, thereby determining a state of the laundry sticking on the inner wall of the drum. When the sticking state of the laundry is sensed, the rpm controller lowers the rpm of the drum, whereby the sticking of the laundry can be suppressed, and the washing power of the washing machine can be increased.

Brief Description of Drawings

[0008]

Fig. 1 shows a structure of a washing machine in accordance with a first embodiment of the present invention.
Fig. 2A shows an operation principle of the washing machine in state X.
Fig. 2B shows frequency characteristics of the washing machine in state X.
Fig. 3A shows an operation principle of the washing machine in state Y.
Fig. 3B shows frequency characteristics of the washing machine in state Y.
Fig. 4A shows an operation principle of the washing machine in state Z.
Fig. 4B shows frequency characteristics of the washing machine in state Z.
Fig. 5 shows a flowchart illustrating an operation of the washing machine shown in Fig. 1.
Fig. 6 illustrates variations in the rpm of the washing machine.
Fig. 7 shows a flowchart illustrating operation of a washing machine in accordance with a second embodiment of the present invention.
Fig. 8 illustrates variations in the rpm of the washing machine in accordance with the second embodiment.
Fig. 9 shows a flowchart illustrating operation of a

washing machine in accordance with a third embodiment of the present invention.

Fig. 10 illustrates variations in the rpm of the washing machine in accordance with the third embodiment.

Fig. 11 shows a structure of a washing machine in accordance with a fourth embodiment of the present invention.

Fig. 12A shows an operation principle of the washing machine in state X in accordance with the fourth embodiment.

Fig. 12B shows frequency characteristics of the washing machine in state X.

Fig. 13A shows an operation principle of the washing machine in state Y.

Fig. 13B shows frequency characteristics of the washing machine in state Y.

Fig. 14A shows an operation principle of the washing machine shown in Fig. 11 in state Z.

Fig. 14B shows frequency characteristics of the washing machine in state Z.

Fig. 15 shows a flowchart illustrating operation of the washing machine in accordance with the fourth embodiment.

Fig. 16 illustrates variations in the rpm of the washing machine shown in Fig. 11.

Fig. 17 shows a flowchart illustrating operation of the washing machine in accordance with a fifth embodiment.

Fig. 18 illustrates variations in the rpm of the washing machine shown in Fig. 17.

Fig. 19 shows a flowchart illustrating operation of the washing machine in accordance with a sixth embodiment.

Fig. 20 illustrates variations in the rpm of the washing machine shown in Fig. 19.

Fig. 21 shows a frequency range of a washing machine in accordance with a seventh embodiment of the present invention.

Fig. 22 shows another frequency range of the washing machine in accordance with the seventh embodiment.

Fig. 23 shows a structure of a conventional washing machine.

Description of Preference Signs

[0009]

1	drum
2	motor
3	drum container
4a	spring (resilient supporting mechanism)
4b	dumper (resilient supporting mechanism)
5	housing
6	vibration sensor
7	frequency component calculator
7a	baffle frequency-component calculator
8	rpm controller
9	baffle
10	laundry

Best Mode for Carrying out the Invention

[0010] Exemplary embodiments of the present invention are demonstrated hereinafter with reference to the accompanying drawings. A washing machine employing a drum slantingly placed therein is used in the following descriptions; however, the drum can be vertically placed, or the washing machine equipped with a dryer can be used. Not to mention, the present invention is not limited to the following embodiments.

Embodiment 1

[0011] Fig. 1 shows a structure of a washing machine in accordance with the first embodiment. Chief structural elements in Fig. 1 are described one by one hereinafter.

[0012] Drum 1 is placed in housing 5, i.e. main body of the washing machine, and works as a washing tub rotating and accommodating laundry 10, such as clothes. Drum 1 connects with motor 2 such that the center axis of drum 1 aligns with the shaft of motor 2, whereby laundry 10 can be washed by the rotation of motor 2. Motor 2 is formed of a brushless motor for rotating drum 1, and the rpm of motor 2 is variable. Motor 2 repeats a forward rotation and a backward rotation for washing laundry 10.

[0013] Drum container 3 accommodates drum1 and water, and is rigidly mounted to housing 5 via resilient supporting mechanism 4 such as spring 4a and dumper 4b.

[0014] Vibration sensor 6 senses drum container 3 vibrating, and is formed of an acceleration sensor (not shown). In this embodiment 1, sensor 6 senses the vibrations (acceleration) along the right and left direction with respect to the front of drum 1. The sensor can be any sensor such as a semiconductor acceleration sensor, a piezoelectric acceleration sensor, and a multi-axial (biaxial or tri-axial) acceleration sensor. Actually the vibration of drum container 3 cannot be always defined to one direction, so that use of tri-axial acceleration sensor can produce a better result because acceleration components of each one of three axes are added together for representing an actual acceleration.

[0015] Frequency component calculator 7 executes Fourier transform by using the vibration sensed with sensor 6, and extracts a frequency component of the vibration corresponding to an rpm of motor 2. Calculator 7 is actually formed of a microprocessor, and executes Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT) by using a signal sensed with sensor 6, thereby calculating a frequency component value (e.g. Fourier vibration spectrum, or power spectrum) at a given frequency (e.g. a frequency of vibration corresponding to an rpm of motor 2) i.e. a vibration component value (frequency component value). The rpm of drum 1 or motor 2 can be obtained from rpm controller 8.

[0016] Rpm controller 8 increases or decreases the rpm of motor 2 in response to the frequency component value, calculated by frequency calculator 7, of the vibration corresponding to the rpm of motor 2.

[0017] The operation principle of the washing machine discussed above is demonstrated hereinafter with reference to Fig. 2A - Fig. 4B, which illustrate the operation principle of the present invention. Figs. 2A, 3A, and 4A show the state of laundry 10 loaded in drum 1. Laundry 10 is indicated with a circle in those Figs. A triangle in each Fig. indicates baffle 9 on which laundry 10 is caught to be lifted and agitated.

[0018] Fig. 2A shows a state where drum 1 rotates at a low rpm (e.g. 41 rpm). The low rpm does not generate great centrifugal force to be applied to laundry 10, which thus just rolls around a lower section of drum 1. In this case, since drum 1 rotates at the low rpm, a little amount of laundry 10 can be lifted with baffle 9, so that a little amount of laundry 10 can be agitated. This state is referred to as "state X" in this embodiment.

[0019] Fig. 3A shows a state where drum 1 rotate at a medium rpm (e.g. 45 rpm) between the case shown in Fig. 2A and the coming case shown in Fig. 4A (a higher rpm). In this case laundry 10 is lifted with baffle 9; however, the centrifugal force is not strong enough so that laundry 10 peels off the inner wall of drum 1 and falls to the lower section of drum 1 due to gravity (since it has a speed, laundry 10 beats on the bottom). This state is referred to as "state Y".

[0020] Fig. 4A shows a state where drum 1 rotates at a high rpm (e.g. 49rpm). Rather greater centrifugal force is applied to laundry 10 due to the high rpm, so that laundry 10 sticks to the inner wall of drum 1, and laundry 10 thus rotates together with drum 1. This state is referred to as "state Z".

[0021] Comparison of the cases shown in Figs. 2A, 3A, and 4A with each other tells in general that the case shown in Fig. 3A is the most suitable for washing, and the case shown in Fig. 4A hardly washes laundry 10.

[0022] State X shown in Fig. 2A is likely to entangle the laundry, and state Z shown in Fig. 4A exerts less washing power because the laundry sticks to the inner wall and does not move at all. From the viewpoint of the torque loaded to motor 2 or the power consumption, although they vary depending on a kind of cloth, state X shown in Fig. 2A burdens drum 1 with the heaviest load, and runs the greatest current in motor 2. Since the foregoing conventional case determines a state of the laundry based on a torque current component, it is likely to select state X shown in Fig. 2A as an optimum state.

[0023] Each vibration data (acceleration along the right and left direction with respect to drum 1), of states X, Y and Z, obtained with vibration sensor 6 undergoes a frequency analysis, thereby obtaining frequency characteristics as shown in Figs. 2B, 3B, and 4B. X-axes of Figs. 2B, 3B, and 4B indicate the frequency (Hz) of the vibration corresponding to the rpm of drum 1. Y-axes thereof indicate Fourier amplitude spectrum (G. sec) showing the values of each one of frequency components. In Figs. 2B, 3B, and 4B, assume that drum 1 rotates at rpm N, and then the frequency corresponding to this rpm N is N/60 Hz. In other words, as shown with a leader line, 41 rpm/60 sec = 0.68 Hz in Fig. 2B, 45 rpm/60 sec = 0.75 Hz in Fig. 3B, and 49 rpm/60 sec = 0.82 Hz in Fig. 4B.

[0024] As those Figs. explicitly show, the frequency component of the vibration corresponding to the rpm of drum 1 is as small as 0.04 (G. sec) in Fig. 2B; however, it is as great as 0.32 (G. sec) in Fig. 4B, while Fig. 3B shows 0.23 (G. sec) which is a medium value between them. The fact tells that laundry 10 sticking to the inner wall of drum 1 burdens drum 1 with eccentric load. To be more specific, the frequency component of the vibration corresponding to the rpm of drum 1 is generated frequently when drum 1 rotates eccentrically, i.e. when laundry 10 sticks to the inner wall of drum 1, and the frequency component is rarely generated in the other cases. Different kinds of cloth will maintain this tendency, so that it can be concluded that the frequency component becomes greater as far as laundry 10 sticks to the inner wall of drum 1. If the drum 1 is jam-packed with the laundry, the laundry always sticks to the inner wall at any rpm, so that no change in the frequency characteristics is found.

[0025] In this first embodiment, the characteristics discussed above are used. In other words, vibration sensor 6 is mounted to drum container 3, and the signal supplied from sensor 6 undergoes the Fourier transform in frequency component calculator 7, thereby finding a frequency component value of the vibration corresponding to the rpm of drum 1. Then rpm controller 8 determines whether or not laundry 10 sticks to the inner wall of drum 1 based on the frequency component value found as discussed above. When laundry 10 sticks to drum 1 (when the frequency component is great), the rpm of motor 2 is lowered. When laundry 10 does not stick to drum 1 (when the frequency component is small), the rpm of motor 2 is increased. This mechanism allows the laundry in the washing process to be beaten against the inner wall as shown in Fig. 3A, so that greater washing power can be expected.

[0026] Fig. 5 shows a flowchart depicting operation of each section of the washing machine for controlling an rpm of drum 1 in the washing process. The steps in the washing process are described hereinafter one by one. This flowchart illustrates the procedure of the washing process, and various steps, such as determining an amount of cloth, loading detergent, pouring water, should be ended before this washing process. In Fig. 5, "S" is used as an abbreviation for "step". First, the washing process starts, and rpm controller 8 initializes the rpm to initial value V0, which can be a value corresponding to an amount of cloth sensed in the previous process, or can be a fixed value (step A1).

[0027] Next, rpm controller 8 rotates motor 2 (drum 1) at rpm V for given time T selected from the range between 10 - 15 seconds. If motor 2 remains rotating based on the previous step in the washing process, motor 2 is then rotated in the reverse direction to the previous one (step A2).

[0028] Then frequency component calculator 7 obtains vibration information sensed with vibration sensor 6 during the rotation of drum 1 in step A2, and the vibration information is handled as time-series data which then undergoes Fourier transform for finding the frequency component of the vibration corresponding to the rpm of drum 1 (step A3). In other words, in the case where drum 1 rotates at rpm V, a frequency component with respect to the frequency V/60 Hz, which indicates the vibration corresponding to the rpm V, is found. Frequency component calculator 7 obtains rpm V from rpm controller 8. In this embodiment, vibration sensor 6 senses the vibration of drum container 3 along one direction (right and left direction); however, when tri-axial acceleration sensor is used, calculator 6 adds the acceleration signals about the three axes together, and the resultant value undergoes the Fourier transform. This procedure results in a more accurate vibration. The Fourier transform can be executed by software installed in the microprocessor forming frequency component calculator 7, and Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT) is executed for calculating a Fourier amplitude spectrum or a power spectrum. The Fourier transform can be also executed by using a dedicated calculating hardware such as a Digital Signal Processor (DSP).

[0029] The Fourier transform produces the frequency component Xv corresponding to rpm V of drum 1, and then rpm controller 8 compares this frequency component Xv with a given range A (a first given range "a0 - a second given range "a1"). The comparison will result in the following three processes:

(1) In the case of Xv < a0: move on to step A5
(2) In the case of Xv > a1: move on to step A6
(3) In the case of a0 ≤ Xv ≤ a1: move on to step A7

[0030] In the case of (1), since the calculated frequency component Xv is small, it is determined that the laundry does not stick to the inner wall of drum 1 yet. Rpm V of drum 1 is thus increased by dV, so that drum 1 is rotated at rpm V+dV (step A5).

[0031] In the case of (2), since the calculated frequency component Xv is great, it is determined that the laundry has stuck to the inner wall of drum 1. Rpm V of drum 1 is thus reduced by dV, so that drum 1 is rotated at rpm V-dV (step A6).

[0032] In the case of (3), it is determined that rpm V is properly selected, so that this process determines whether or not the washing time ends. In the case where the washing time does not end yet, the step returns to step A2 for repeating the operation discussed above. In the case where the washing time ends, the step moves on to the next step, e.g. dehydrating step (step A7).

[0033] Fig. 6 shows variations in the rpm of drum 1 due to the operation in step A1 - A7 discussed above. Fig. 6 tells that rpm controller 8 varies the rpm of drum 1 such that the frequency component values calculated by frequency component calculator 7 can fall within a given range A.

[0034] To be more specific, rotate drum 1 at rpm V for a given time T (S61 in Fig. 6), then compare frequency component Xv with range A (S62). The comparison finds that frequency component Xv1 is smaller than a0, then increase rpm V to V+dV, and rotate drum 1 for a given time T (S63). In a similar way, compare Xv with range A (S64) to find that Xv2 is smaller than a0, then increase the rpm to V+dV again and rotates drum 1 for a given time T (S65). Then compare Xv with range A (S66) to find that Xv3 is greater than a1, and reduce the rpm of drum 1 to V-dV, and rotate drum 1 for a given time T (S67). Then compare Xv with range A (S68) to find that Xv4 falls within range A, and maintain the rpm of drum 1 for a given time T (S69).

[0035] The operation discussed above allows the laundry to stay in state Y where the laundry is in the state just before sticking to drum 1, i.e. the laundry beats on the inner wall of drum 1 for being well washed as shown in Fig. 3A. The laundry thus can be washed more effectively, so that the washing time can be shortened.

[0036] Frequency component Xv calculated in step A3 shown in Fig. 5 can be stored in rpm controller 8. When the rpm is changed and a frequency component is newly calculated in step A5 and A6, the present frequency component is compared with the stored one, and if no change is found, the rpm needs not to be changed. This procedure allows solving the following problem: when drum 1 is jam-packed with the laundry, the frequency characteristics of the vibration of drum 1 won't varied by the rpm. In such a case, the laundry can be washed at an rpm close to initial value V0.

[0037] As discussed above, this first embodiment proves that frequency component calculator 7 calculates a frequency component value with respect to the vibration sensed by vibration sensor 6, and rpm controller 8 varies the rpm of motor 2 in response to the frequency component value. The present invention thus allows varying the rpm of motor 2 appropriately in response to the vibrations of laundry 10 and drum 1.

[0038] On top of that, rpm controller 8 increases the rpm of motor 2 when the frequency component value is smaller than a given range, while it reduces the rpm when the frequency component is greater than the given range. The present invention thus allows preventing laundry 10 from sticking to drum 1, and resultantly improving the washing power.

[0039] In a case where a multi-axial acceleration sensor is used in vibration sensor 6, not only vibration information along each one of the axial directions but also the total vibration information can be used. Since drum container 3 not always vibrates along one direction only, use of the total vibration information along the multi-axes allows obtaining more accurate vibration of drum container 3, i.e. vibration of drum 1.

Embodiment 2

[0040] In embodiment 1 discussed previously, the output signals from vibration sensor 6 always undergo a frequency analysis during the washing process, and the rpm of drum 1 is varied based on the analysis result. In this embodiment 2, the rpm is changed only at the beginning of the washing process.

[0041] Embodiment 2 is demonstrated hereinafter with reference to Figs. 7 and 8. Fig. 7 shows a flowchart of embodiment 2, and Fig. 8 illustrates the operation of embodiment 2.

[0042] First, the rpm of drum 1 (motor 2) is initialized to V1 at the beginning of the washing process (step B1). In this embodiment 2, initial value V1 is an upper limit of the rpm of drum 1 (motor 2).

[0043] The upper limit of the rpm refers to the maximum rpm at which motor 2 can rotate drum 1 with laundry 10 loaded in drum 1. In general, motor 2 consumes greater power at a lower rpm, so that an extremely small rpm cannot be set (except when the motor is halted). Therefore, motor 2 has a lower limit of rpm. In this embodiment 2, the rpm of drum 1 is varied within the following range in response to the performance of motor 2: upper limit = V1 and lower limit = V2. These limits are set appropriately in response to the performance, power consumption, mechanism, and durability of motor 2.

[0044] Then rpm controller 8 rotates drum 1 (motor 2) at rpm V for a given time T. If drum 1 still remains rotating based on the previous step, drum 1 should be rotated in a reverse direction to the previous one (step B2).

[0045] Then similar to step A3, frequency component calculator 7 calculates frequency component Xv of the vibration with respect to rpm V of drum 1 by using the time series data sensed by vibration sensor 6 (step B3).

[0046] Next, rpm controller 8 compares frequency component Xv calculated by calculator 7 with a give threshold value "a2" (step B4). In the case of $Xv \leq a2$, the laundry is determined not to stick to drum 1 at the present rpm V, so that the step moves on to step B7, and the laundry is kept washing at rpm V until the washing ends.

[0047] In the case of $Xv > a2$, the laundry is determined to stick to drum 1, so that the step moves on to step B5. Rpm controller 8 checks whether or not the present rpm V is greater than lower limit V2 (step B5). In a case where drum 1 is jam-packed with laundry 10, reduction in the rpm sometimes cannot change the sticking state. In such a case, drum 1 should not be rotated at an extremely small value, but it is rotated at the rpm close to lower limit V2. In this embodiment 2, when the rpm becomes lower than lower limit V2 or equal to V2 ("No" in Fag.7), the step moves on to step B7, and the laundry is kept washing onward at this rpm. When the rpm is greater than lower limit V2 ("Yes" in Fig. 7), the step moves on to step B6 where rpm V is reduced by dV, and then the step returns to step B2 for repeating the operation discussed above.

[0048] The foregoing operation allows varying the rpm, e.g. as shown in Fig. 8, which varies rpm V of drum 1, at the beginning of the washing, from upper limit V1 to lower limit V2 until the frequency component becomes an appropriate value (until the frequency component becomes lower than threshold value a2). When the frequency component becomes the appropriate value, the rpm is maintained onward during the washing process.

[0049] To be more specific, rotate drum 1 at rpm V1 for a given time T (S81 in Fig. 8), then compare frequency component Xv with threshold value a2 (S82). The comparison finds that frequency component Xv1 is greater than a2, then reduce rpm V to V-dV, and rotate drum 1 for a given time T (S83). In a similar way, compare Xv with threshold value a2 (S84) to find Xv2 is smaller than a2, and then the rpm is maintained onward (S85).

[0050] This method allows rpm controller 8 to determine an appropriate rpm of drum 1 at the beginning of the washing, so that the laundry can beats on drum 1 as the first embodiment does for being washed efficiently. In general, motor 2 needs torque at a low rpm of drum 1, so that greater power is consumed. The rpm is thus varied from the higher one to the lower one as discussed above in the process of determining the rpm, so that a determination of a low rpm can be avoided, which can reduce the power consumption. In this embodiment 2, it is not needed to calculate the frequency component always during the washing, so that the microprocessor of frequency component calculator 7 needs not to be a sophisticated one.

[0051] The flowchart shown in Fig. 7 is carried out at the beginning of the washing process; however, it can be done in the midway of the washing process. Because sometimes it is more efficient that the rpm is determined after laundry 10 absorbs water sufficiently.

Embodiment 3

[0052] In this embodiment 3, the rpm of drum 1 is varied from the lower limit to the upper limit, while in embodiment 2 previously discussed the rpm of drum 1 is varied from the upper limit to the lower limit. Embodiment 3 is demonstrated hereinafter with reference to Figs. 9 and 10.

[0053] Fig. 9 shows a flowchart illustrating embodiment 3, and Fig. 10 illustrates a principle of operation of embodiment 3. The flowchart shown in Fig. 9 is basically similar to that shown in Fig. 7 except steps B1', B4', B5', and B6'. In step B1', initialize rpm V of drum 1 to lower limit V2. In step B4', compare the calculated frequency component Xv with threshold value a3, and in the case of $Xv \geq a3$, the step moves on to step B7 for maintaining rpm V onward, while in the case of $Xv < a3$, the step moves on to step B5'. In step B5', compare rpm V with upper limit V1, and in the case of $V \geq V1$ ("No" in Fig. 9), the step moves on to step B7, and maintain rpm V onward for washing. In the case of $V < V1$ ("Yes" in Fig. 9), the step moves on to step B6', where rpm V is increased to V+dV, and then moves on to step B2. The operation following this flowchart shown in Fig. 9 allows varying the rpm as shown in Fig. 10.

[0054] To be more specific, rotate drum 1 at rpm V2 for a given time T (S101), and compare frequency component Xv with threshold value a3 (S102). When the comparison result finds that frequency component Xv1 is smaller than threshold value a3, the rpm is increased to V+dV, and then drum 1 is rotated for a given time T (S103). Operation similar to the foregoing one is repeated, and frequency component Xv is compared with threshold value a3 (S104). When the comparison result finds that frequency component Xv2 is greater than threshold value a3, the rpm of drum 1 is not varied but maintained for rotating drum 1. (S105).

[0055] As discussed above, the rpm of drum 1 is increased from the lower one to the higher one. During this process of determining the rpm, the laundry can be prevented from sticking to drum 1, so that the washing power as a whole can be improved.

[0056] Embodiments 1, 2 and 3 discussed above obtain a frequency component value of the vibration corresponding to an rpm of drum 1, and vary the rpm of drum 1 in response to the frequency component value. This operation allows determining the rpm of drum 1 appropriately for the washing onward, and prevents laundry 10 from sticking to drum1 so that laundry 10 can always beat on drum 1 for better washing. As a result, the washing power can be increased, and thus the washing time can be shortened.

[0057] This embodiment 3 does not need to calculate the frequency component value always during the washing, so that frequency component calculator 7 does not need to have a sophisticated microprocessor, as discussed in embodiment 2.

Embodiment 4

[0058] In embodiments 1 - 3 discussed previously, frequency component calculator 7 has a function of extracting a frequency component of the vibration corresponding to an rpm of motor 2; however, in this embodiment 4 frequency component calculator 7 has a function of extracting a frequency component of the vibration generated by agitating the laundry with baffles. Embodiment 4 is demonstrated hereinafter with reference to Fig. 11.

[0059] Fig. 11 shows a structure of a washing machine in accordance with embodiment 4. Structural elements similar to those in embodiments 1-3 have the same reference signs, and the descriptions thereof are omitted here.

[0060] Drum 1 accommodating laundry 10 such as clothes works as a washing tub and rotates for washing. Drum 1 is coupled to motor 2, and rotates for washing the laundry. Drum 1 includes baffles 9 therein for agitating laundry 10. In this embodiment 4, three (n=3) baffles 9 are used.

[0061] Baffle frequency-component calculator 7a is the counterpart of frequency component calculator 7 used in embodiments 1 - 3. Baffles 9 agitate laundry 10, so that a frequency is generated. A frequency component value of the vibration is calculated by calculator 7a. To be more specific, calculator 7a is formed of a microprocessor as discussed in embodiment 1 - 3, and a signal supplied from vibration sensor 6 undergoes Discrete Fourier Transform or Fast Fourier Transform for calculating the frequency component value (Fourier amplitude spectrum or a power spectrum) corresponding to the vibration at a given frequency. In this embodiment 4, assume that drum 1 (motor 2) rotates at rpm V, then a frequency component of $V/60 \times n$(Hz) is calculated by using the data supplied from vibration sensor 6. Rpm V can be supplied from rpm controller 8.

[0062] Rpm controller 8 varies the rpm of motor 2 in response to the frequency component value calculated by baffle frequency-component calculator 7a.

[0063] The other structures remain unchanged from those of embodiments 1 - 3. The operation principle of the washing machine discussed above is demonstrated hereinafter with reference to Figs. 12A - 14B, which illustrate the operation principle of the present invention. Figs. 12A, 13A, and 14A show the state of the laundry loaded in drum 1, as embodiment 1 describes. In this embodiment 4 drum 1 includes three baffles. (number of baffles n = 3)

[0064] Fig. 12A shows a state where drum 1 rotates at a low rpm (e.g. 41 rpm). The low rpm does not generate great centrifugal force to be applied to laundry 10, which thus just rolls around a lower section of drum 1. In this case, since drum 1 rotates at the low rpm, a little amount of laundry 10 can be lifted with baffle 9, so that a little amount of laundry 10 can be agitated. This state is referred to as "state X" in this embodiment.

[0065] Fig. 13A shows a state where drum 1 rotate at a medium rpm (e.g. 45 rpm) between the case shown in Fig. 12A and the coming case shown in Fig. 14A (a higher rpm). In this case laundry 10 is lifted with baffle 9; however, the centrifugal force is not strong enough so that laundry 10 peels off the inner wall of drum 1 and falls to the lower section of drum 1 due to gravity (since it has a speed, laundry 10 beats on the bottom). This state is referred to as "state Y".

[0066] Fig. 14A shows a state where drum 1 rotates at a high rpm (e.g. 49rpm). Rather greater centrifugal force is applied to laundry 10 due to the high rpm, so that laundry 10 sticks to the inner wall of drum 1, and laundry 10 thus rotates together with drum 1. This state is referred to as "state Z".

[0067] Comparison of the cases shown in Figs. 12A, 13A, and 14A with each other in terms of the washing power tells, in general, that the case shown in Fig. 13A, i.e. state "Y" or the case shown in Fig. 12A, i.e. state "X" is suitable for washing, and the case shown in Fig. 14A, i.e. state "Z" exerts lower washing power, because laundry 10 sticks to the inner wall of drum 1 and does not move at all.

[0068] Each vibration data (acceleration along the right and left direction with respect to drum 1), of states X (Fig.

12A), Y (Fig. 13A) and Z (Fig. 14A), obtained by vibration sensor 6 undergoes a frequency analysis, thereby obtaining frequency characteristics as shown in Figs. 12B, 13B, and 14B. X-axes of Figs. 12B, 13B, and 14B indicate the frequency (Hz) of the vibration generated by the rotation of drum 1. Y-axes thereof indicate Fourier amplitude spectrum (G. sec) showing the values of each one of frequency components. In Figs. 12B, 13B, and 14B, baffle frequencies are pointed with leader lines. The baffle frequency is calculated this way: a frequency corresponding to a given rpm is multiplied by the number (n) of baffles. In the case of rpm V and n = 3, the baffle frequency is expressed with this equation: $V/60 \times n = V/60 \times 3$ (Hz). The resultant frequency is a typical frequency of the vibration given to laundry 10 by baffles 9. To be more specific, as shown with the leader lines, in the case of Fig. 12B, 41rpm/60 sec $\times$ 3 = 2.05 Hz is found, and in the case of Fig. 13B, 45rpm/60 sec $\times$ 3 = 2.25 Hz is found, and in the case of Fig. 14B, 49rpm)/60 sec $\times$ 3 = 2.45 Hz is found.

[0069] As Figs. 12B - 14B explicitly show, the frequency component of the vibration corresponding to the rpm of drum 1 is as small as 0.1.4 G sec in Fig. 14B where laundry 10 sticks to drum 1; however, it becomes rather great such as 0.26 G · sec in Fig. 13B, and 0.18 G · sec in Fig. 12B. Because laundry 10 sticks to the inner wall of drum 1 in state "Z" shown in Fig. 14B, and agitating effect by baffles 9 becomes thus smaller. Different kinds of cloth or different amount of clothes still maintain this tendency, and the sticking state of laundry 10 reduces the frequency component value of the vibration at the baffle frequency. In general, a greater frequency component at the baffle frequency agitates the clothes in drum 1 more violently with baffles 9, so that greater washing power can be expected. The control of the rpm of drum 1 thus can improve the washing power.

[0070] In this embodiment 4, the characteristics discussed above is used, and signals supplied from vibration sensor 6 mounted to drum container 3 undergo the Fourier transform, thereby finding a frequency component value of the vibration at the baffle frequency. Drum 1 is rotated at the rpm where the frequency component value becomes maximum or higher than a given value, whereby the washing power of the washing machine can be increased.

[0071] Fig. 15 shows a flowchart depicting the operation, following the operation principle discussed above, of each structural element for controlling an rpm of drum 1 in the washing process. The steps are described hereinafter one by one. This flowchart illustrates the procedure of the washing process, and various steps, such as determining an amount of cloth, loading detergent, pouring water, should be ended before this washing process.

[0072] First, after the washing process starts, rpm controller 8 sets an appropriate value to variable Vi (i = 0, ..., M) which represents an rpm of drum 1 (motor 2) (step C1). Variable Vi is a candidate of the rpm. This variable can be changed depending on an amount of cloth, or can be a fixed one. In this embodiment 4, variable Vi is fixed, and V0=41rpm, V1=45rpm, V2=49rpm, and V3=53rpm at M=3 are set.

[0073] Next, variable "i", namely, an rpm candidate, is initialized to 0 (zero) (step C2). Then rpm controller 8 rotates motor 2 (drum 1) at rpm Vi for a given time T (step C3). The given time T falls within a range between 10 - 15 seconds in this embodiment 4. If motor 2 remains rotating based on the previous step in the washing process, motor 2 is then rotated in the reverse direction to the previous one. This reverse rotation allows preventing the clothes from being tangled with each other during a search for the rpm.

[0074] Next, baffle frequency-component calculator 7a obtains vibration information, sensed by vibration sensor 6 during the rotation of drum 1 in step C3, as time-series data, which then undergoes the Fourier transform. Calculator 7a then finds a frequency component value of the vibration corresponding to the baffle frequency of drum 1. (step C4). In other words, calculator 7a finds the frequency component value of the vibration at the frequency of Vi/60 $\times$ 3Hz. Calculator 7a obtains rpm Vi from rpm controller 8. The magnitude of the vibration corresponding to the calculated baffle frequency is represented by frequency component value Fi.

[0075] In this embodiment 4, vibration sensor 6 senses vibrations along one direction (right and left direction) of drum container 3; however, when a tri-axial acceleration sensor is used, baffle frequency-component calculator 7a adds acceleration signals together along not only the right-left direction, but also up-down direction and back-forth direction, and then the added-up value undergoes the Fourier transform. The vibrations can be thus calculated more accurately with the tri-axial acceleration sensor. The Fourier transform can be executed by software installed in the microprocessor which forms baffle frequency-component calculator 7a, and Discrete Fourier Transform or Fast Fourier Transform is executed for calculating a Fourier amplitude spectrum or a power spectrum. The Fourier transform can be also executed by using a dedicated calculating hardware such as a Digital Signal Processor (DSP).

[0076] Next, variable "i", namely, a candidate of the rpm, is compared with M, which is a total number of the candidates, in order to check whether or not variable "i" is equal to M (step C5). In other words, the comparison is done to check whether or not frequency component value Fi is found for each one of the candidates of the rpm. In the case of variable i = M (Yes in Fig. 15), the step moves on to step C7 because the frequency component value has been found for each one the candidates. In the case of variable $i \neq M$ (No in Fig. 15), "i" is increased by 1 (one) in step C6 because some candidates, of which frequency components are not yet calculated, still remain, and then the step returns to step C3, where frequency component value Fi is calculated for the next candidate of the rpm.

[0077] Rpm controller 8 compares frequency component values Fi (i = 1, ..., M) found in step C4 with each other, and selects the maximum value for finding rpm Vi at the maximum frequency component value Fi (step C7). Rpm controller 8 then drives motor 2 for rotating drum 1 at rpm Vi found in step C7, and keeps the washing onward (step C8).

[0078] Fig. 16 shows an instance of varying the rpm of drum 1 through steps C1 - C8 discussed above. The instance shows that the rpm is changed in four steps, i.e. V0, V1, V2, V3, at the beginning of the washing process, and frequency component values F0, F1, F2, F3 of the vibration at the baffle frequency are calculated for each rpm respectively. The washing is carried out onward at the rpm corresponding to the maximum frequency component value.

[0079] To be more specific, rotate drum 1 at rpm V0 for a given time T (s161), and calculate frequency component value F0 of the baffle frequency (S162). Repeat a similar operation, and finally, rotate drum 1 at rpm V3 for the given time T (S164), and calculate frequency component value F3 of the baffle frequency (S164). Next, find the maximum value among F0 - F3 with rpm controller 8 (in this embodiment, the maximum one is F1), and keep motor 2 rotating at rpm V1 corresponding to frequency component value F1 (S165).

[0080] The operation discussed above allows the laundry to stay in state Y, where the laundry is in the state just before sticking to drum 1, i.e. the laundry beats on the inner wall of drum 1 for being well washed as shown in Fig. 3A. The laundry thus can be washed more effectively, so that the washing time can be shortened.

[0081] The foregoing operation allows selecting the rpm which can maximize the vibration at the baffle frequency, so that laundry 10 can be prevented from sticking to the inner wall of drum 1 as shown in Fig. 14A. What is more, baffles 9 also can maximize the agitating effect to laundry 10. The washing machine with improved washing power is thus obtainable, so that the washing time can be shortened.

[0082] In this embodiment 4, the rpm candidates are set at 41rpm, 45rpm, 49rpm and 53rpm in a simply increasing manner; however, they can be set in a simply decreasing manner, or can be set in a manner neglecting the order of rpm size, e.g. 41rpm, 53rpm, 49rpm, and 45rpm.

[0083] Embodiment 4 thus proves that baffle frequency-component calculator 7a calculates a frequency component value of the vibration, which is generated by agitating laundry 10 with baffles 9 and sensed by vibration sensor 6, and then rpm controller 8 varies the rpm of motor 2 in response to the frequency component value. Therefore, the rpm of motor 2 can be appropriately changed in response to a magnitude of the vibration generated by agitating laundry 10 with baffles 9.

[0084] On top of that, calculator 7a extracts a frequency component value at the frequency of $V/60 \times n$ (Hz). Calculator 7a thus can accurately calculate the magnitude of the vibration generated by agitating the laundry with the baffles, whereby the rpm of motor 2 (drum 1) can be accurately controlled.

[0085] Rpm controller 8 compares the frequency component values at each rpm with each other, and finds the rpm where the frequency component value becomes the maximum, and then drives the motor at the rpm. Therefore, rpm controller 8 can rotate motor 2 (drum 1) at the rpm which maximizes the vibration generated by agitating laundry 10 with baffles 9. As a result, the washing power of the washing machine can be increased.

Embodiment 5

[0086] Embodiment 4 discussed previously finds the rpm that maximizes the frequency component value of the vibration generated at the baffle frequency. This embodiment 5 sets a threshold value of a frequency component value, and finds an rpm when the frequency component value exceeds the threshold value. Embodiment 5 is demonstrated hereinafter with reference to Figs. 17 and 18.

[0087] Fig. 17 shows a flowchart of embodiment 5, and Fig. 18 illustrates the operation principle of embodiment 5. Each one of the steps of the operation is detailed hereinafter.

[0088] Drum 1 (motor 2) is driven at rpm V. At the beginning of the washing process, rpm V of drum 1 is initialized to initial rpm Vt (step D1), which is an upper limit of the rpm of drum 1. The rpm of drum 1 is varied within a given range such as Vb - Vt (upper limit = Vt, lower limit = Vb). The upper limit refers to the maximum rpm at which motor 2 rotates drum 1 with laundry 10 loaded in drum 1. In general, motor 2 consumes greater power at a lower rpm, so that an extremely small rpm cannot be set (except when the motor is halted). Motor 2 thus has a lower limit rpm. Upper limit Vt and lower limit Vb can be determined appropriately based on the performance, mechanism, durability of the motor.

[0089] Then rpm controller 8 rotates motor 2 (drum 1) at rpm V for a given time T (step D2). The given time T falls within a range between 10 - 15 seconds in this embodiment 5. If motor 2 remains rotating based on the previous step in the washing process, motor 2 is then rotated in the reverse direction to the previous one.

[0090] Next, similar to step C4, baffle frequency-component calculator 7a calculates frequency component value Fv of the vibration of drum container 3 when drum 1 rotates at rpm V (step D3). This calculation is done by using time series data sensed by vibration sensor 6. Frequency component value Fv represents a magnitude of the vibration produced by baffles 9 at rpm V.

[0091] Next, rpm controller 8 compares frequency component value Fv calculated by calculator 7a with a given threshold value "a1" (step D4). In the case of $Fv \geq a1$ laundry 10 is determined that it is sufficiently agitated by baffles 9 at the present rpm V and laundry 10 does not stick to drum 1. The step thus moves on to step D7. Then laundry 10 is kept washing at rpm V until the washing ends. In the case of Fv < a1, laundry 10 is determined that it sticks to drum 1 at the present rpm V, and the step moves on to step D5.

[0092] Rpm controller 8 checks whether or not the present rpm V is greater than lower limit Vb (step D5). In the case where drum 1 is jam-packed with laundry 10, reduction in the rpm sometimes cannot change the sticking state. In such a case, drum 1 should not be rotated at an extremely small rpm, but it is rotated at the rpm close to lower limit Vv. In this embodiment 5, when the rpm becomes lower than lower limit Vb or equal to Vb ("No" in Fig. 17), the step moves on to step d7, and the laundry is kept washing onward at this rpm. When the rpm is greater than lower limit Vb ("Yes" in Fig. 17), the step moves on to step D6 where rpm V is reduced by dV, i.e. the rpm is set at V - Vd, and then the step returns to step D2 for repeating the operation discussed above (step D6).

[0093] In the case of Fv > a1, or when frequency component value Fv won't exceed threshold value a1 although the rpm is varied from upper limit Vt to lower limit Vb, laundry 10 is kept washing at the present rpm V onward (step D7).

[0094] Fig. 18 shows the variation in the rpm of drum 1 operated based on steps D1 - D7 discussed above. Fig. 18 illustrates that the rpm of drum 1 is varied from a high value to a low value at the beginning of the washing until the frequency component value of the vibration at the baffle frequency reaches an appropriate value, i.e. until the frequency component value exceeds threshold value a1. When the frequency component value reaches an appropriate value, then the rpm at this appropriate value is maintained for the washing onward.

[0095] To be more specific, rotate drum 1 at upper limit rpm Vt for a given time T (S181), and compare frequency component value Fv with threshold value a1 (S182). The comparison finds that frequency component value Fv1 is smaller than threshold value a1, then the rpm of drum 1 is lowered to V - dV for rotating drum 1 for the given time T (S183). Operation similar to what is discussed above is repeated, and comparison of Fv with a1 (S184) finds that Fv2 is greater than a1 (S184). Then the rpm of drum 1 is not varied but maintained for rotating drum 1 (S185).

[0096] The foregoing operation allows rpm controller 8 to determine an appropriate rpm of drum 1 at the beginning of the washing, so that the laundry can be well agitated with the baffles for achieving the more powerful washing. On top of that, the baffle frequency-component value is not always calculated for every possible rpm of motor 2, so that the rpm can be determined within a shorter time. In general, motor 2 needs torque when drum 1 rotates at a low rpm, so that motor 2 consumes great electric power. In this embodiment 5, the rpm is varied from the higher one, so that use of a low rpm in determining the rpm can be avoided. As a result, lower power consumption can be expected.

[0097] This embodiment 5 is carried out at the beginning of the washing process; however, it can be done in the midway of the washing process. Because sometimes it is more efficient that the rpm is determined after the laundry sufficiently absorbs water.

Embodiment 6

[0098] In embodiment 5 discussed previously the rpm of drum 1 is varied from upper limit Vt to lower limit Vb; however, in this embodiment 6, the rpm is varied reversely, i.e. from lower limit Vb to upper limit Vt within a given range of Vb - Vt. Embodiment 6 is demonstrated hereinafter with reference to Figs. 19 and 20.

[0099] Fig. 19 shows a flowchart of embodiment 6, and Fig. 20 illustrates an operation principle of embodiment 6. The flowchart shown in Fig. 19 is basically similar to the one shown in Fig. 17 except steps D1', D5', and D6'. In step D1' substitute lower limit Vb for rpm V as an initial value. Instep D5' compare rpm V with upper limit Vt, and in the case of $V \geq Vt$ (No in Fig. 19), the step moves on to step D7, and the washing is kept going at rpm V onward. In the case of $V < Vt$ (Yes in Fig. 19), the step moves on to step D6', where the rpm is increased by dV, i.e. drum 1 is driven at rpm V+V'd, and the step moves on to step D2. The operation following the flowchart shown in Fig. 19 allows varying the rpm as shown in Fig. 20.

[0100] To be more specific, rotate drum 1 at lower limit rpm Vb for a given time T (S201), and compare frequency component value Fv with threshold value a1 (S202). The comparison finds that frequency component value Fv1 is smaller than threshold value a1, then the rpm of drum 1 is increased to V+dV for rotating drum 1 for the given time T (S203). Operation similar to what is discussed above is repeated, and when comparison of Fv with a1 (S204) finds that Fv2 is greater than a1, the rpm of drum 1 is not varied but maintained for rotating drum 1 (S205).

[0101] Variation in the rpm from a lower value to a higher value as discussed in the foregoing operation allows preventing the laundry from sticking to drum 1 during the process of determining the rpm. As a result, the washing power as a whole can be increased. On top of that, the baffle frequency-component value is not always calculated for every possible rpm of motor 2, so that the rpm can be determined within a shorter time.

[0102] As discussed above, embodiments 4 - 6 extract a frequency component value of the baffle frequency from the vibration of drum container 3, and vary the rpm of drum 1 (motor 2) in response to each one of the frequency components. This mechanism allows preventing laundry 10 from sticking to drum 1, and allows laundry 10 to be agitated well with baffles 9, whereby the washing power can be increased. As a result, the washing can be done within a shorter time.

Embodiment 7

[0103] In embodiments 1 - 3 discussed previously the

Fourier transform is used for finding the frequency component value of the vibration corresponding to the rpm of drum 1 from the vibration data supplied from vibration sensor 6. In general, drum 1 does not always rotate at a constant rpm because the rpm of drum 1 frequently varies due to changes in behavior of laundry 10 loaded in drum 1. Frequency component calculator 7, as shown in Fig. 21, can thus calculate frequency components of vibrations with respect to frequency Fp within a given range having a center frequency of the vibration corresponding to the rpm of drum 1. Then calculator 7 can output a maximum value or an average value of the frequency components within the given range as a frequency component corresponding to the rpm of drum 1.

[0104] For instance, as shown in Fig. 21, drum 1 rotates at 49rpm with a speed error of ±5rpm. The given range of frequency Fp is thus 44rpm/60sec - 54rpm/60sec, i.e. 0.73Hz - 0.9Hz. Use of one of a total value, an average value, or a maximum value of the frequency component values within this range allows achieving an appropriate rpm control which prevents the laundry from sticking to drum 1 even when the rpm of drum 1 has some speed error.

[0105] In a similar way, embodiments 4 - 6 prove that the vibration data supplied from vibration sensor 6 undergoes the Fourier transform, whereby a frequency component value at the baffle frequency, i.e. an rpm/60sec × the number of baffles can be obtained. In this case, the rpm of drum 1 does not always stay at a constant rpm, and yet, the rpm sometimes varies over 20%. The baffle frequency thus preferably has a given range taking the speed error into consideration.

[0106] For instance, in the case of rpm = 45 and the number of baffles = 3 as shown in Fig. 22, the baffle frequency is calculated this way: 45rpm/60sec × 3 = 2.25Hz. In this case, baffle frequency-component calculator 7a calculates frequency components of vibrations with respect to frequency Fp falling within a given range which includes the baffle frequency of drum 1. Calculator 7a can then output any one of the maximum value, the average value or the total value of the frequency components within the given rang.

[0107] In the case of the instance shown in Fig. 22, assume that speed error at 45 rpm is ±5rpm, then frequency Fp within the given range falls within the range between 40rpm/60sec × 3 and 50rpm/60sec × 3 because the number of the baffles is three (n=3), namely, frequency Fp falls within the range from 2 Hz to 2.5 Hz. Use of any one of the total value, the average value, or the maximum value of the frequency component within this range allows controlling the rpm appropriately although the rpm of drum 1 includes some speed error.

[0108] The methods discussed in the previous embodiments for controlling the rpm of drum 1 of the washing machine can be programmed for computers.

Industrial Applicability

[0109] The present invention can control an rpm of a drum of a washing machine by using a frequency component of a drum container, thereby improving the washing power of the washing machine. The present invention can be thus applied not only to household washing machines but also to washing machines with dryers or professional type washing machines.

Claims

1. A washing machine comprising:

   a drum for being rotated with laundry loaded therein;
   a drum container supported from a housing of the washing machine by a resilient supporting mechanism for accommodating the drum;
   a motor for rotating the drum;
   a vibration sensor for sensing a vibration of the drum container;
   a frequency component calculator for calculating a frequency component value of the vibration sensed by the vibration sensor; and
   an rpm controller for varying an rpm of the motor in response to the frequency component value.

2. The washing machine of claim 1, wherein the vibration sensor includes at least one acceleration sensor for sensing a vibration along at least one of a vertical direction, a right and left direction, and a back and forth direction of the drum container, and outputting a total value of accelerations along each one of the directions of the sensed vibrations.

3. The washing machine of claim 1, wherein the frequency component calculator calculates a frequency component value of a vibration at a frequency corresponding to an rpm of the drum, and the rpm controller increases the rpm of the motor in a case where the frequency component value is smaller than a first given range, and reduces the rpm of the motor in a case where the frequency component value is greater than a second given range.

4. The washing machine of claim 1, wherein the frequency component calculator calculates a frequency component value of a vibration at a frequency corresponding to an rpm of the drum, and the rpm controller varies the rpm of the drum from an upper limit to a lower limit while the frequency component calculator finds a frequency component value, and the rpm controller keeps washing the laundry onward at an rpm at which the frequency component value becomes smaller than a given value.

5. The washing machine of claim 1, wherein the frequency component calculator calculates a frequency component value of a vibration at a frequency corresponding to an rpm of the drum, and the rpm controller varies the rpm of the drum from a lower limit to an upper limit while the frequency component calculator finds a frequency component value, and the rpm controller keeps washing the laundry onward at an rpm at which the frequency component value becomes greater than a given value.

6. The washing machine of claim 3, wherein the frequency component calculator calculates frequency component values of the vibrations at frequencies falling within a given range which corresponds to a varying range of the rpm of the drum, and outputs a maximum value or an average value of the frequency component value within the given range as a frequency component value of the vibration corresponding to the rpm of the drum.

7. The washing machine of claim 1, wherein the drum includes at least one baffle for agitating the laundry, and the frequency component calculator calculates a frequency component value of a vibration generated through agitation of the laundry agitated with the baffle.

8. The washing machine of claim 7, wherein the rpm controller controls the motor for varying the rpm of the drum to a plurality of rpm values, and the frequency component calculator calculates frequency component values of vibrations, generated through the agitation of the laundry with the baffles, at each one of the varied rpm values, and the rpm controller rotates the motor at the rpm corresponding to a maximum frequency component value among the frequency component values at each one of the varied rpm values.

9. The washing machine of claim 7, wherein the rpm controller controls the motor for varying the rpm of the drum from an upper limit to a lower limit or from the lower limit to the upper limit, and the frequency component calculator calculates frequency components, at the varied rpm values, of vibrations generated through the agitation of the laundry with the baffle, and the rpm controller drives the motor at an rpm at which the frequency component value becomes greater than a given value.

10. The washing machine of claim 7, wherein the frequency component calculator has a signal sensed by the vibration sensor undergo Fourier transform under a condition where the drum is rotated at rpm "V" and the drum includes the baffles in the number of "n", and calculates a frequency component value of a vibration at a frequency of "V"/60 × "n" Hz.

11. The washing machine of claim 10, wherein the frequency component calculator calculates frequency component values within a given range including the frequency of "V"/60 × "n" Hz, and outputs any one of a total value, an average value or a maximum value of the calculated frequency component values.

12. A method for controlling an rpm of a washing machine which includes a drum for being rotated with laundry loaded therein, a drum container for accommodating the drum, and a motor for rotating the drum, the method comprising the steps of:

sensing a vibration of the drum container;
calculating a frequency component value of the sensed vibration; and
varying an rpm of the motor in response to the calculated frequency component value.

13. A program of the method, defined in claim 12, for controlling an rpm of the drum of the washing machine, wherein the program can be executed by a computer.

FIG. 1

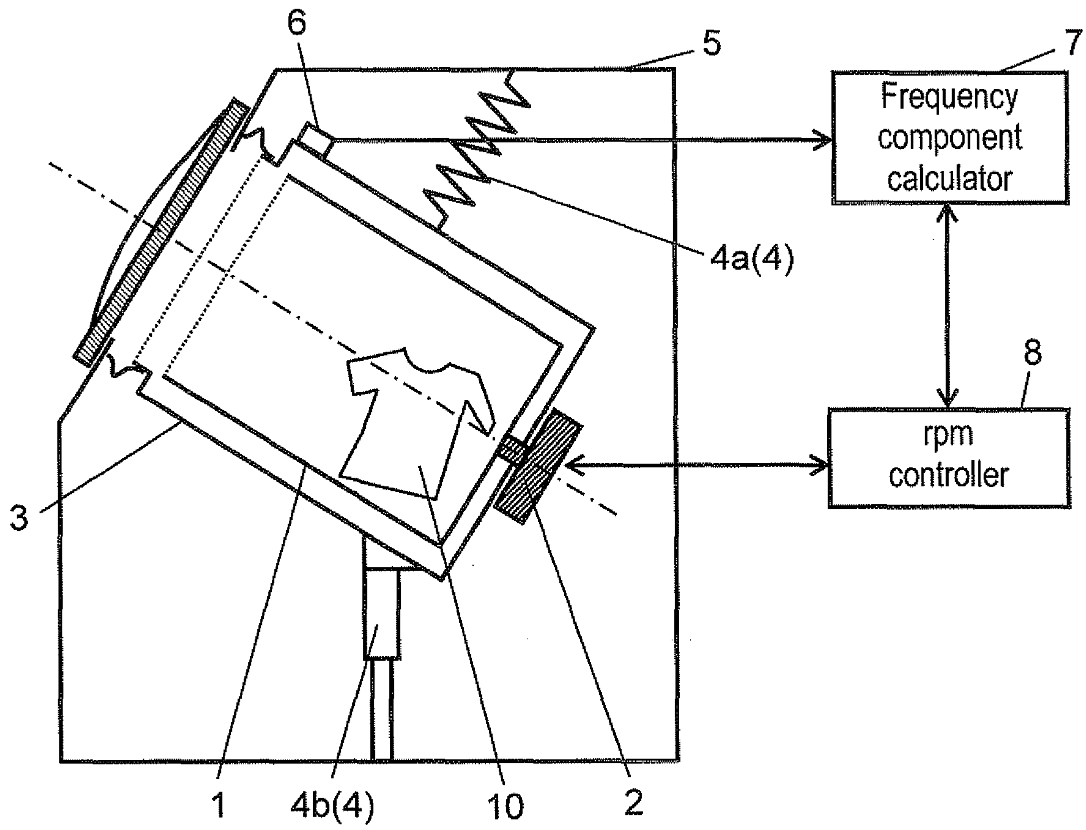


FIG. 2A

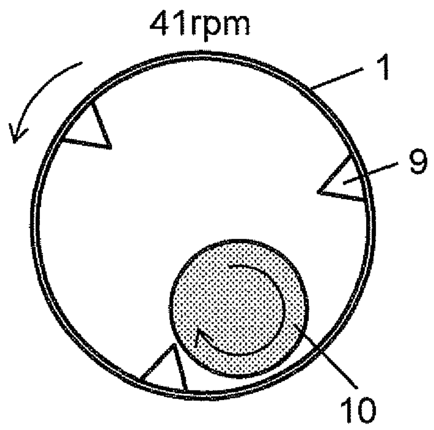


FIG. 2B

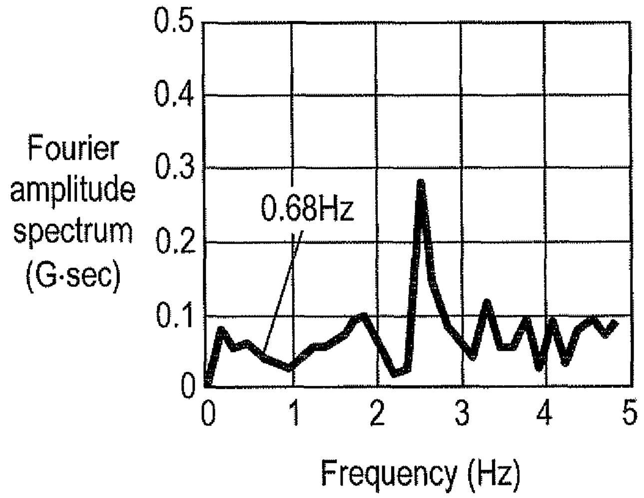


FIG. 3A

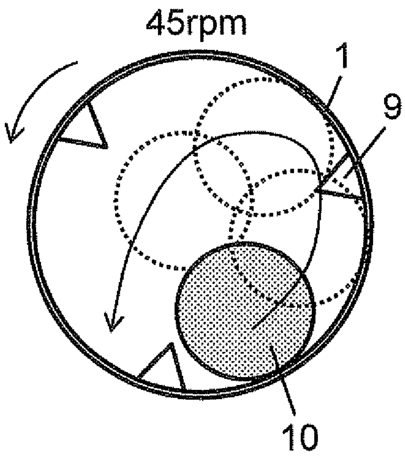


FIG. 3B

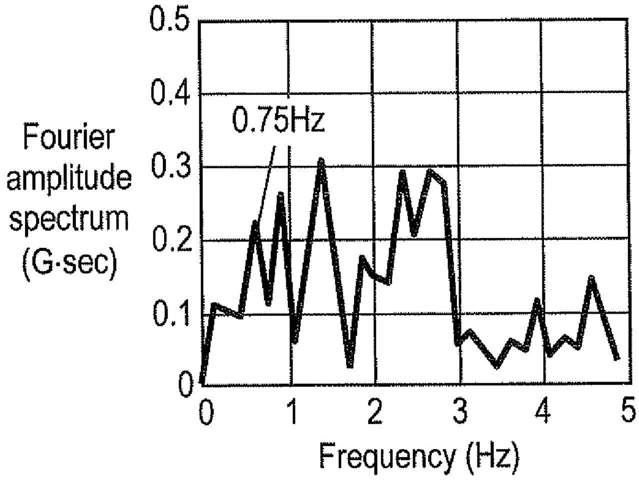


FIG. 4A

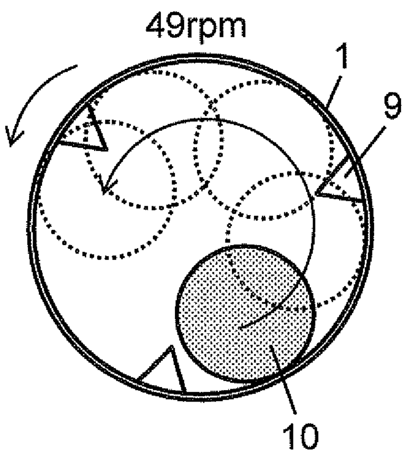


FIG. 4B

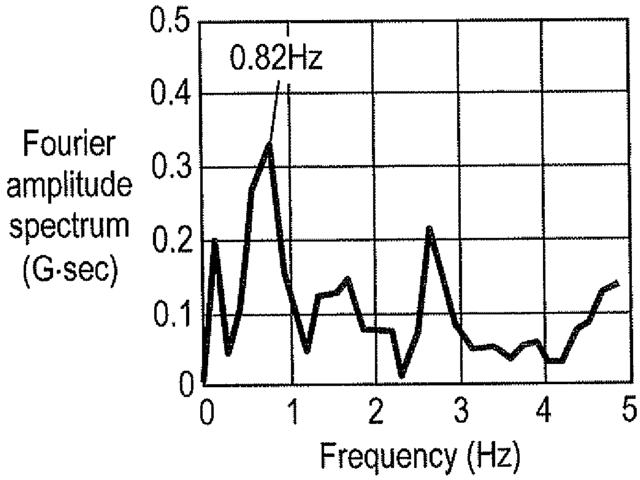


FIG. 5

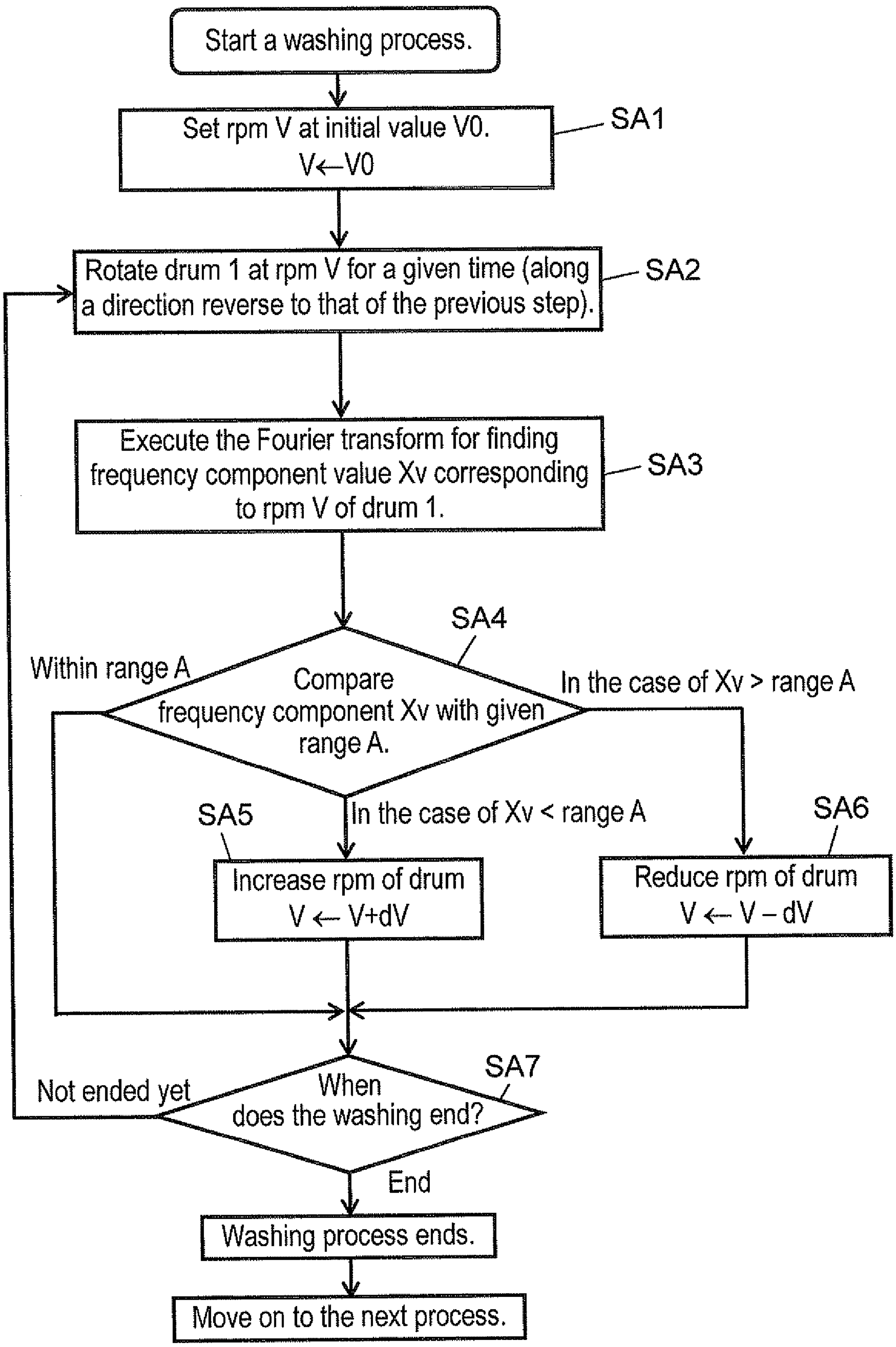

Start a washing process.
Set rpm V at initial value V0.
V←V0
SA1
Rotate drum 1 at rpm V for a given time (along a direction reverse to that of the previous step).
SA2
Execute the Fourier transform for finding frequency component value Xv corresponding to rpm V of drum 1.
SA3
SA4
Within range A
Compare frequency component Xv with given range A.
In the case of Xv > range A
SA5
In the case of Xv < range A
SA6
Increase rpm of drum
V ← V+dV
Reduce rpm of drum
V ← V – dV
SA7
Not ended yet
When does the washing end?
End
Washing process ends.
Move on to the next process.

FIG. 6

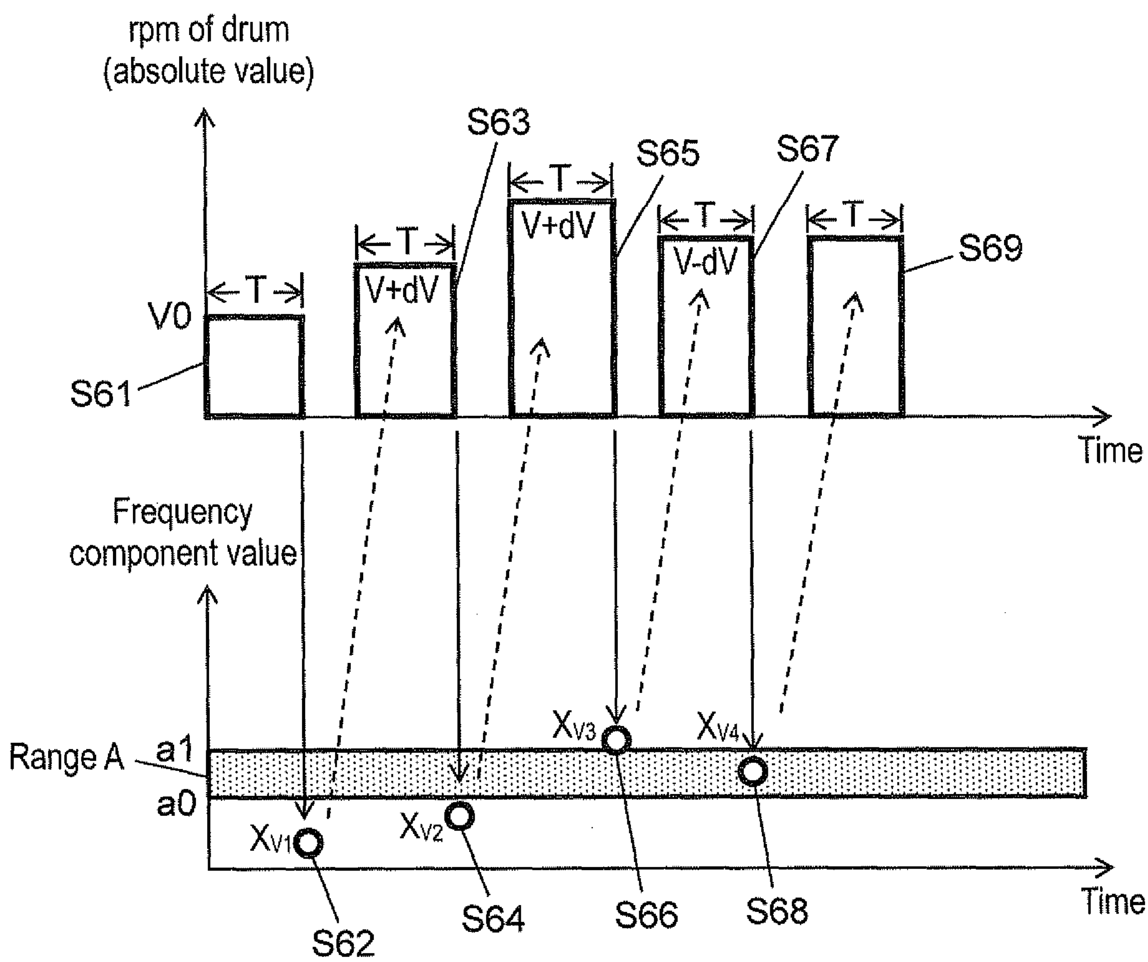

rpm of drum
(absolute value)
S63
S65
S67
T
T
T
T
T
V+dV
V+dV
V-dV
S69
V0
S61
Time
Frequency
component value
Range A
a1
a0
XV1
XV2
XV3
XV4
S62
S64
S66
S68
Time

FIG. 7

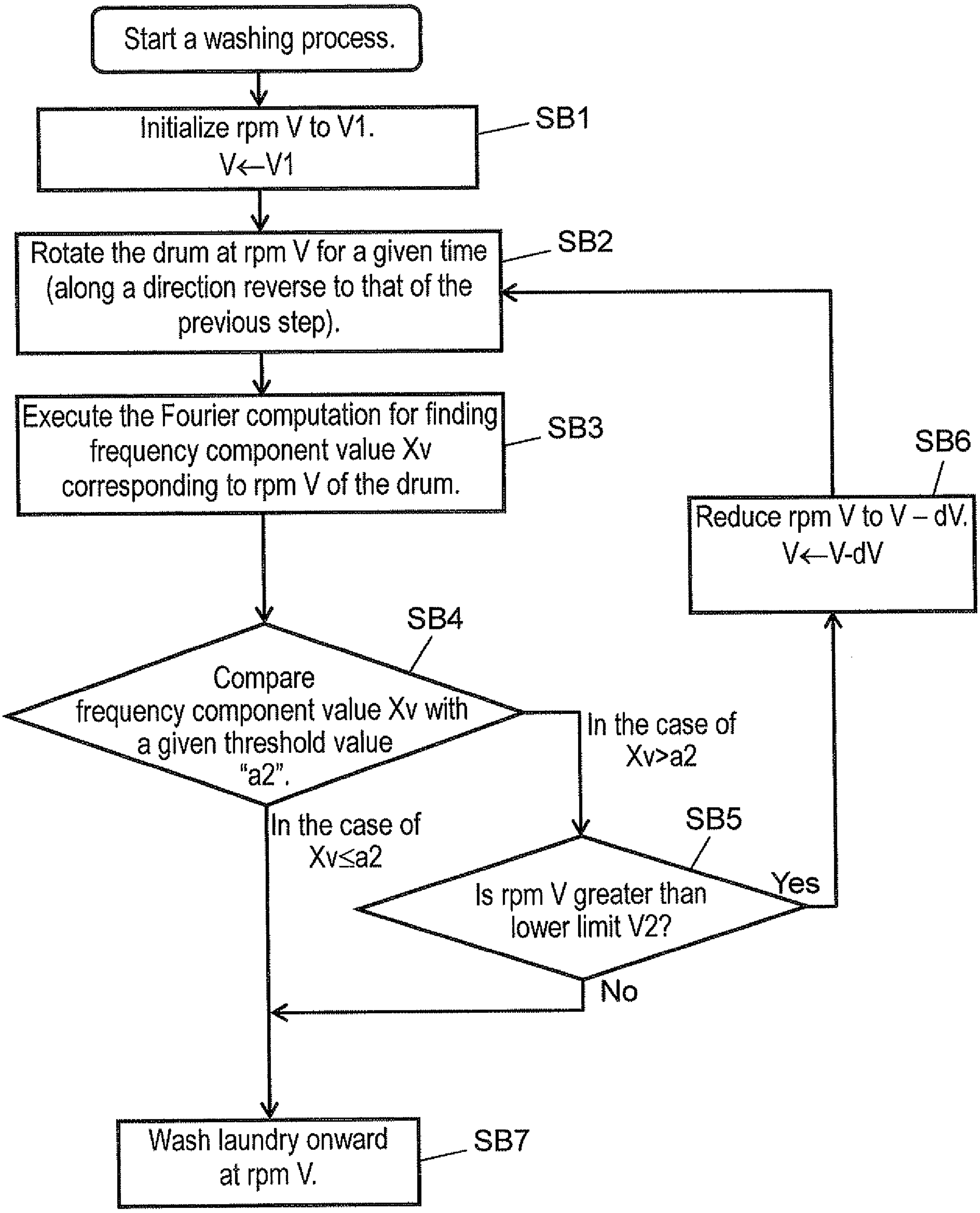

Start a washing process.
Initialize rpm V to V1.
V←V1
SB1
Rotate the drum at rpm V for a given time (along a direction reverse to that of the previous step).
SB2
Execute the Fourier computation for finding frequency component value Xv corresponding to rpm V of the drum.
SB3
SB6
Reduce rpm V to V – dV.
V←V-dV
SB4
Compare frequency component value Xv with a given threshold value "a2".
In the case of Xv>a2
SB5
In the case of Xv≤a2
Yes
Is rpm V greater than lower limit V2?
No
Wash laundry onward at rpm V.
SB7

FIG. 8

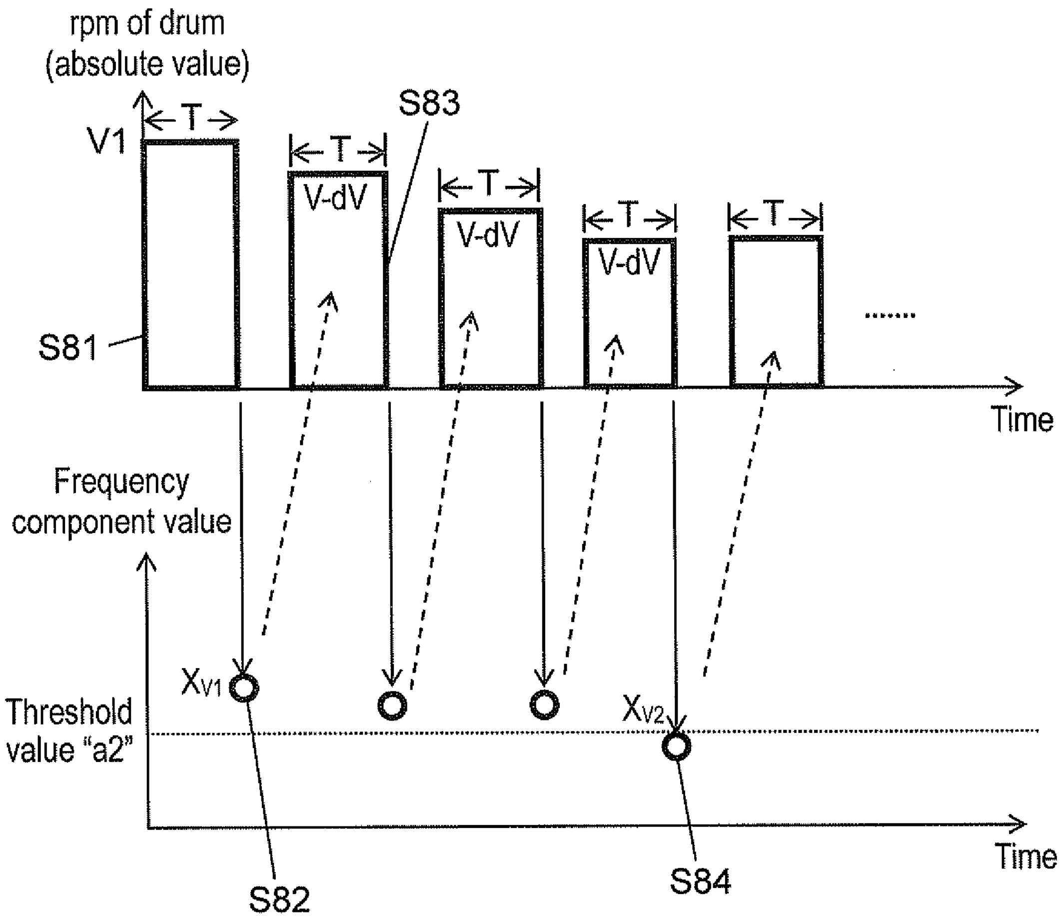

rpm of drum
(absolute value)
T
V1
S83
V-dV
S81
....
Time
Frequency
component value
X_{V1}
Threshold
value "a2"
X_{V2}
S82
S84
Time

FIG. 9

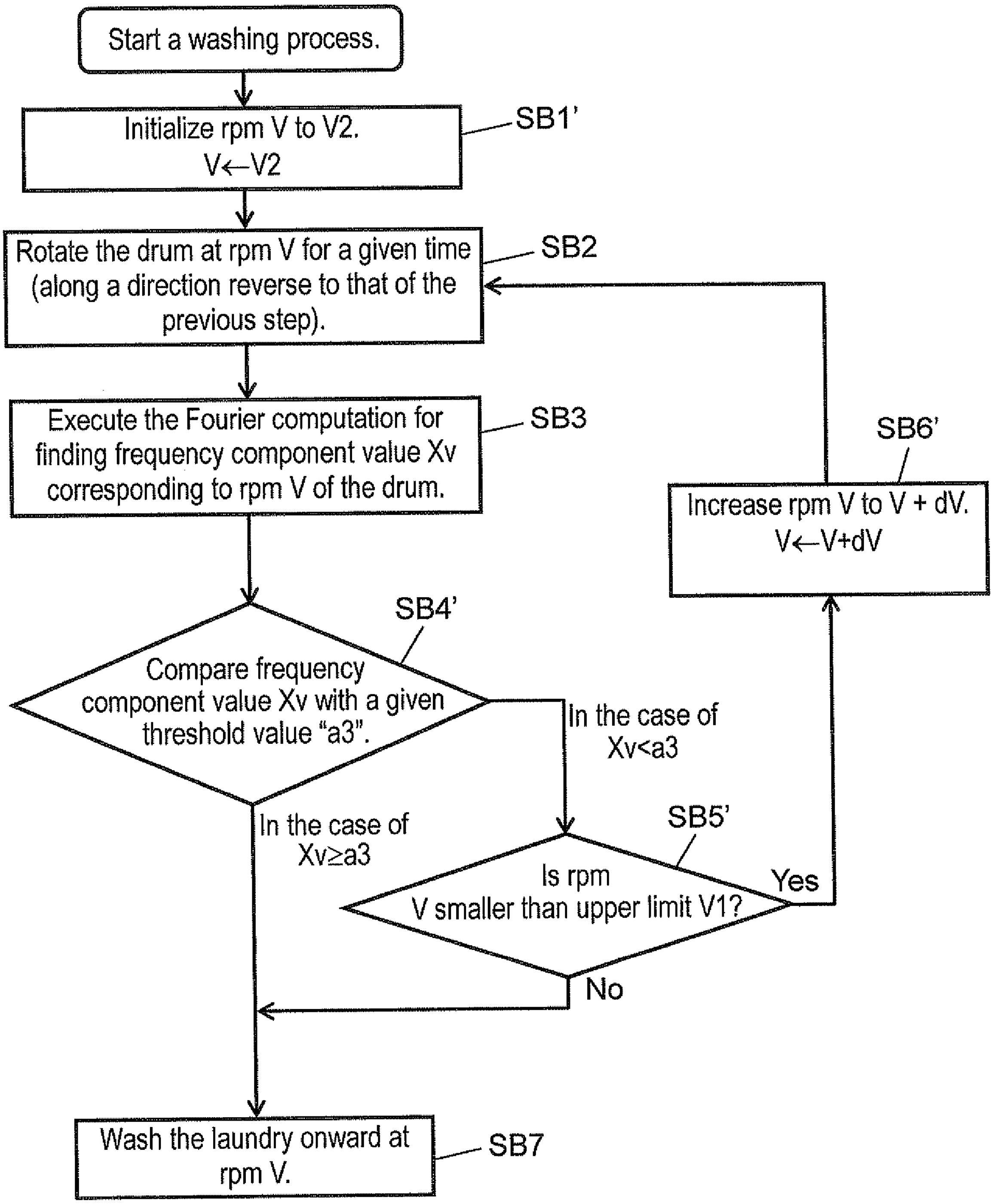

Start a washing process.
Initialize rpm V to V2.
V←V2
SB1'
Rotate the drum at rpm V for a given time (along a direction reverse to that of the previous step).
SB2
Execute the Fourier computation for finding frequency component value Xv corresponding to rpm V of the drum.
SB3
SB6'
Increase rpm V to V + dV.
V←V+dV
SB4'
Compare frequency component value Xv with a given threshold value "a3".
In the case of Xv<a3
In the case of Xv≥a3
SB5'
Is rpm V smaller than upper limit V1?
Yes
No
Wash the laundry onward at rpm V.
SB7

FIG. 10

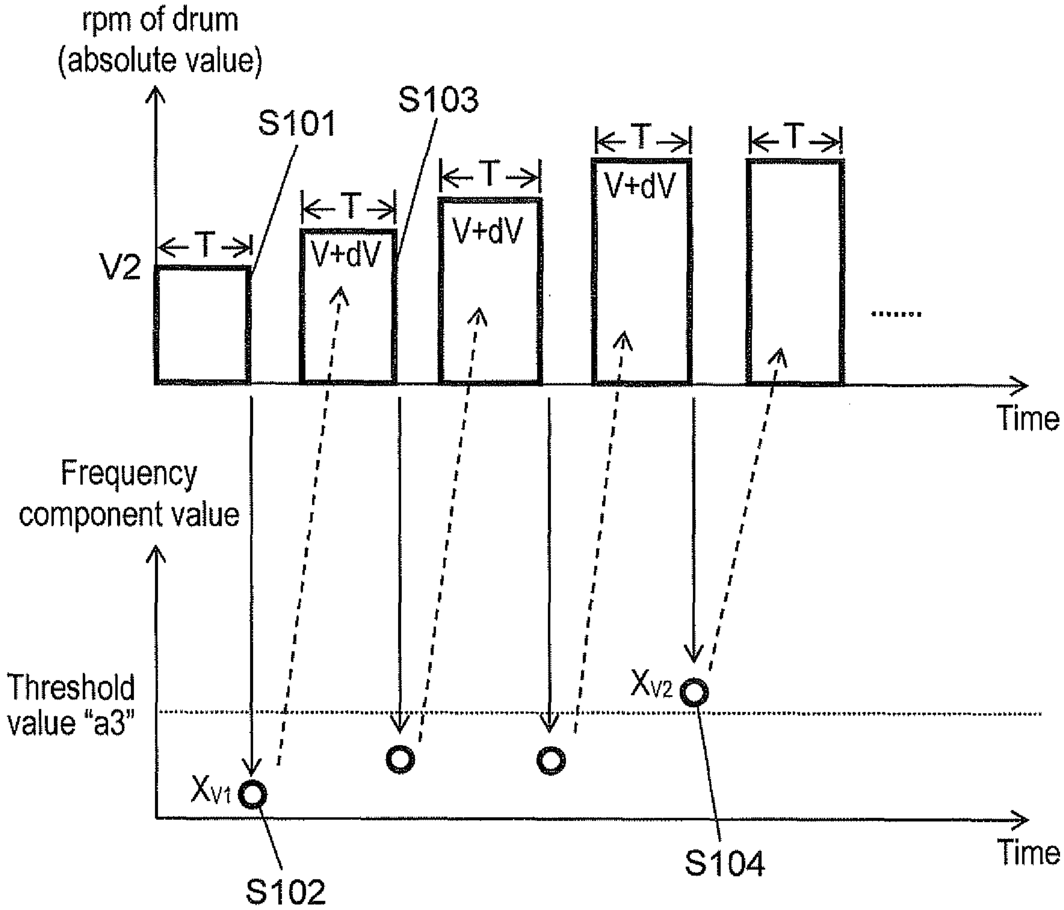

rpm of drum
(absolute value)
S101
S103
V2
T
V+dV
....
Time
Frequency
component value
Threshold
value "a3"
Xv1
Xv2
S102
S104
Time

FIG. 11

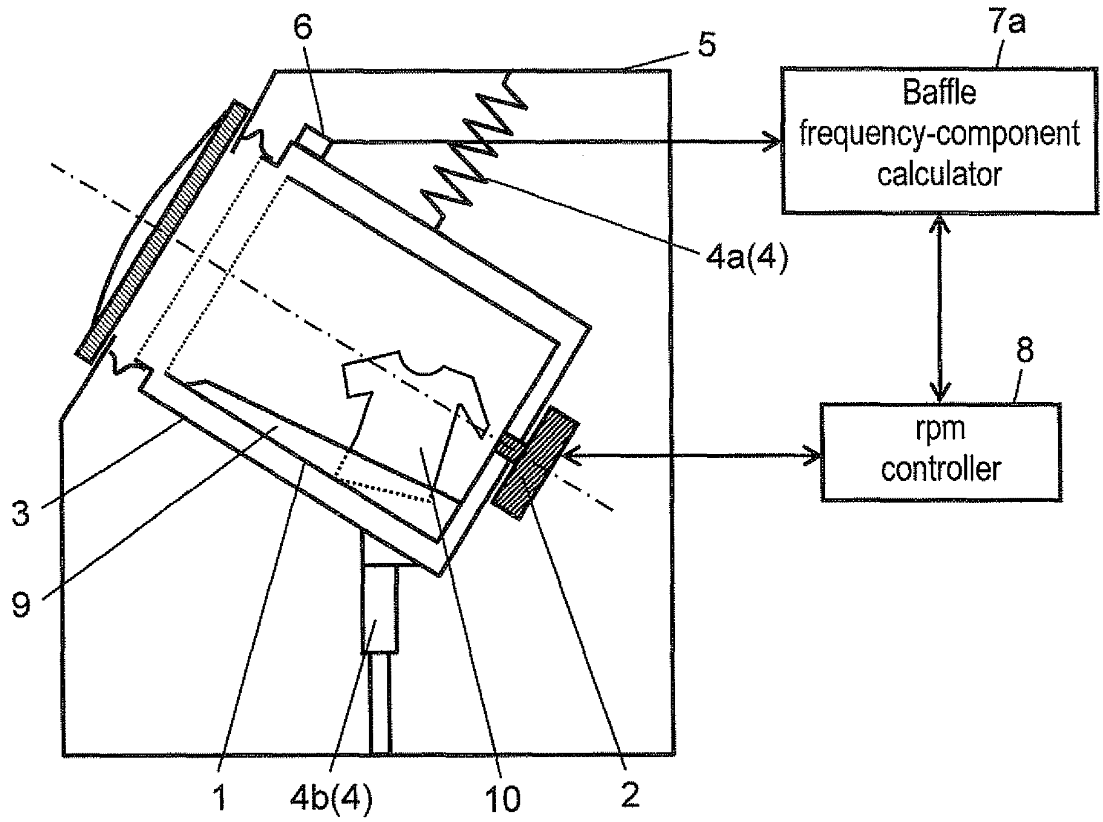


FIG. 12A

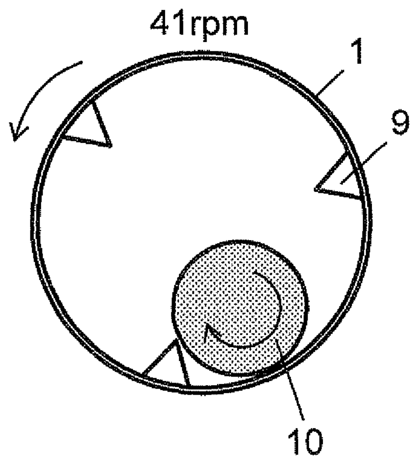


FIG. 12B

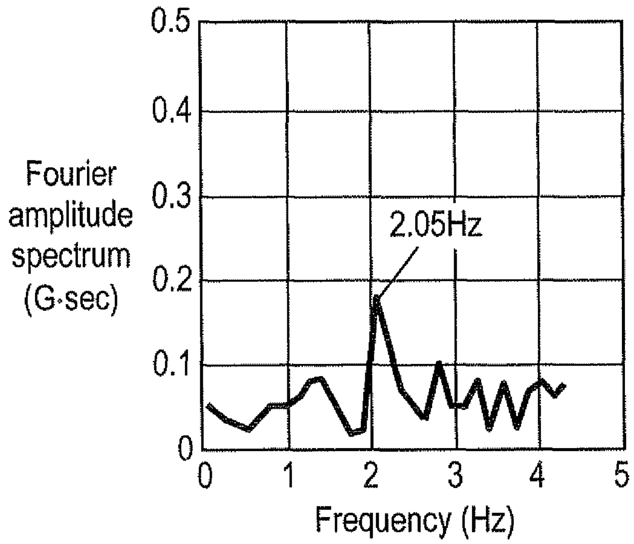


FIG. 13A

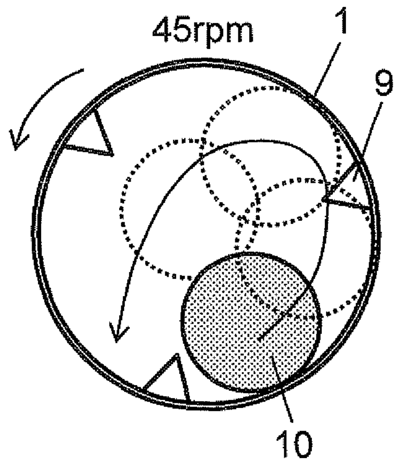


FIG. 13B

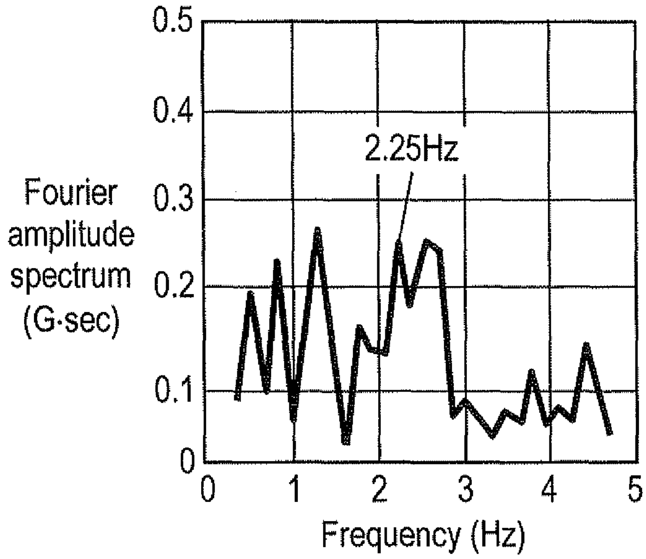


FIG. 14A

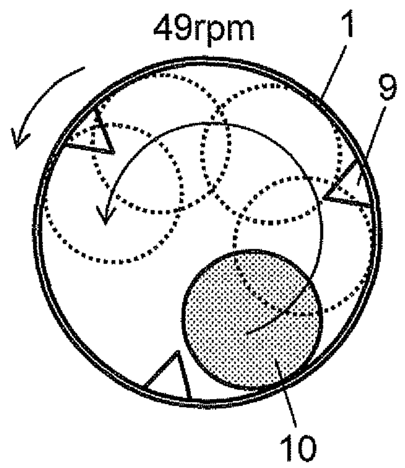


FIG. 14B

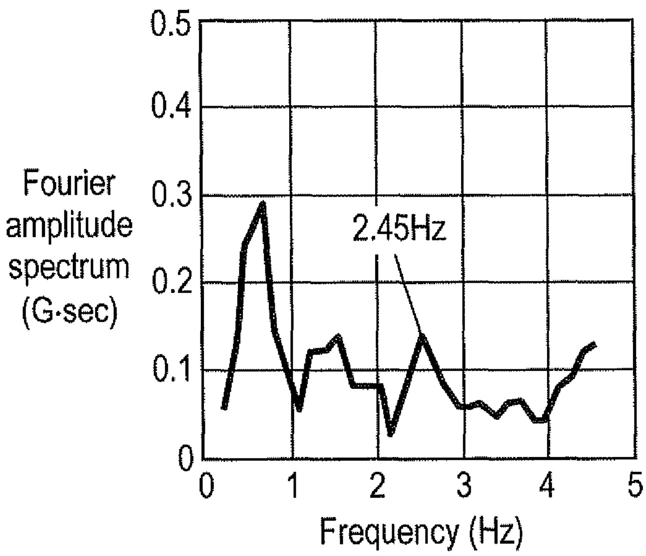


FIG. 15

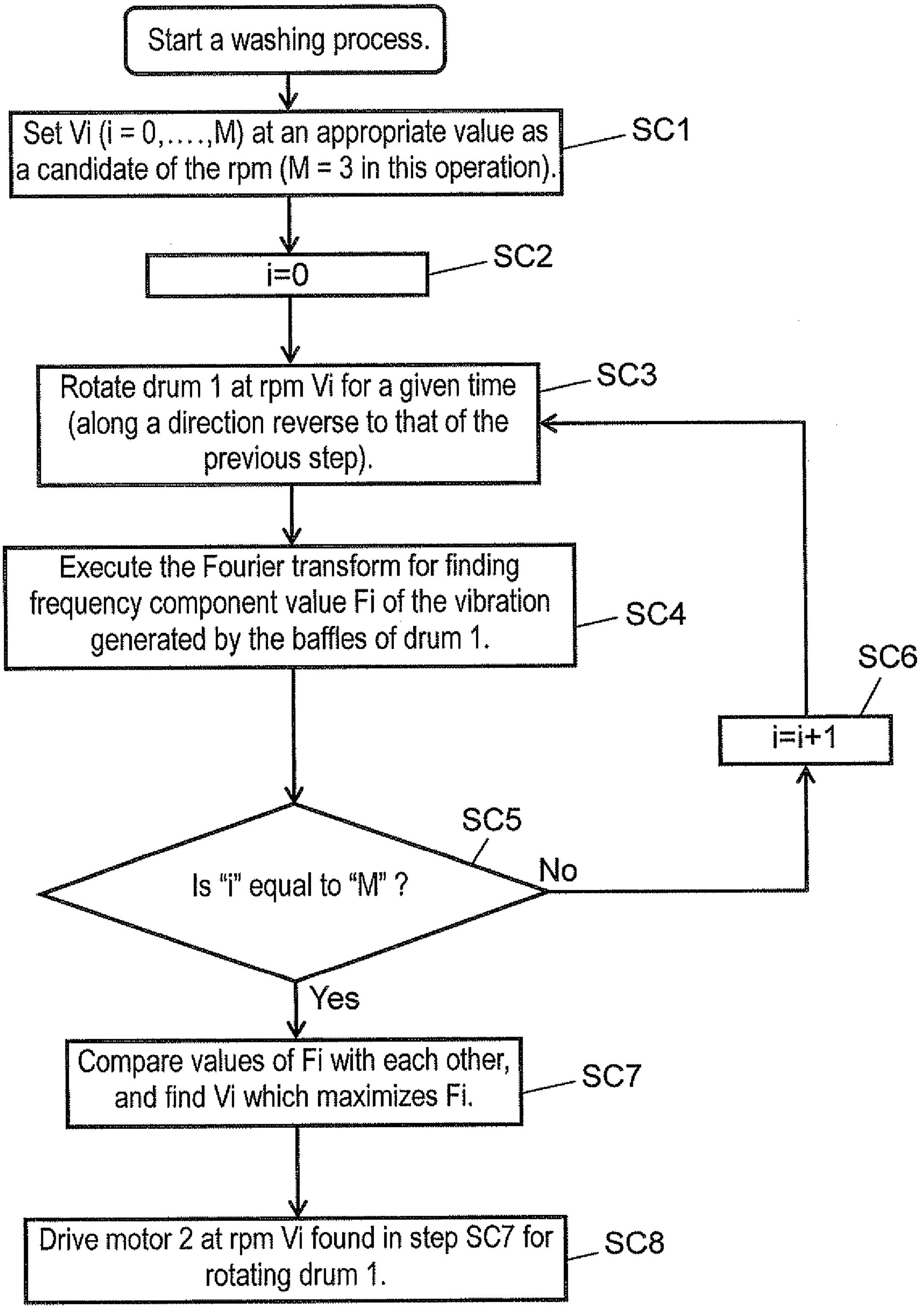

Start a washing process.
Set Vi (i = 0,....,M) at an appropriate value as a candidate of the rpm (M = 3 in this operation).
SC1
i=0
SC2
Rotate drum 1 at rpm Vi for a given time (along a direction reverse to that of the previous step).
SC3
Execute the Fourier transform for finding frequency component value Fi of the vibration generated by the baffles of drum 1.
SC4
SC6
i=i+1
SC5
No
Is "i" equal to "M" ?
Yes
Compare values of Fi with each other, and find Vi which maximizes Fi.
SC7
Drive motor 2 at rpm Vi found in step SC7 for rotating drum 1.
SC8

FIG. 16

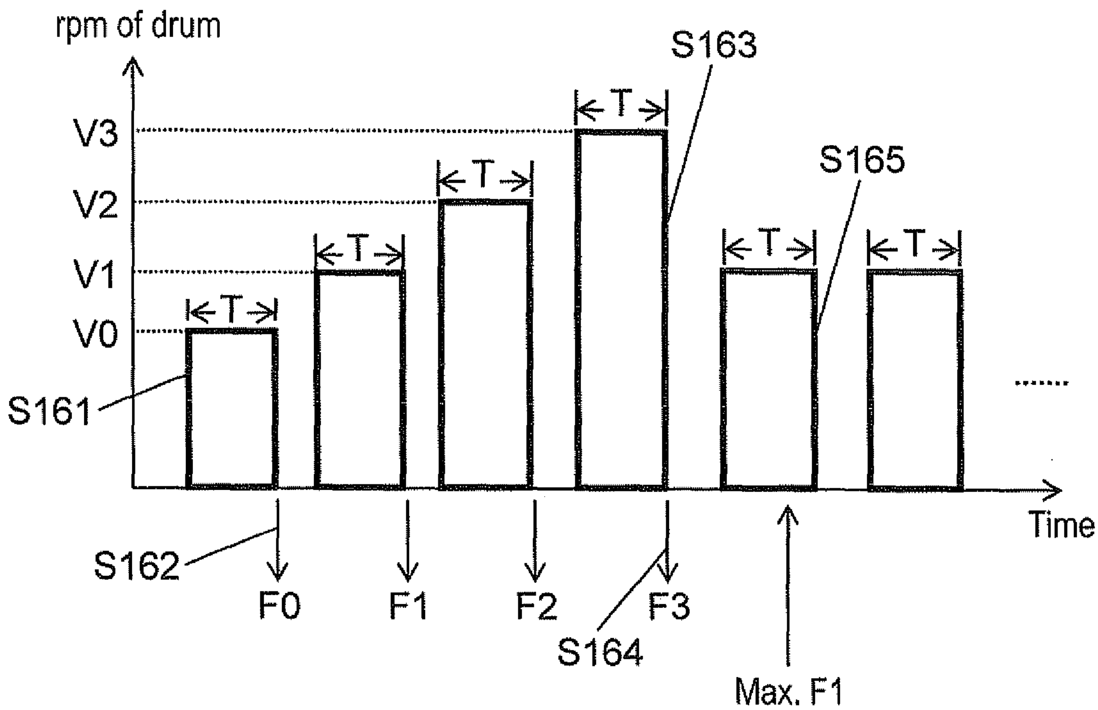

rpm of drum
S163
V3
V2
V1
V0
T
S165
S161
......
Time
S162
F0
F1
F2
F3
S164
Max. F1

FIG. 17

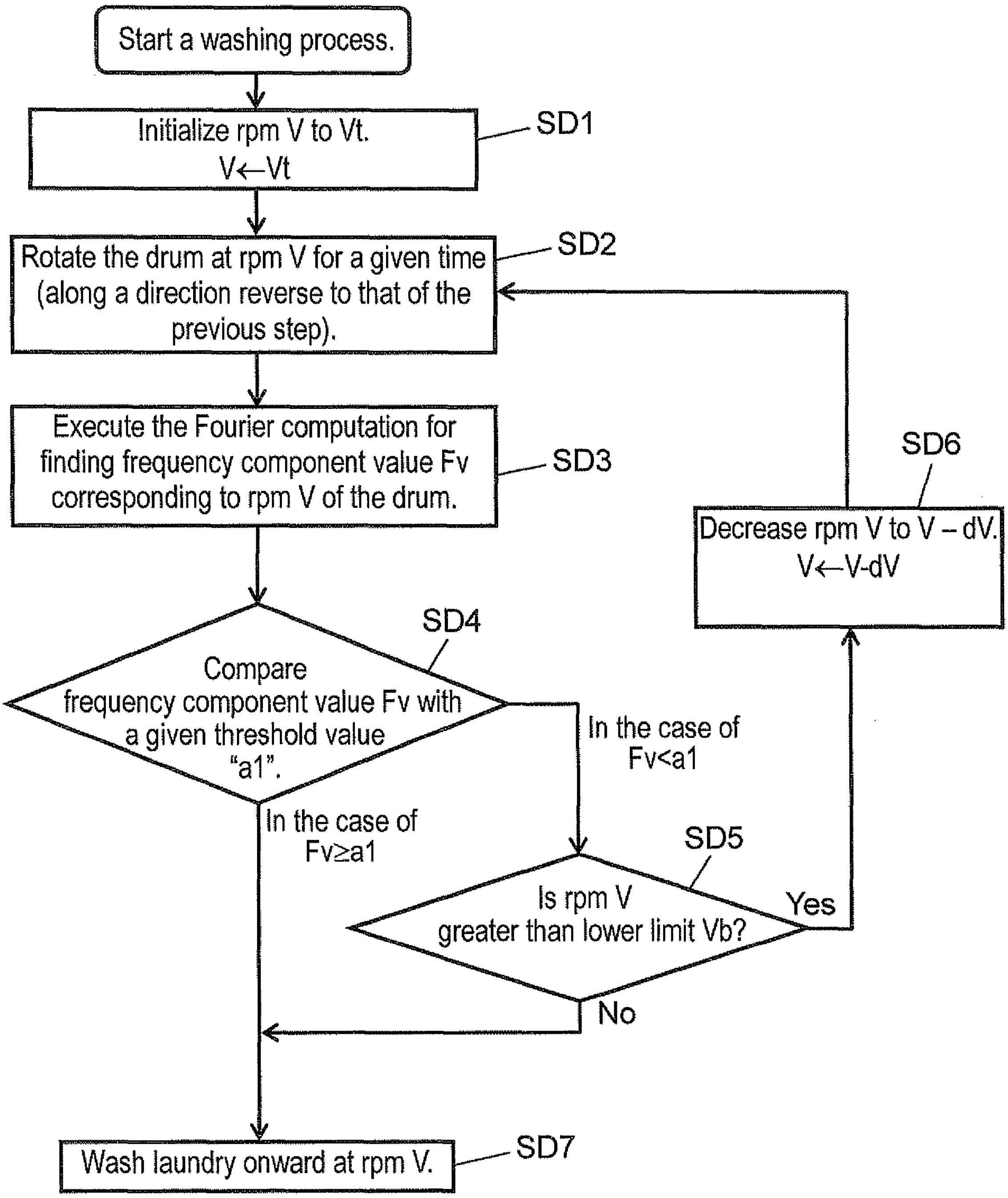

Start a washing process.
Initialize rpm V to Vt.
V←Vt
SD1
Rotate the drum at rpm V for a given time (along a direction reverse to that of the previous step).
SD2
Execute the Fourier computation for finding frequency component value Fv corresponding to rpm V of the drum.
SD3
Compare frequency component value Fv with a given threshold value "a1".
SD4
In the case of Fv<a1
In the case of Fv≥a1
Is rpm V greater than lower limit Vb?
SD5
Yes
No
Decrease rpm V to V – dV.
V←V-dV
SD6
Wash laundry onward at rpm V.
SD7

FIG. 18

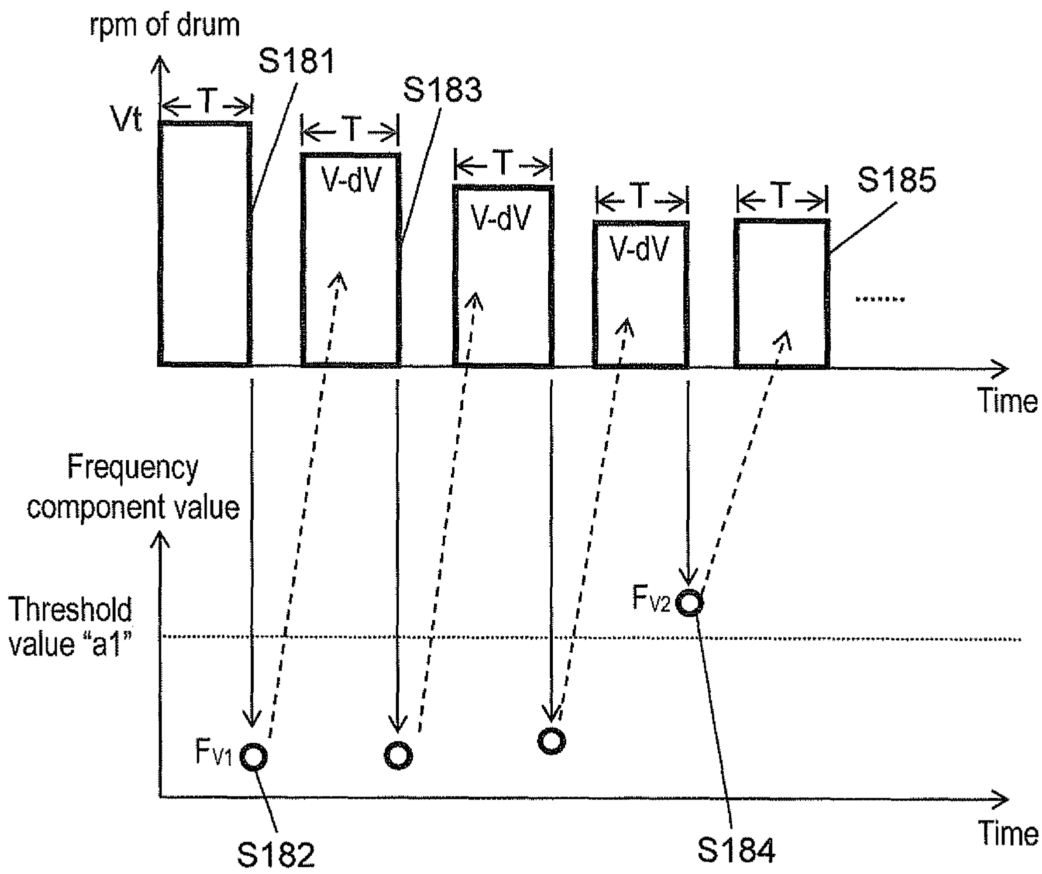
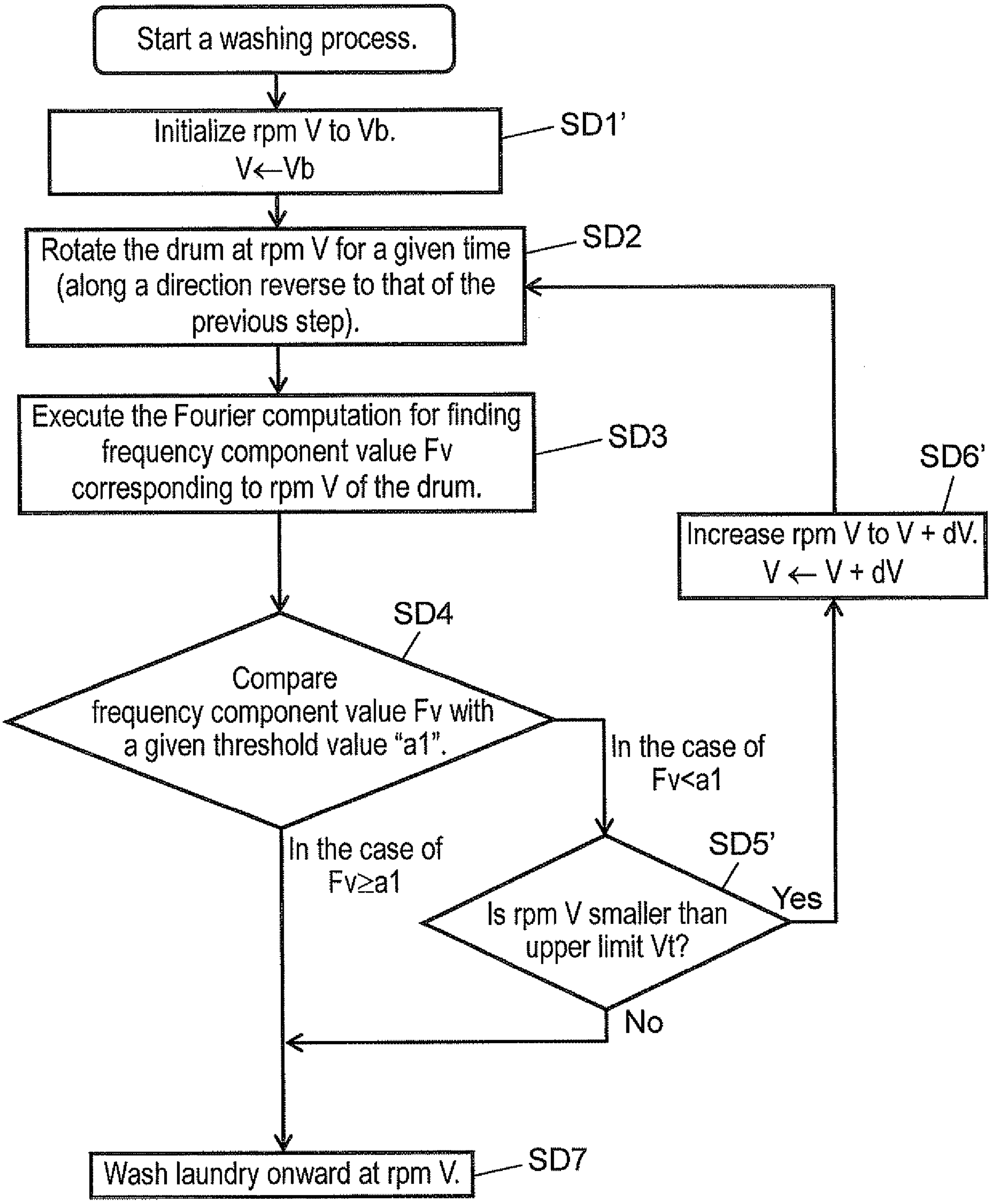

rpm of drum
S181
S183
Vt
T
V-dV
S185
Time
Frequency
component value
Threshold
value "a1"
FV2
FV1
S182
S184
Time

FIG. 19



Start a washing process.
Initialize rpm V to Vb.
V←Vb
SD1'
Rotate the drum at rpm V for a given time (along a direction reverse to that of the previous step).
SD2
Execute the Fourier computation for finding frequency component value Fv corresponding to rpm V of the drum.
SD3
SD6'
Increase rpm V to V + dV.
V ← V + dV
SD4
Compare frequency component value Fv with a given threshold value "a1".
In the case of Fv<a1
In the case of Fv≥a1
SD5'
Yes
Is rpm V smaller than upper limit Vt?
No
Wash laundry onward at rpm V.
SD7

FIG. 20

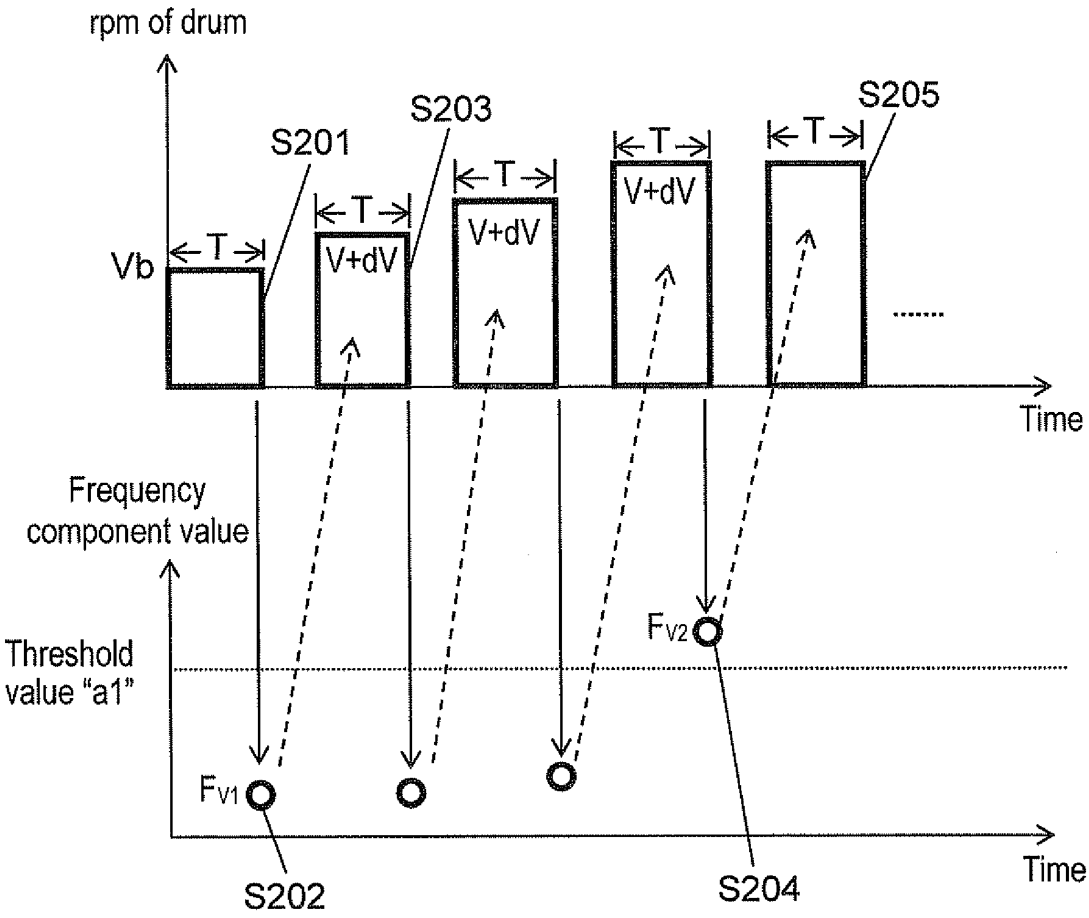

rpm of drum
S201
S203
S205
T
Vb
V+dV
....
Time
Frequency component value
Threshold value "a1"
FV1
FV2
S202
S204
Time

FIG. 21

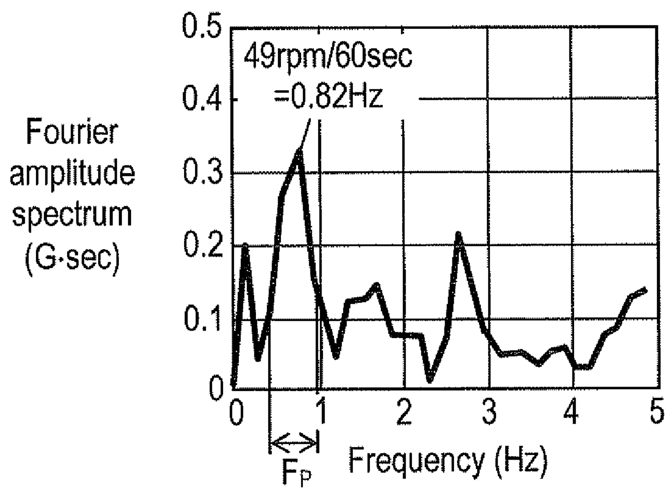

Fourier amplitude spectrum (G·sec)
0.5
0.4
0.3
0.2
0.1
0
49rpm/60sec
=0.82Hz
0
1
2
3
4
5
FP
Frequency (Hz)

FIG. 22

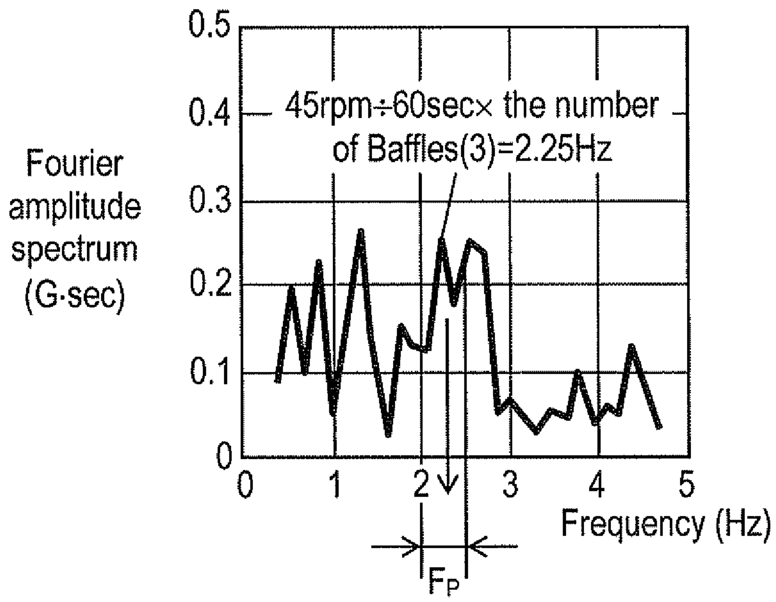
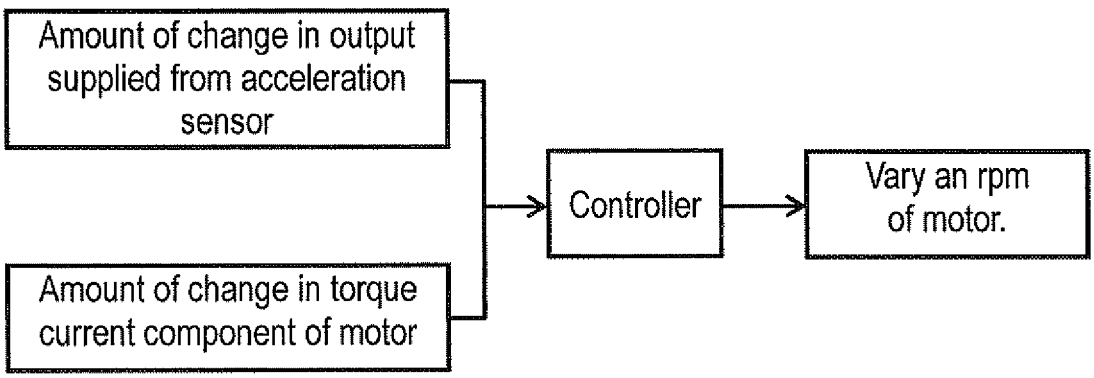

0.5
0.4
0.3
0.2
0.1
0
45rpm÷60sec× the number
of Baffles(3)=2.25Hz
Fourier
amplitude
spectrum
(G·sec)
0
1
2
3
4
5
Frequency (Hz)
FP

FIG. 23


Amount of change in output supplied from acceleration sensor
Amount of change in torque current component of motor
Controller
Vary an rpm of motor.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/002416

A. CLASSIFICATION OF SUBJECT MATTER
D06F33/02(2006.01)i, *D06F37/04*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D06F33/02, D06F37/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 6-254286 A (Matsushita Electric Industrial Co., Ltd.), 13 September, 1994 (13.09.94), Full text; all drawings (Family: none)	1-9,12,13 10,11
Y A	JP 2007-236585 A (Matsushita Electric Industrial Co., Ltd.), 20 September, 2007 (20.09.07), Par. Nos. [0058] to [0063]; Figs. 1 to 2 (Family: none)	1-9,12,13 10,11

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 December, 2008 (01.12.08)	09 December, 2008 (09.12.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/002416

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-320762 A (Fisher & Paykel Appliances Ltd.), 30 November, 2006 (30.11.06), Full text; all drawings & US 6477867 B1 & EP 1764436 A1 & WO 2000/039382 A1 & AU 1900500 A & BR 9916837 A & NZ 0512351 A & CA 2353814 A & CN 1342231 A	1-9,12,13

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Patent documents cited in the description

- JP 2006346270 A **[0004]**