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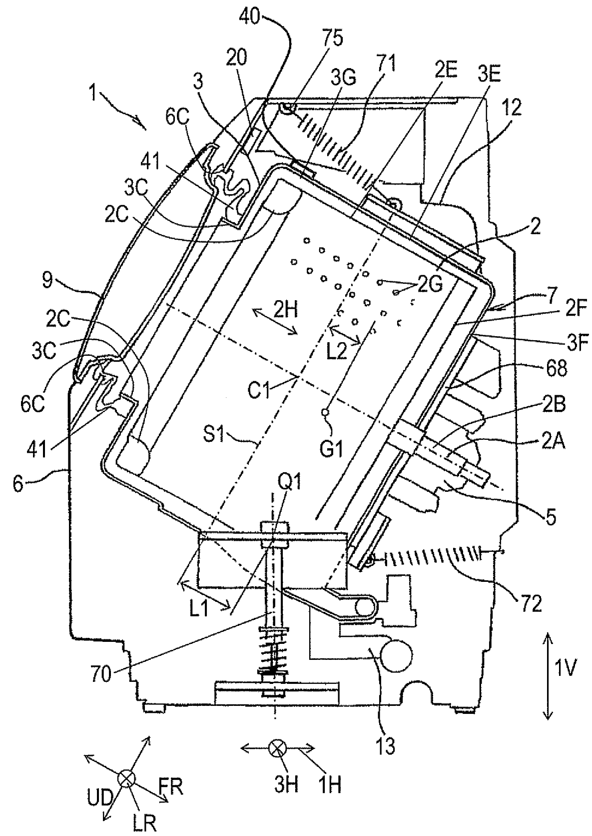
(54) Drum type washing machine

(57) A drum type washing machine (1) includes a housing, a washtub unit (7) accommodated in the housing, a damper (70) for elastically supporting the washtub at a supporting position, a vibration sensor (40) for detecting a vibration of the washtub. The vibration sensor outputs a first signal and a second signal corresponding to a component of vibration of a portion of the washtub along a first direction and a component of the vibration along a second direction perpendicular to the first direction, respectively. The portion of the washtub is between the center plane of the washtub and the opening of the washtub. A controller determines, based on the first and second signals output from the vibration sensor, whether or not the laundry is distributed in the rotary drum in a front unbalance in which the laundry is biased from the center plane towards the opening of the rotary drum, and whether or not the laundry is distributed in the rotary drum in a rear unbalance in which the laundry is biased from the center plane towards the bottom of the rotary drum. The drum type washing machine enables to detect unbalance of a laundry even when the laundry is biased in the rotary drum towards a bottom of the rotary drum.

FIG. 1



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a drum type washing machine including a rotary drum rotatable about a rotary axis slanting or extending horizontally.

BACKGROUND OF THE INVENTION

[0002] Fig. 7 is a cross sectional view of a conventional drum type washing machine 501. The conventional drum type washing machine 501 including a housing 506 having a loading/unloading opening provided therein, a washtub 503 elastically supported with an anti-vibration damper 570 and accommodated in the housing 506, a motor 505 mounted onto a rear side of the washtub 506, a rotary drum 502 accommodated in the washtub 503, a door 509 mounted to the housing 506 for opening and closing the loading/unloading opening, and an elastic sealing member 541 mounted at the loading/unloading opening in the housing 506. The washtub 503, the rotary drum 502, and the motor 505 are assembled together to form a washtub unit 507. The rotary drum 502 has a lot of apertures provided therein. The washtub 503 communicates at the opening with the loading/unloading opening in the housing 506. The rotary drum 502 has an opening provided therein for communicating with the loading/unloading opening of the housing 506 and the opening of the washtub 503. The rotary drum 502 is driven by the motor 505 for rotating about a rotary axis 502A which slants or extends horizontally from the opening to the rear side. Upon the door 509 being opened, a laundry is loaded into and unloaded from the rotary drum 502 via the opening of the washtub 403 and the opening of the rotary drum 502. The elastic sealing member 541 is made of elastic material, such as rubber, for sealing between the door 509 and the washtub 503 at the opening upon being compressed between the washtub 503 and the door 509.

[0003] Since the rotary drum 502 is extended horizontally or slants, the laundry and water is biased at a bottom of the drum when the drum is stopped. At this moment, upon the rotary drum 502 starting rotating, the laundry and water biased at the bottom may often produce vibration. After a washing process or a rinsing process is finished, the laundry contains therein a certain amount of water and is biased at the bottom of the rotary drum 502. Then, upon rotating at a high speed for removing the water from the laundry at a dewatering process, the rotary drum 502 may start vibrating and cause the washtub 503 fixedly connected via the motor 505 with the rotary drum 502 to produce excessive vibration. This vibration may produce abnormal vibration and noise on the washing machine 501

[0004] In the dewatering process, the rotary drum 502 spins at a speed within a wide range from a low speed to a high speed. When the laundry is unbalanced along the rotary axis 502A, the rotary drum 502 may deflect excessively depending on the rotation speed, accordingly striking against the washtub 502 and producing noise. Particularly in the case that the laundry is biased at a front portion of the drum along the rotary axis 502A, the rotary drum 502 may deflect greater than the case that the laundry is biased towards a rear portion of the drum.

[0005] A conventional drum type washing machine disclosed in JP2006-311884A includes a vibration sensor for detecting components of the vibration of the washtub 503 along different directions. When the laundry is excessively unbalanced, the rotary drum 502 vibrates so that the axis 502A traces a side surface of a conical shape having a vertex held by the motor 505. This washing machine detects the position of the laundry having a large weight according to the detected components of vibration, and determines whether the laundry is biased towards the front and unbalanced in the rotary drum 502.

[0006] In the washing machine 501, the frequency of the vibration of the rotary drum 502 varies depending on the weight of the rotary drum 502 including the laundry and the position of the laundry. If the frequency of the vibration of the rotary drum 502 is close to a resonant frequency of the washtub 503, the washtub unit 507 may vibrate excessively and produce noise. Water drops or splash may be produced during the washing process, the rinsing, process, and the dewatering process. The material of the elastic sealing member 541 is relatively rigid in order to produce a sealing pressure enough to be prevented from excessive compression to inhibit the water drops and the splash from passing between the elastic sealing member 541 and the door 509 during the washing process, the rinsing process, or the dewatering process. This rigid member may cause the vibration of the washtub 506 to propagate via the elastic sealing member 541 to the housing 506 and to cause the housing 506 to vibrate. If the frequency of the vibration is close to the resonant frequency of the housing 506, the housing 506 produces large vibration and affects the vibration of the washtub unit 507. In this case, the conventional drum type washing machine 501 shown in Fig. 7 may not determine accurately the unbalance of the laundry in the rotary drum 502 which largely affects other components.

SUMMARY OF THE INVENTION

[0007] A drum type washing machine includes a housing, a washtub unit accommodated in the housing, a damper for elastically supporting the washtub at a supporting position, a vibration sensor for detecting a vibration of the washtub. The washtub unit includes a washtub having an opening therein, a rotary drum accommodated in the washtub, and a motor fixed to a bottom of the washtub and joined to a bottom of the rotary drum for rotating the rotary drum about a rotary axis. The rotary drum is adapted to accommodate a laundry. The supporting position and a center of gravity of the washtub unit approximate to the motor from a center plane which passes a center of the washtub and which is perpendicular to the rotary axis. The supporting position is distanced farther from the motor along a horizontal direction than the center of gravity is. The vibration sensor outputs a first signal and a second signal corresponding to a component of vibration of a portion of the washtub along a first direction and a component of the vibration along a second direction perpendicular to the first direction, respectively. The portion of the washtub is between the center plane of the washtub and the opening of the washtub. A controller determines, based on the first and second signals output from the vibration sensor, whether or not the laundry is distributed in the rotary drum in a front unbalance in which the laundry is biased from the center plane towards the opening of the rotary drum, and whether or not the laundry is distributed in the rotary drum in a rear unbalance in which the laundry is biased from the center plane towards the bottom of the rotary drum.

[0008] The drum type washing machine enables to detect unbalance of a laundry even when the laundry is biased in the rotary drum towards a bottom of the rotary drum.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is a cross sectional view of a drum type washing machine according to an exemplary embodiment of the present invention,

Fig. 2 is a circuit block diagram of the drum type washing machine according to the embodiment.

Figs. 3A to 3C illustrate profiles of vibration of a washtub of the drum type washing machine according to the embodiment.

Fig. 4 is a profile of an amplitude of vibration of the drum type washing machine according to the embodiment.

Fig. 5 is a profile of the vibration of the drum type washing machine according to the embodiment.

Figs. 6A and 6B are flowcharts illustrating an operation of the drum type washing machine according to the embodiment.

Fig. 7 is a cross sectional view of a conventional drum type washing machine.

DETAIL DESCRIPTION OF PREFERRED EMBODIMENT

[0010] Fig. 1 is a cross sectional view of a drum type washing machine 1 according to an exemplary embodiment of the present invention. The washing machine 1 includes a housing 6 and a washtub unit 7 installed in the housing 6. The washtub unit 7 includes a washtub 3, a rotary drum 2 accommodated in the washtub 3, a bearing 68 fixed to the washtub 3, and a motor 5 fixed to the washtub 3. The motor 5 is connected via a rotary shaft 2B with the rotary drum 2 for rotating the rotary drum 2 about a rotary axis 2A. The rotary shaft 2B is supported by the bearing 68. The rotary drum 2 has a side wall 2E and a bottom 2F joined to the rotary shaft .2B to face the motor 5. The side wall 2E of the rotary drum 2 has a cylindrical shape extending along the rotary axis 2A The side wall 2E has a lot of apertures 2G provided therein. The rotary drum 2 has an opening 2C provided therein opposite to the bottom 2F. The opening 2C opens towards a front of the housing 6 and is located on the rotary axis 2A. The washtub 3 has an opening 3C provided therein. The opening 3C opens towards the front of the housing 6 and is located on the rotary axis 2A. The housing 6 has a loading/unloading opening 6C provided therein. The opening 6C opens towards the front and is located on the rotary axis 2A for loading and unloading a laundry to be washed in the rotary drum 2. The opening 2C, the opening 3C, and the loading/unloading opening 6C communicate with each other on the rotary axis 2A. The rotary axis 2A slants downwardly from the opening 2C to the bottom 2F of the rotary drum 2. The rotary axis 2A may extend horizontally. The washtub 3 has a side wall 3E and a bottom 3F facing the side wall 2E and the bottom 2F of the rotary drum 2, respectively. The opening 3C in the washtub 3 is located opposite to the bottom 3F. Since the motor 5 and the bearing 68 having large weights are located at the bottom 3F of the washtub 3, the center G1 of gravity of the washtub unit 7 is located close to a rear side or the motor 5 but not at the center C1 of the washtub unit 7, hence making the washtub unit 7 unstable. The washtub unit 7 or the washtub 3 is supported with an anti-vibration damper 70 at a supporting position Q1. The supporting position Q1 is opposite to the motor 5 about the center G1 of gravity along a horizontal direction 1H. More particularly, the supporting position Q1 is distanced farther along the horizontal direction 1H from the motor 5 than the center G1 of gravity is. A coil spring 71 is provided between a support fitting 75 fixed to an upper side of the washtub 3 and an upper side of the housing 6 for urging the washtub unit 7 (the washtub 3) towards a direction opposite to the motor 5. A coil spring 72 is provided below the supporting position Q1 of the anti-vibration damper 70 and between the rear side of the washtub unit 7 and the rear side of the housing 6. The coil spring 72 protects the washtub unit 7 from inclining to the rear side towards the motor 5. Thus, the washtub unit 7 is supported with a high anti-vibration capability with the anti-vibration damper 70 and the coil springs 71 and 72. A center plane S1 extending perpendicularly to the rotary axis 2A and passing on the center C1 of the washtub (the washtub unit 7) is defined. Along a direction 2H in which the rotary axis 2A extends, each of the supporting position Q1 of the anti-vibration damper 70 and the center of gravity G1 is located more rearward or closer to the motor 5 than the center plane S1 is. That is, the supporting position Q1 and the center G1 of gravity of the washtub unit 7 approximate to the motor 5 from the center plane S1 which passes the center C1 of the washtub 3 and which is perpendicular to the rotary axis 2A.

The distance L1 between the center plane S1 and the supporting position Q1 is greater than the distance L2 between the center plane S1 and the center of gravity G1. Along the horizontal direction 1H, the supporting position Q1 is not located rearward beyond the center G1 of gravity, that is, between the center G1 of gravity and the motor 5. However, the supporting position Q1 is located close to the center G1 of gravity along the horizontal direction 1H, hence suppressing vibration of the rear portion of the washtub unit 7. A vibration sensor 40 is located at a position 3G on the washtub 3 between the opening 3C and the center plane S1 of the washtub 3 for detecting components of the vibration at the position 3G along different directions perpendicular to each other.

[0011] A door 9 is provided at the loading/unloading opening 6C in the housing 6. An elastic sealing member 41 is provided at the loading/unloading opening 6C of the housing 6. When the door 9 is opened, the laundry to be washed is loaded into and unloaded from the rotary drum 2 through the opening 3C in the washtub 3, the opening 2C in the rotary drum 2, and the loading/unloading opening 6C in the housing 3. The elastic sealing member 41 is made of elastic material, such as rubber, for sealing between the door 9 and the washtub 3 at the opening 3C while being compressed between the door 9 and the washtub 3 at the opening 3C.

[0012] Fig. 2 is a circuit diagram of the drum type washing machine 1. The drum type washing machine 1 includes a blower fan 17 for blowing hot air into the rotary drum 2 and heaters 18 and 19 generating the hot air, thus having a dryer function. A controller 20 monitors an operation of each component and the entry of a command from a user and controlling a series of operations performed by the washing machine 1. The operations include a washing process for washing the laundry, a rinsing process for rinsing the washed laundry, a dewatering process for removing water from the rinsed laundry, and a drying process for drying the dewatered laundry.

[0013] An alternating-current power 31 is rectified by a rectifier 32 and smoothed by a smoothing circuit including mainly a chalk coil 33 and a smoothing capacitor 34, thus producing a direct-current (DC) power. The DC power drives the motor 5 via an inverter 26, thereby allowing the motor to rotate. The controller 20, according to a command input from an input unit 21 and an operation status detected by sensors, controls the rotation of the motor 5 and operations of loads, such as a water supply valve 64, a water drain valve 13, the blowing fan 17, the heaters 18 and 19 and other components, by directing a load driver 37

[0014] The motor 5 is a DC brushless motor including a stator having three-phase wirings 5A, 5B, and 5C, a rotor having two-pole permanent magnet, and three position sensors 24A, 24B, and 24C for detecting the position of the rotor. The inverter 26 includes switching elements 26A to 26F for driving the motor 5 by a pulse-width modulation (PWM) method. The position sensors 24A to 24C produce signals indicating the position of the rotor, and transmit the signals to the controller 20 directing a driver 25 to turn on and off the switching elements 26A to 26F to energize the three-phase wirings 5A to 5C of the stator under control by the PWM method, thereby allowing the rotor to rotate at a predetermined rotation speed. The controller 20 includes a rotation speed detector 24. Every time when one of the signals output from the position sensors 24A to 24C changes, the rotation speed detector 24 measures the period of the changing signal, and calculates the rotation speed of the rotor based on the period.

[0015] Since the rotary axis 2A of the rotary drum 2 extends horizontally or slants, the laundry and water in the rotary drum 2 may be biased downward while the rotary drum 2 rotates. The washtub 3 supporting the rotary drum 2 is supported by the elastic anti-vibration damper 70 and the coil springs 71 and 77 to the housing 6, and can easily vibrate when the rotary drum 2 rotates. In the dewatering process, the rotary drum 2 rotates at a higher speed ranging from 1000 rpm to 1600 rpm to remove water from the laundry. In the dewatering process, the laundry containing water after the washing process or the rinsing process and having a large weight may be aggregated unevenly in the rotary drum 2. In the case that the laundry is biased, the washtub 3 supporting the rotary drum 2 produces large vibration, thus providing the washing machine 1 with abnormal vibration and noise. The elastic sealing member 41 sealing between the door 9 and the washtub unit 7 (the washtub 3) is pushed by a significant sealing pressure against the door 9 and the washtub 3 to prevent water drops or splash from entering from between the door 9 and the washtub 3. The elastic sealing member 41 is made of relatively rigid, elastic material. This material allows the vibration produced by the washtub unit 7 (the washtub 3) to propagate to the housing 6 more via the elastic sealing member 41 than via the anti-vibration damper 70. Accordingly, the housing 6 may resonate with the vibration of the washtub 3.

[0016] The conventional drum type washing machine 501 shown in Fig. 7 detects that the rotary drum 502 contacts the washtub 503. When the resonant vibration on the washtub 503 caused by the vibration of the rotary drum 502 is at a primary resonant rotation speed of about 120 rpm, at a secondary resonant rotation speed of about 250 rpm, or at a higher rotation speed exceeding 1000 rpm, the washtub unit 507 itself vibrates severely. An abnormal noise produced by such severe vibration of the washtub unit 507 is not eliminated by detecting only the direct contact between the rotary drum 502 and the washtub 503. In order to suppress the abnormal noise, the washer necessarily detects front unbalance in which the laundry concentrates at the front portion in the rotary drum 502 and rear unbalance in which the laundry concentrates at the rear portion in the rotary drum 502. The behavior of the rotary drum 502 during the vibration may be different from that of the washtub 503 regardless of the position of the biased laundry. This may damage the motor 505 joined to the rotary drum 502 and the washtub 502.

[0017] In the drum type washing machine 1 according to the embodiment, the center plane S1 extending perpendicularly to the rotary axis 2A of the washtub 3 and passing on the center C1 on the rotary axis 2A is defined. The center G1 of gravity of the washtub unit 7 is spaced by the distance L2 from the center plane S1 and is located closer to the motor 5 than the center plane S1 is. The supporting position Q1 of the supporting damper 70 is spaced by the distance L1 from the center plane S1 and is located closer to the motor 5 than the center plane S1 is. The supporting position Q1 is more forward along the horizontal direction 1H than the center G1 of gravity is. Under those conditions, the vibration at the bottom 3F of the washtub 3 is correlated closely with the vibration on the front portion at the opening 3C of the washtub 3. The vibration sensor 40 produces and releases a signal indicating amplitudes of components along different directions of the vibration at the front portion of the washtub 3. Based on the amplitude of the vibration, the controller 20 determines whether the laundry is biased frontward from the center plane S1 towards the opening 3C or rearward from the center plane S1 towards the bottom 3F and the motor 5.

[0018] As shown in Fig. 1, the vibration sensor 40 produces signals corresponding to a displacement S_{FFR}, a displacement S_{FLR}, and a displacement S_{FUD} of the front portion of the washtub 3 due to vibration of the washtub 3, respectively. The displacement S_{FFR} of the washtub 3 is along a frontward and rearward direction FR parallel with the rotary axis 2A. The displacement S_{FLR} of the washtub 3 is along a leftward and rightward direction LR perpendicular to the rotary axis 2A and parallel with a horizontal direction 3H. The displacement S_{FUD} of the washtub 3 is along an upward and downward direction UD perpendicular to the rotary axis 2A and parallel with a vertical direction 1V. The vibration sensor 40 according to this embodiment may be implemented by a 3D acceleration sensor detecting components of acceleration, however, may detect components of a speed or a displacement. The vibration sensor 40 may not necessarily detect one of the displacement S_{FLR} along the leftward and rightward direction LR and the displacement S_{FUD} along the upward and downward direction UD of the washtub 3 at the point 3G

[0019] Fig. 3A illustrates the displacements S_{FFR}, S_{FLR}, and S_{FUD} of the washtub 3 and respective amplitudes A_{FFR}, A_{FLR}, and A_{FUD} of the displacements S_{FFR}, S_{FLR}, and S_{FUD} detected by the vibration sensor 40 when the laundry weighing 500g is distributed in the front unbalance in which the laundry is biased from the center plane S1 towards the opening 3C of the washtub 3. Fig. 3B illustrates the displacements S_{FFR}, S_{FLR}, and S_{FUD} of the washtub 3 and respective amplitudes A_{FFR}, A_{FLR}, and A_{FUD} of the displacements S_{FFR}, S_{FLR}, and S_{FUD} detected by the vibration sensor 40 when the laundry weighing 500g is distributed in the rear unbalance in which the laundry is biased from the center plane S1 towards the bottom 3F of the washtub 3. Fig. 3C illustrates the displacements S_{FFR}, S_{FLR}, and S_{FUD} of the washtub 3 and respective amplitudes A_{FFR}, A_{FLR}, and A_{FUD} of the displacements S_{FFR}, S_{FLR}, and S_{FUD} detected by the vibration sensor 40 when the laundry weighing 500g is distributed in center unbalance in which the laundry is biased at the center plane S1. The displacements S_{FFR}, S_{FLR}, S_{FUD} and the amplitudes A_{FFR}, A_{FLR}, and A_{FUD} illustrated are actually obtained as signals, such as voltages or currents.

[0020] As shown in Figs. 3A to 3C, the front unbalance, the rear unbalance, and the center unbalance are correlated with the amplitudes A_{FFR}, A_{FLR}, and A_{FUD}. The amplitudes A_{FLR} and A_{FUD} at the rear unbalance shown in Fig. 3B are smaller to the amplitudes A_{FLR} and A_{FUD} at the front unbalance shown in Fig. 3A. The amplitude A_{FLR} at the center unbalance shown in Fig. 3C is between the amplitude A_{FLR} at the front unbalance shown in Fig. 3A and the amplitude A_{FLR} at the rear unbalance shown in Fig. 3B. The amplitude A_{FUD} at the center unbalance shown in Fig. 3C is between the amplitude A_{FUD} at the front unbalance shown in Fig. 3A and the amplitude A_{FUD} at the rear unbalance shown in Fig. 3B. The amplitude A_{FFR} at the front unbalance shown in Fig. 3A is smaller than the amplitudes A_{FLR} and A_{FUD} at the front unbalance shown in Fig. 3A. The amplitude A_{FFR} at the rear unbalance shown in Fig. 3B is greater than the amplitudes A_{FLR} and A_{FUD} at the rear unbalance shown in Fig. 3B. The amplitude A_{FFR} at the center unbalance shown in Fig. 3C is smaller than the amplitude A_{FFR} at the front unbalance shown in Fig. 3A and the amplitude A_{FFR} at the rear unbalance shown in Fig. 3B. The amplitude A_{FFR} at the rear unbalance shown in Fig. 3B is substantially identical to the amplitude A_{FFR} at the front unbalance shown in Fig. 3A. Thus, the front unbalance, the rear unbalance, and the center unbalance which the laundry is biased in are correlated with the amplitudes A_{FFR}, A_{FLR}, and A_{FUD} and the rising rates, the periods, and the phases of the displacements S_{FFR}, S_{FLR}, and S_{FUD}. The component (the displacement S_{FLR}) of the vibration along the direction LR and the component (the displacement SFLR) of the vibration along the direction LR at the front portion of the washtub 3 are perpendicular to the rotary axis 2A, and are different only in the gravity, hence being similar to each other since the rotation of the rotary drum 2 affects equally. The displacement S_{FLR}, the component of the vibration at the front portion of the washtub 3 along the direction LR varies in advance of the displacement S_{FFR}, the component of the vibration along the direction FR. That is, the phase of the displacement S_{FLR} is advanced of the phase of the displacement S_{FFR}.

[0021] In the case that there is a significant unbalance of the weight of the laundry, the rotary drum 2 may vibrate while the rotary axis 2A tracing a side surface of a conical shape having a vertex held at the motor 5. Even when the vibration of the rotary drum 2 is large, the amplitude of the vibration at a position close to the motor 5 is small, hence not causing the position to contact the washtub 3. However, the motor 5, upon vibrating, may cause the washtub 3 to vibrate entirely along the wash tab 3 including the front portion since the motor 5 has a large weight. The front portion and the rear portion of washtub unit 7 are different from each other in behavior of the vibration and the resonant vibration. Thus, depending on the status of the unbalance of the laundry, the vibration on the washtub unit 7 may be affected by not only the vibration at the front portion of the washtub 3 but also the vibration at the rear portion of the washtub 3 close to the bottom 3F, and may produce abnormal noise.

[0022] The displacements S_{FFR}, S_{FLR}, and S_{FUD} of the washtub 3 are the components of the vibration along the three different directions at the front portion of the washtub 3. The front portion of the washtub 3 is closer to the opening 3C than the center plane S1 is. The displacements S_{FFP}, S_{FLR}, and S_{FUD} are detected by the vibration sensor 40 and are correlated with the components of the vibration along the three directions at the rear portion of the washtub 3. The rear portion of the washtub 3 is closer to the bottom 3F than the center plane S1 is. Fig. 4 illustrates the amplitudes A_{FLR} and A_{FFR} of the vibration on the washtub 3 and the amplitude A_{RLR} of the vibration along the direction LR at the rear portion close to the bottom 3F of the washtub 3 when the laundry is biased in the rear unbalance in which the laundry is biased from the center plane S1 towards the bottom 3F of the washtub 3. As shown in Fig. 4, the amplitude A_{FFR} of the vibration at the front portion along the frontward and rearward direction FR is very similar to the amplitude A_{RLR} of the vibration at the rear portion along the left and right direction LR. The sensor 40 detects the amplitude A_{FFR} of the vibration at the front portion along the frontward and rearward direction, and the controller 20 can estimate the amplitude A_{RLR} of the vibration at the rear portion along the left and right direction LR based on the amplitude A_{FFR}. The vibration sensor 40 is located at the front portion and closer to the opening 3C than the center plane S1 is, and outputs signals accurately indicating the vibration at the front portion of the washtub 3.

[0023] An operation action of the drum type washing machine 1 determining, based on the vibration at the front portion of the washtub 3, whether the distribution of the laundry in the rotary drum 2 is distributed in the front unbalance or in the rear unbalance will be described below. The vibration sensor 40 outputs a signal indicating a component of the vibration along the frontward and rearward direction FR parallel with the rotary axis 2A of the rotary drum 2, and outputs a signal indicating a component of the vibration along the leftward and rightward direction LR perpendicular to the rotary axis 2A of the rotary drum 2 and in parallel with the horizontal direction 3H out of the components of the vibration of the front portion of the washtub 3 along the different directions. The controller 20 extracts, from the signals, the displacement S_{FLR} along the leftward and rightward direction LR at the front portion of the washtub 3 and the displacement S_{FFR} along the frontward and rearward direction FR at the front portion of the washtub 3. Fig. 5 illustrates the displacement S_{FLR} along the leftward and rightward direction LR and the displacement S_{FFR} along the frontward and rearward direction FR.

[0024] As described above, the displacement S_{FLR} along the leftward and rightward direction LR varies in advance of the displacement S_{FFR} along the frontward and rearward direction FR. When the displacement S_{FLR} along the leftward and rightward direction LR does not reach a predetermined reference level B1, that is, when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the reference level B1, the controller 20 determines that the laundry is not distributed in the front unbalance or the rear unbalance. When the displacement S_{FLR} along the leftward and rightward direction LR reaches the predetermined reference level B1, that is when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than the reference level B1, the controller 20 determines that the laundry is distributed in either the front unbalance or the rear unbalance.

[0025] In the case that the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than the reference level B1, when an increase ΔB of the displacement S_{FFR} along the frontward and rearward direction FR during a predetermined duration ΔT from a time point P at which the displacement S_{FFR} increases from a level smaller than the reference level B1 to the reference level B1 is equal to or larger than a predetermined value B2, the controller 20 determines that the laundry is distributed in the front unbalance. When the increase ΔB is smaller than the value B2, the controller 20 determines that the laundry is distributed in the rear unbalance.

[0026] Alternatively, in the case that the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than the reference level B1, when an increasing rate $\Delta B/\Delta T$, the ratio of the increase ΔB to the predetermined duration ΔT is equal to or larger than a predetermined value B3, the controller 20 determines that the laundry is distributed in the front unbalance. When the increasing rate $\Delta B/\Delta T$ is smaller than the value B3, the controller 20 determines that the laundry is distributed in the rear unbalance.

[0027] An operation of the drum type washing machine 1 determining, from the vibration at the front portion of the washtub 3, whether the distribution of the laundry in the rotary drum 2 is excessively biased in an excessive front unbalance or an excessive rear unbalance will be described below. The laundry is biased more at the front portion of the washtub 3, that is, more from the center plane S1 towards the opening 3C of the washtub 3 in the excessive front unbalance than in the front unbalance. Similarly, the laundry is biased more at the rear portion of the washtub3, that is, more from the center plane S1 towards the bottom 3F of the washtub 3 in the excessive rear unbalance than in the rear unbalance. Upon determining that the laundry is distributed in the front unbalance in the above method, the controller 20 determines that the laundry is distributed in an excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a predetermined threshold A1. Upon determining that the laundry is distributed in the front unbalance, the controller 20 determines that the laundry is distributed in the front unbalance but not in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the threshold A1. The predetermined threshold A1 for determining whether or not the laundry is distributed in the excessive from unbalance is larger than the predetermined reference level B1 for determining whether or not the laundry is distributed in either the front unbalance or the rear unbalance. Similarly, upon determining that the laundry is distributed in the rear unbalance by the above method, the controller 20 determines that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is equal to or larger than a predetermined threshold A2. Upon determining that the laundry is distributed in the rear unbalance by the above method, the controller 20 determines that the laundry is distributed in the rear unbalance but not in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is smaller than the threshold A2. When the laundry is distributed in the excessive front unbalance or in the excessive rear unbalance, the controller 20 directs the rotary drum 2 to rotate to distribute the laundry evenly in the rotary drum 2 or to stop the rotation of the rotary drum 2, and notifies the user that the laundry is excessively biased in the rotary drum 2. Vibration in the excessive rear unbalance affects the washtub unit 7, particularly, the motor 5 and the hearing 68 more than vibration in the excessive front unbalance. Therefore, the predetermined threshold A2 for examining whether or not the laundry is distributed in the excessive rear unbalance is determined to be smaller than the predetermined threshold A1 for examining whether or not the laundry is distributed in the excessive front unbalance.

[0028] Based on the signals output from the vibration sensor 40 detecting the vibration at the front portion of the washtub 3, the controller 20 determines that the laundry is distributed neither in the front unbalance nor in the rear unbalance when the amplitude A_{FLR} of the displacement S_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the predetermined reference level B1. That is, the controller 20 may not necessarily determine, from the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR and the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR, whether or not the laundry is distributed in the excessive front unbalance or in the excessive rear unbalance. In this case, the controller may not necessarily determine, from the displacement S_{FFR} along the frontward and rearward direction FR, whether or not the laundry is either in the front unbalance or in the rear unbalance. Further, the controller 20 may not necessarily even detect the displacement S_{FFR}.

[0029] In the drum type washing machine 1 according to the embodiment, the reference level B1 for determining whether the laundry is distributed in the front unbalance or the rear unbalance is equal to or larger than 15mm while the duration ΔT for determining whether or not the laundry is distributed in the rear unbalance is 2 seconds, and the reference B2 is equal to or larger than 1 mm. The predetermined threshold A1 for determining whether or not the laundry is distributed in the excessive front unbalance is 25 mm while the predetermined threshold A2 for determining whether or not the laundry is distributed in the excessive rear unbalance is 20 mm. However, these values are not limited to the above described values.

[0030] The controller 20 stores the threshold A1 and the threshold A2 smaller than the threshold A1. Alternatively, the controller 20 may store the threshold A1 and a predetermined difference A3 to use, as the threshold A2, a value provided by subtracting the difference A3 from the threshold A1 so as to determine whether or not the laundry is distributed in the excessive rear unbalance. This operation can modify the threshold A2 following the threshold A1. Alternatively, in order to detect the excessive rear unbalance, the controller 20 may calculate the sum of the amplitude AFFR along the frontward and the rearward direction FR and the predetermined difference A3. The controller 20 may determine that the laundry is distributed in the excessive rear unbalance when the sum is equal to or larger than the threshold A1, and determine that the laundry is not distributed in the excessive rear unbalance when the sum is smaller than the threshold A1.

[0031] Alternatively, the controller 20 may determine that the laundry is distributed in the front unbalance when the amplitude A_{FLR} of the displacement S_{FLR} at the front portion of the washtub 3 along the leftward and rightward direction LR is smaller than the reference B1. Since the displacement S_{FLR} is detected in advance of the displacement S^{FFR} along the frontward and rearward direction RR, the laundry is not in neither the front unbalance nor the rear unbalance when the amplitude A_{FLR} is smaller than the reference level B1, thus not producing abnormal vibration.

[0032] When the amount of the laundry is small, the laundry tends towards the bottom 2F of the rotary drum 2. In this case, the laundry tends to be biased to the rear portion from the center plane 1 towards the bottom 3F of the washtub 3, that is, distributed in the rear unbalance. In the case that the amount of the laundry is smaller than a predetermined amount, when the amplitude A_{FLR} along the leftward and right direction LR is equal to or larger than the reference level B1, the controller 20 may determine that the laundry is distributed in the rear unbalance but not that the laundry is distributed in either the front unbalance or the rear unbalance. This operation allows the controller 20 to quickly determine whether or not the laundry is distributed in the excessive rear unbalance while the controller does not determine that the laundry is distributed in the excessive front unbalance. Since the amount of the laundry is correlated with the load on the rotation of the rotary drum 2, a current flowing from the inverter 26 to the motor 5 at the startup of the rotation of the rotary drum 2 varies depending on the amount of the laundry. The more the amount of the laundry, the greater the current flows. A current detector 29 detects the current in the inverter 26 based on a voltage between both ends of a resistor 28 connected in series to the inverter 26. The controller 20 can thus determine the amount of the laundry based on the detected current.

[0033] The controller 20 increases the rotation speed of the rotary drum 2 towards a target rotation speed until the controller determines that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance. Upon determining that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance before the rotation speed of the rotary drum 2 is increased to the target speed, if the rotation speed of the rotary drum 2 is lower than a reference rotation speed which is lower than the target speed, the controller 20 temporarily decreases the rotation speed of the rotary drum 2 or stops the rotation of the rotary drum 2. Then, the controller 20 controls the motor 5 to rotate the rotary drum 2 by an angle smaller than a half turn, to rotate the rotary drum 2 in a reverse direction by an angle smaller than one turn, and to rotate the rotary drum 2 in the previous direction by an angle smaller than one turn, thus repeating to arcuately rotating the drum. Thereby, the controller 20 eliminates the excessive unbalance in which the laundry is excessively biased. Then, the controller 20 increases again the rotation speed of the rotary drum 2 towards the target rotation speed. Thus, the controller 20 finishes the dewatering process without suffering from the excessive unbalance. Alternatively, the controller 20 may increase the rotation speed of the rotary drum 2 after eliminating the excessive unbalance, and maintain the rotation speed of the drum at the reference rotation speed once the rotation speed of the drum reaches the reference rotation speed. In this case, the controller 20 rotates the rotary drum 2 for a duration longer than a duration for which the controller rotates the rotary drum 2 at the target rotation speed. This operation allows the controller 20 to complete the dewatering process without suffering from the excessive unbalance although the reference rotation speed is lower than the target rotation speed. The reference rotation speed is determined to protect the washing machine 1 from damage even when the controller 20 determines that the laundry is distributed in the excessive unbalance. The reference rotation speed according to the embodiment ranges from about 880 rpm to 900 rpm.

[0034] As described, the controller 20 of the drum type washing machine 1 determines, from the vibration at the front portion of the washtub 3, whether the laundry in the rotary drum 2 is distributed in the front unbalance or the rear unbalance without detecting the vibration at the rear portion of the washtub 3 from the center plane S1 to the bottom 3F.

[0035] An operation of the drum type washing machine 1 executing the dewatering process to remove water from the laundry will be described below. Figs. 6A and 6B are flowcharts illustrating an operation of the rotary drum 2 during the dewatering process. The washtub 3 resonates when the rotation speed of the rotary drum 2 is a primary resonant rotation speed and a secondary resonant rotation speed. According to this embodiment, the primary resonant rotation speed is 120 rpm, and the secondary resonant speed is 240 rpm, while they are not limited to these speeds. The target rotation speed of the rotary drum 2 is the maximum rotation speed, e.g. 1600rpm according to the embodiment, but is not limited to this.

[0036] Upon starting the dewatering process, the controller 20 sets a number N for counting the number of occurrences of the excessive unbalance of laundry to initialize the number N to "1" (N=1) (Step 100). Then, the washtub 3 is drained (Step 101), and an untangling process to untangle the laundry in the rotary tub 2 is executed (Step 102). In the untangling process, the controller 20 controls the motor 5 to rotate the rotary drum 2 at a predetermined untangling speed (e.g. 40 rpm) by an angle larger than 90 degrees and smaller than 180 degrees so as to lift the laundry up to an angular position larger than 90 degrees and smaller than 180 degrees, and stops the rotation abruptly. Then, the controller 20 rotates the rotary drum 2 at the untangling speed in a reverse direction by an angle smaller than one turn so as to lift the laundry up to an angular position larger than 90 degrees and smaller than 180 degrees, and stops the rotation abruptly. The controller 20 further rotates the rotary drum 2 by the untangling speed in the previous direction by an angle smaller than one turn so as to lift the laundry up to an angular position larger than 90 degrees and smaller than 180 degrees, and stops the rotation abruptly, thus repetitively rotating the drum arcuately. This operation applies a large inertia force to the laundry attached onto the side wall 2E of the rotary drum 2, removes the laundry from the side wall of the rotary drum 2, and drops the laundry in a direction opposite to the direction in which the laundry is lifted up. This operation untangles the removed laundry while moving the laundry along the arcuate rotation in opposite directions, and distributes the laundry uniformly in all the frontward, rearward, leftward, and rightward directions in the rotary drum 2.

[0037] Then, the controller 20 increases moderately the rotation speed of the rotary drum 2 to such a predetermined speed (e.g. 70 rpm) that the laundry is attached onto an inner surface of the rotary drum 2 (Step 103). Then, the controller 20 further increases the rotation speed of the rotary drum 2 to a first predetermined rotation speed (e.g. 80 rpm) lower than the first resonant rotation speed of the washtub unit 7, and maintains the first rotation speed (Step 104A). The controller 20 determines whether or not the laundry is distributed in the excessive unbalance (Step 104B). At this moment, the controller 20 determines whether or not the laundry is distributed in the excessive unbalance only based on the displacement S_{FLR} of the washtub 3 along the leftward and rightward direction LR which represents both the front unbalance and the rear unbalance while the controller 20 does not determine it based on the displacement S_{FFR} of the washtub 3 along the frontward and rearward direction FR. In particularly, the controller 20 determines that the laundry is distributed in unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a threshold A11, and does not determine that the laundry is distributed in unbalance when the amplitude is smaller than the threshold A11. The threshold A11 is larger than the threshold A1, and is 40 mm according to this embodiment. When the laundry is distributed in the excessive unbalance, the rotation speed of the rotary drum 2 is not constant and varies unstably. The controller 20 may determine that the laundry is distributed in the excessive the unbalance at Step 104B when the position sensors 24A, 24B, and 24C does not output the signals at predetermined intervals, instead of comparing the amplitude A_{FLR} with the threshold A11.

[0038] If the controller 20 determines at Step 104B that the laundry is distributed in the excessive unbalance, the controller 20 determines whether the number N is equal to or more than four (Step 105). Upon determining at Step 105 that the number N is smaller than four, the controller 20 temporarily stops the rotation of the rotary drum 2 (Step 106). Then, the controller increments the number N by 1 (Step 107), and executes the untangling process at Step 102.

[0039] If the number N is equal to or more than four at Step 105, the controller 20 determines that the untangling process at Step 102 fails to eliminate the excessive unbalance of the laundry, and determines whether or not the number N is equal to or more than 10. When judging at Step 108 that the number N is smaller than 10, the controller 20 supplies water to the rotary drum 2 to eliminate the excessive unbalance of the laundry (Step 110). In the process at Step 110, similar to the process at Step 102, the controller 20 controls the motor 5 to rotate the rotary drum 2 at a predetermined untangling speed (e.g. 40 rpm) by an angle larger than 90 degrees and smaller than 180 degrees so as to lift the laundry up to an angular position larger than 90 degrees and smaller than 180 degrees and stops the rotation abruptly. Then, the controller 20 rotates the rotary drum 2 in a reverse direction by an angle smaller than one turn so as to lift the laundry up to an angular larger than 90 degrees and smaller than 180 degrees, and stops the rotation abruptly. The controller 20 further rotates the drum 2 in the previous direction by an angle smaller than one turn so as to lift the laundry up to an angular position lager than 90 degrees and smaller than 180 degrees and stops the rotation abruptly, thus repetitively rotating the drum arcuately. This operation applies a larger inertia force to the laundry attached onto the side wall 2E of the rotary drum 2, removes the laundry from the side wall of the rotary drum 2, and drops the laundry in a direction opposite to the direction in which the laundry is lifted up. This operation untangles the removed laundry while moving the laundry along the arcuate rotation in opposite directions, and distributes the laundry uniformly in all the frontward, rearward, leftward, and rightward directions in the rotary drum 2.

[0040] If the number N is 10 at Step 108, the controller 20 determines that the unbalance of the laundry is not eliminated, and indicating the excessive unbalance while stopping the operation of the drum type washing machine 1 (Step 109).

[0041] If the controller 20 does not determine, for a predetermined period of time, at Step 104B that the laundry is the excessive unbalance, the controller 20 controls the motor 5 to increase the rotation speed of the rotary drum 2 to the primary resonant rotation speed (e.g. equivalent to 120Hz) of the washtub unit 7, and maintain the resonant rotation speed for a predetermined period of time (Step 111A). At Step 111A, the controller 20 may conduct rotate the rotary drum 2 at a rotation speed (e.g. ranging from 120 rpm to 140 rpm) which is close to the primary resonant rotation speed. While the rotary drum 2 rotates at the above speed, the controller 20 determines the front unbalance and the rear unbalance of the laundry based on the displacements S_{FLR} and S_{FFR} and the amplitudes A_{FLR} and A_{FFR} of the vibration at the front portion of the washtub 3, the reference level B1, and the increase ΔB by the above method. The controller 20 further determines the front excessive unbalance and the excessive rear unbalance of the laundry (Step 111B). Alternatively, in order to determine at Step 111B whether the laundry is distributed in either the front unbalance or the rear unbalance, the controller 20 may determine that the laundry is distributed in the front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR, and determines that the laundry is distributed in the rear unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR, instead of the method shown in Fig. 5 employing the increase ΔB of the displacement S_{FFR}. At Step 111B, the controller 20 determines that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a threshold A12, and does not determine that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the threshold A12. Similarly, the controller 20 determines at Step 111B that the laundry is in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is equal to or larger than a threshold A22, and does not determine that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is smaller than the threshold A22. In general, vibration, particularly the component of the vibration along the leftward and rightward direction LR having a frequency close to the primary resonant rotation speed of the washtub unit 7 is larger than vibration having a frequency close to the secondary resonant rotation speed. In this respect, the threshold A12 at Step 111B is set to 40 mm which is larger than the threshold A1 (25 mm). The threshold A22 is set to a level smaller than 24 mm.

[0042] If the controller 20 determines at Step 111B that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance, the controller 20 examines at Step 105 whether or not the number N is equal to or greater than four. Then, the controller 20 may execute the untangling process at Step 102, or may eliminate the excessive unbalance at Step 110, or may stop the operation of the drum type washing machine 1 at Step 109.

[0043] If the controller 20 does not determine, for a predetermined period of time at Step 111B, that the laundry is distributed in either the excessive front unbalance or the excessive rear unbalance, the controller 20 controls the motor 5 to increase the rotation speed of the rotary drum 2 to the secondary resonant rotation speed (e.g. equivalent to 240 Hz) of the washtub unit 7 and to maintain the resonant rotation speed for a predetermined period of time (Step 112A). At Step 112A, the controller 20 may rotate the rotary drum 2 at a rotation speed (e.g. ranging from 141 rpm to 330 rpm) which is higher than the speed at Step 111B and is close to the secondary resonant rotation speed. While rotating the rotary drum 2 at the above rotation speed, the controller 20 examines the front unbalance and the rear unbalance of the laundry based on the displacements S_{FLR} and S_{FFR} and the amplitudes A_{FLR} and A_{FFR} of the vibration on the front portion of the washtub 3, the reference level B1, and the increase ΔB by the above method. Then, the controller 20 determines whether or not the laundry is distributed in the excessive front unbalance or the excessive rear unbalance (Step 112B). At Step 112B, the controller 20 determines that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a threshold A13, and does not determine that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} is smaller than the threshold A13. Similarly, the controller 20 determines at Step 112B that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is equal to or larger than a threshold A23, and does not determine that the laundry is in the excessive rear unbalance when the amplitude A_{FFR} is smaller than the threshold A23. The threshold A13 at Step 112B is set to 25 mm which is equal to the threshold A1. The threshold A23 is set to 20 mm which is equal to the threshold A2.

[0044] If the controller 20 determines at Step 112B that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance, the controller 20 examines at Step 105 whether or not the count N is equal to or greater than four. Then, as described above, the controller 20 executes the untangling process at Step 102, or eliminates the excessive unbalance the action of Step 110, or stops the operation of the drum type washing machine 1 at Step 109.

[0045] If the controller 20 does not determine, for a predetermined period of time at Step 112B, that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance, the controller 20 controls the motor 5 to rotate the rotary drum 2 at a reference rotation speed (e.g. ranging from 880 rpm to 900 rpm) which is higher than the rotation speeds at Steps 112A and 112B for a predetermined period of time (Step 113A). While rotating the rotary drum 2 at the above reference rotation speed, the controller 20 examines the front unbalance and the rear unbalance of the laundry based on the displacements S_{FLR} and S_{FFR} and the amplitudes A_{FLR} and A_{FFR} of the vibration on the front portion of the washtub 3, the reference level B1, and the increase ΔB by the above method. Then, the controller 20 determines whether or not the laundry is distributed in the excessive unbalance or the excessive rear unbalance (Step 113B). At Step 113B, the controller 20 determines that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a threshold A14, and does not determine that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} is smaller than the threshold A14. Similarly, the controller 20 determines at Step 113B that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is equal to or larger than a threshold A24, and determines that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} is smaller than the threshold A24. The thresholds A14 and A24 at Step 113B are set to be equal to the thresholds A13 and A23 at Step 112B, respectively.

[0046] If the controller 20 determines at Step 113B that the laundry is distributed in the front excessive unbalance or the excessive rear unbalance, the controller 20 examines at Step 105 whether or not the number N is equal to or greater than four. Then, the controller 20 executes the untangling process at Step 102, or eliminates the excessive unbalance at Step 110, or stops the operation of the drum type washing machine 1 at Step 109.

[0047] If the controller 20 does not determine for a predetermined period of time at Step 113B that the laundry is distributed in the excessive front unbalance or the excessive unbalance, the controller 20 controls the motor 5 to increase the rotation speed of the rotary drum 2 from the reference rotation speed towards a target rotation speed (e.g. 1600 rpm) which is the maximum rotation speed of the drum 2 (Step 114A). While the rotary drum 2 rotates at the rotation speed at Step 114A, the controller 20 examines the front unbalance and the rear unbalance of the laundry based on the displacements S_{FLR} and S_{FFR} and the amplitudes A_{FLR} and A_{FFR} of the vibration at the front portion of the washtub 3, the reference level B1, and the increase ΔB by the above method. Then, the controller 20 determines that whether or not the laundry is distributed in the excessive front unbalance or the excessive rear unbalance (Step 114B). At Step 114B, the controller 20 determines that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than a threshold A15, and does not determine that the laundry is distributed in the excessive front unbalance when the amplitude A_{FLR} is smaller than the threshold A15. Similarly, the controller 20 determines at Step 114B that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR is equal to or larger than a threshold A25, and does not determine that the laundry is distributed in the excessive rear unbalance when the amplitude A_{FFR} is smaller than the threshold A25. Since the rotation speed of the rotary drum 2 is high at Step 114B, the controller 20 sets the threshold A15 to 12 mm which is smaller than the threshold A14 due to physical strength of the washtub unit 7, and decreases the threshold A14 as the rotation speed increases. Similarly, the controller 20 sets the threshold A25 to 10 mm which is smaller than the thresholds A24 and A15, and decreases the threshold A25 as the rotation speed increases. Alternatively, in order to determine at Step 114B whether or not the laundry is distributed in the front unbalance or the rear unbalance, the controller 20 may determine that the laundry is distributed in the front unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is equal to or larger than the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR, and determine that the laundry is distributed in the rear unbalance when the amplitude A_{FLR} of the vibration along the leftward and rightward direction LR is smaller than the amplitude A_{FFR} of the vibration along the frontward and rearward direction FR, instead of the method shown in Fig. 5 employing the increase ΔB of the displacement S_{FFR}.

[0048] If the controller 20 does not determine at Step 114B that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance, the controller 20 determines whether or not the rotation speed of the rotary drum 2 reaches the target rotation speed (Step 115).

[0049] If the controller 20 determines at Step 115 that the rotation speed of the rotary drum 2 reaches the target rotation speed, the controller 20 maintain the rotation action of the rotary drum 2 at the target rotation speed for a predetermined period of time (Step 116A), and stops the rotation of the rotary drum 2 (Step 117) to terminate the dewatering process. If the controller 20 does not determine at Step 115 that the rotation speed of the rotary drum 2 reaches the target rotation speed, the controller 20 controls the motor 5 to increase the rotation speed of the rotary drum 2 towards the target rotation speed. While the rotary drum 2 rotates at Step 114B, the controller 20 examines the front unbalance and the rear unbalance of the laundry based on the displacements S_{FLR} and S_{FFR} and the amplitudes A_{FLR} and A_{FFR} of the vibration at the front portion of the washtub 3, the reference level B1, and the increase ΔB by the above method. Then, the controller 20 determines whether or not the laundry is distributed in the excessive front unbalance and the excessive rear unbalance.

[0050] If the controller 20 determines at Step 114B that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance, the controller 20 maintain the rotation action of the rotary drum 2 for a predetermined period of time at the rotation speed (which is higher than the reference rotation speed and lower than the target rotation speed) at which the controller 20 determines at Step 114B that the laundry is distributed in the excessive front unbalance or the excessive rear unbalance (Step 116B). Then, the controller 20 stops the rotation of the rotary drum 2 to terminate the dewatering process (Step 117). The predetermined period of time at Step 116B for maintaining the rotation speed of the rotary drum 2 is longer than the predetermined period of time at Step 116A for maintaining the target rotation speed of the rotary drum 2.

[0051] As set forth above, the drum type washing machine 1 according to the embodiment 1 efficiently detects the excessive unbalance at the primary resonant rotation speed and the secondary resonant rotation speed which may produce abnormal vibration on the washtub unit 7, and reliably protect the washtub unit 7 from producing the abnormal vibration and noise.

[0052] The drum type washing machine 1 according to the embodiment 1 detects the distribution of the laundry based on the amplitudes and the phases of the signals, such as voltage signals or current signals, output from the vibration sensor 40. The signals vary according to the change of the displacements, the rotation speed, and the acceleration, and released from the vibration sensor 40.

[0053] The drum type washing machine 1 detects the distribution of the laundry based on the displacements S_{FLR} and S_{FFR} of the washtub 3 along the leftward and rightward direction LR and the frontward and rearward direction FR, respectively, caused by the vibration. Since the displacement S_{FLR} of the washtub 3 along the leftward and rightward direction LR is similar to the displacement S_{FUD} of the washtub 3 along the upward and downward direction UD, the controller 20 may detect the distribution of the laundry based on the displacements S_{FUD} and S_{FFR}. Alternatively, the distribution of the laundry may be detected based on the displacement due to the vibration at the front portion of the washtub 3 along a direction perpendicular to the rotary axis 2A and the displacement S_{FFR} due to the vibration in parallel to the rotary axis 2A. The drum type washing machine 1 detects the distribution of the laundry based on the displacement of the vibration at the front portion of the washtub 3. Since the waveforms of the displacements S_{FLR}, S_{FFR}, and S_{FUD} shown in Figs. 3A to 3C are close to sine waves, the relationship of the phases and the amplitudes of the waveforms does not change even after the wave forms are differentiated or integrated. The controller 20 of the drum type washing machine 1 according to the embodiment may detect the distribution of the laundry based on the speed or acceleration of the vibration at the front portion of the washtub 3.

[0054] The present invention is not limited to the above embodiment.

[0055] The drum type washing machine according to the present invention can determine the unbalance of the laundry in the rotary drum even when the laundry is biased towards the bottom of the rotary drum, hence being applicable to a drum type washing machine which executes a certain process when the laundry is distributed in excessive unbalance.

Claims

1. A drum type washing machine comprising:

a housing;
a washtub unit including

a washtub accommodated in the housing, the washtub having an opening provided therein and a bottom thereof located opposite to the opening,
a rotary drum accommodated in the washtub, the rotary drum having a side wall and a bottom, the side wall of the rotary drum having a cylindrical shape in parallel to a rotary axis, the bottom of the rotary drum being situated on the rotary axis and facing the bottom of the washtub, the rotary drum being adapted to accommodate a laundry therein, the rotary drum having an opening which is situated on the rotary axis and opposite to the bottom of the rotary drum, the opening of the rotary drum communicating with the opening of the washtub, the rotary drum being rotatable about the rotary axis, and
a motor fixed to the bottom of the washtub and joined to the bottom of the rotary drum for rotating the rotary drum about the rotary axis;
a damper for elastically supporting the washtub at a supporting position;
a controller for controlling the motor; and
a vibration sensor for detecting a vibration of the washtub, wherein
the rotary axis of the rotary drum extends horizontally or inclines downwardly from the opening of the rotary drum towards the bottom of the rotary drum, the supporting position and a center of gravity of the washtub unit approximate to the motor from a center plane which passes a center of the washtub and which is perpendicular to the rotary axis,
the supporting position is distanced farther from the motor along a horizontal direction than the center of gravity is,
the vibration sensor outputs a first signal and a second signal corresponding to a component of vibration of a portion of the washtub along a first direction and a component of the vibration along a second direction perpendicular to the first direction, respectively, the portion of the washtub being between the center plane of the washtub and the opening of the washtub, and
the controller determines, based on the first signal and the second signal output from the vibration sensor, whether or not the laundry is distributed in the rotary drum in a front unbalance in which the laundry is biased from the center plane towards the opening of the rotary drum, and whether or not the laundry is distributed in the rotary drum in a rear unbalance in which the laundry is biased from the center plane towards the bottom of the rotary drum.

2. The drum type washing machine according to claim 1, wherein
the first direction is perpendicular to the rotary axis, and
the second direction is in parallel with the rotary axis.

3. The drum type washing machine according to claim 1 or 2, wherein the controller is operable to
determine an excessive front unbalance of the front unbalance by determining whether or not an amplitude of the first signal output from the vibration sensor is equal to or larger than a first threshold, and
determine an excessive rear unbalance of the rear unbalance by determining whether or not an amplitude of the second signal output from the vibration sensor is equal to or larger than a second threshold.

4. The drum type washing machine according to claim 3, wherein the housing has a loading/unloading opening therein communicating with the opening of the washtub, said drum type washing machine further comprising:

a door for opening and closing the loading/unloading opening; and
an elastic sealing member provided at the loading/unloading opening on the housing for sealing between the door and the washtub at the opening of the washtub.

5. The drum type washing machine according to claim 1, wherein the housing has a loading/unloading opening therein communicating with the opening of the washtub, said drum type washing machine further comprising:

a door for opening and closing the loading/unloading opening; and
an elastic sealing member provided at the loading/unloading opening on the housing for sealing between the door and the washtub at the opening of the washtub.

FIG. 1

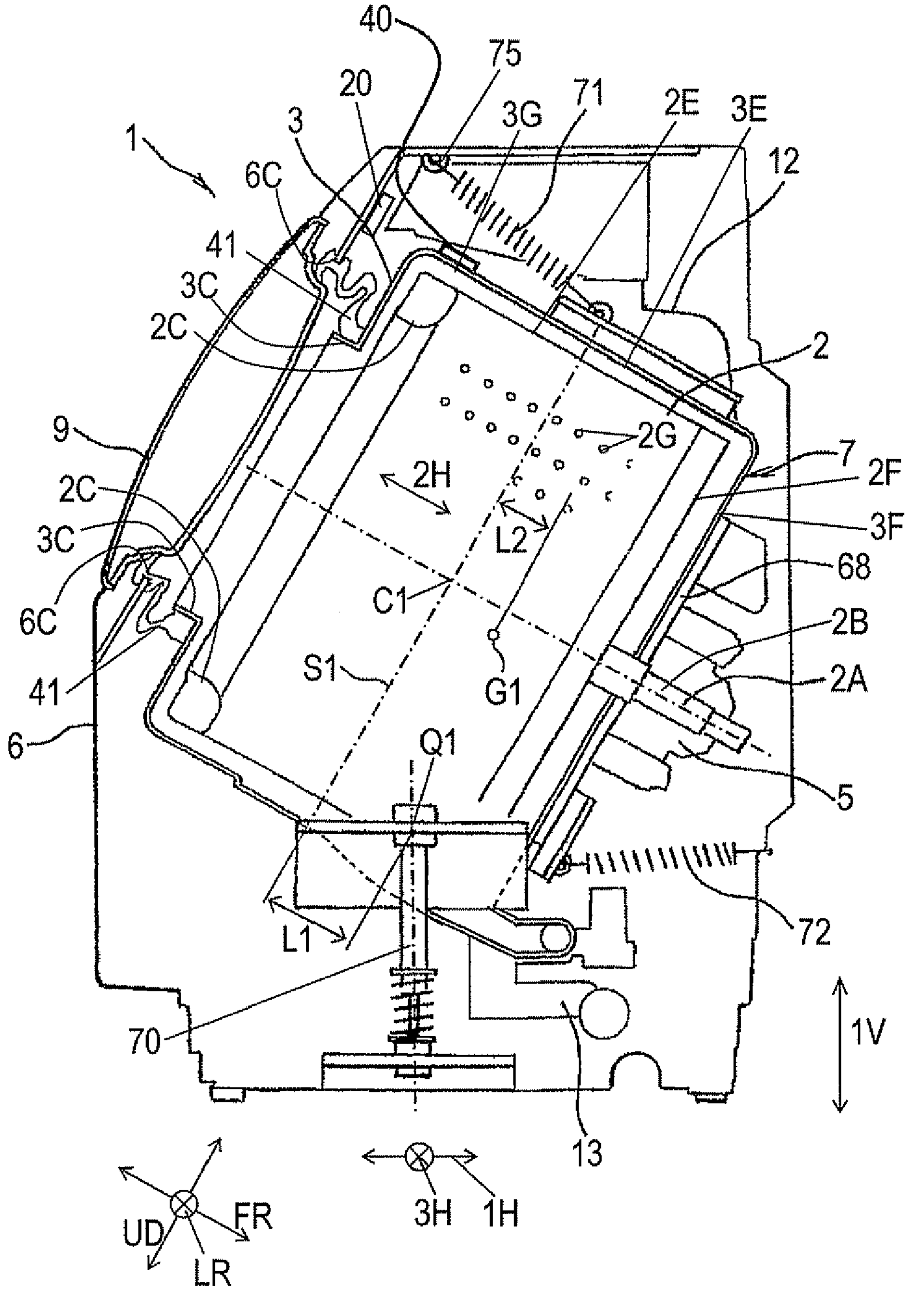
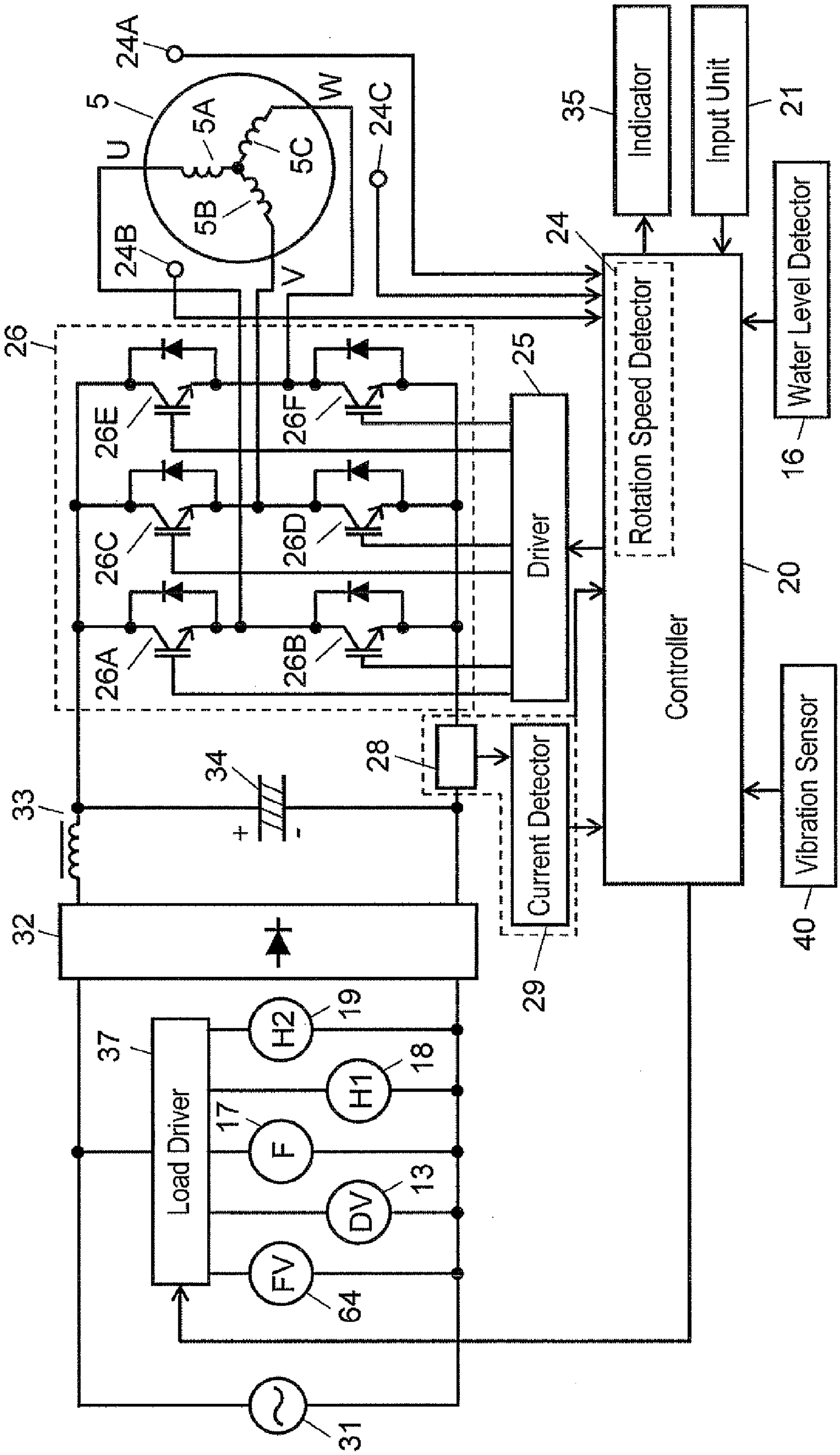

40
75
20
3
3G
71
2E
3E
1
6C
12
41
3C
2C
2
9
2G
7
2H
2F
2C
L2
3C
3F
68
C1
6C
2B
S1
G1
41
2A
6
Q1
5
72
L1
70
1V
13
UD
FR
LR
3H
1H

FIG. 2



24A
5
U
5A
W
5C
24C
5B
24B
V
35
Indicator
Input Unit
21
24
Rotation Speed Detector
Water Level Detector
16
26
26E
26F
25
26C
26D
Driver
20
Controller
26A
26B
28
34
+
-
Current Detector
33
Vibration Sensor
40
32
29
37
Load Driver
H2
19
H1
18
17
F
DV
13
FV
64
31

FIG. 3A

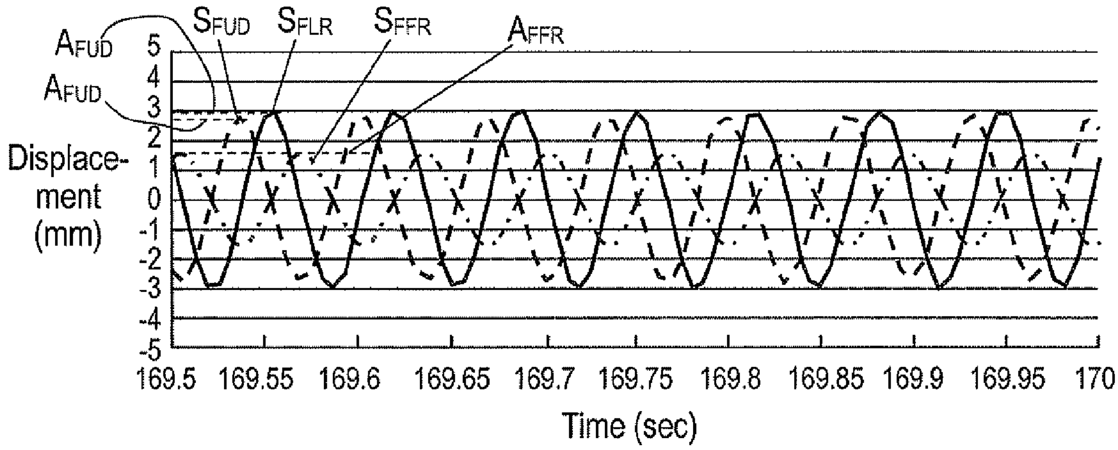


FIG. 3B

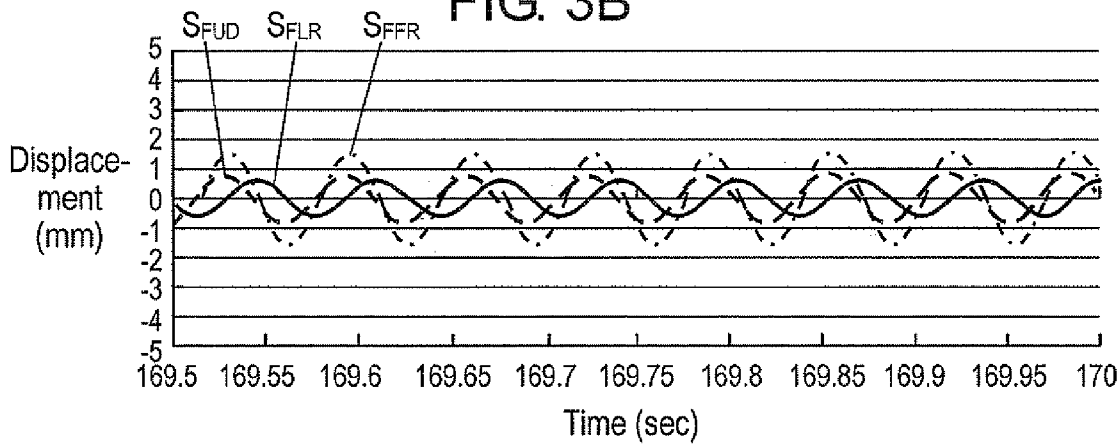


FIG. 3C

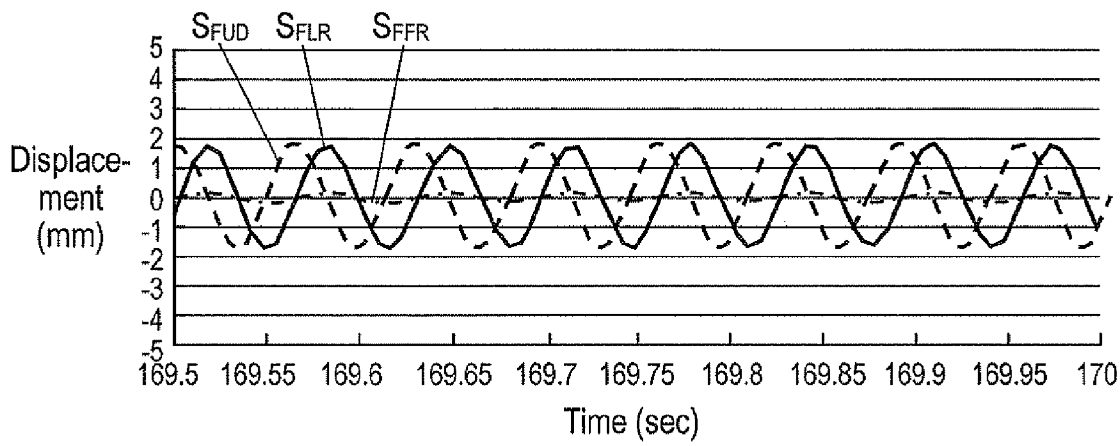


FIG. 4

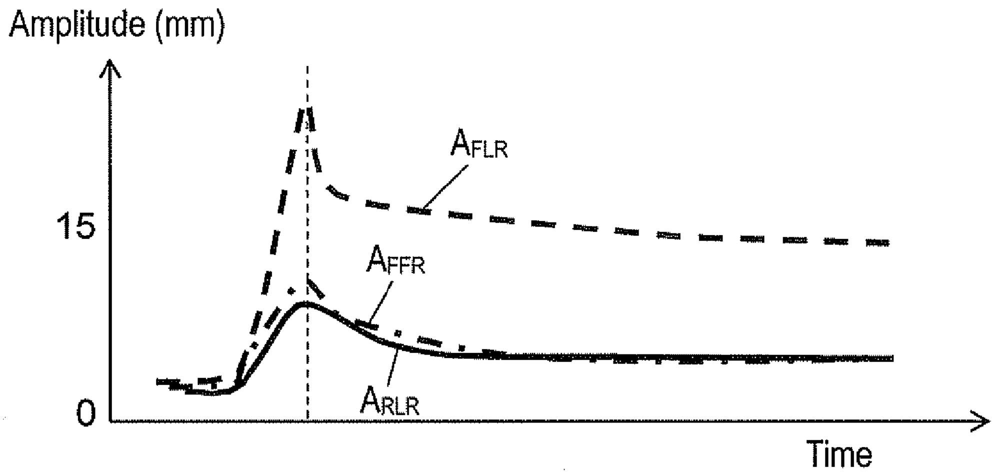

Amplitude (mm)
AFLR
15
AFFR
ARLR
0
Time

FIG. 5

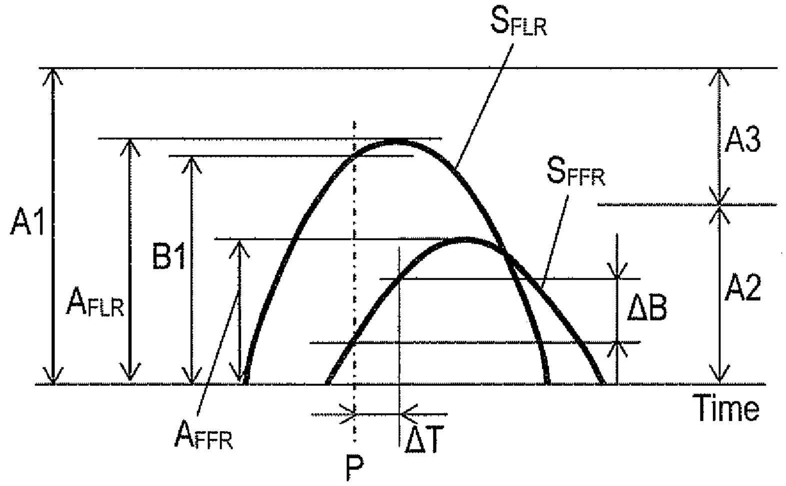

SFLR
A3
SFFR
A1
B1
AFLR
ΔB
A2
Time
AFFR
ΔT
P

FIG. 6A

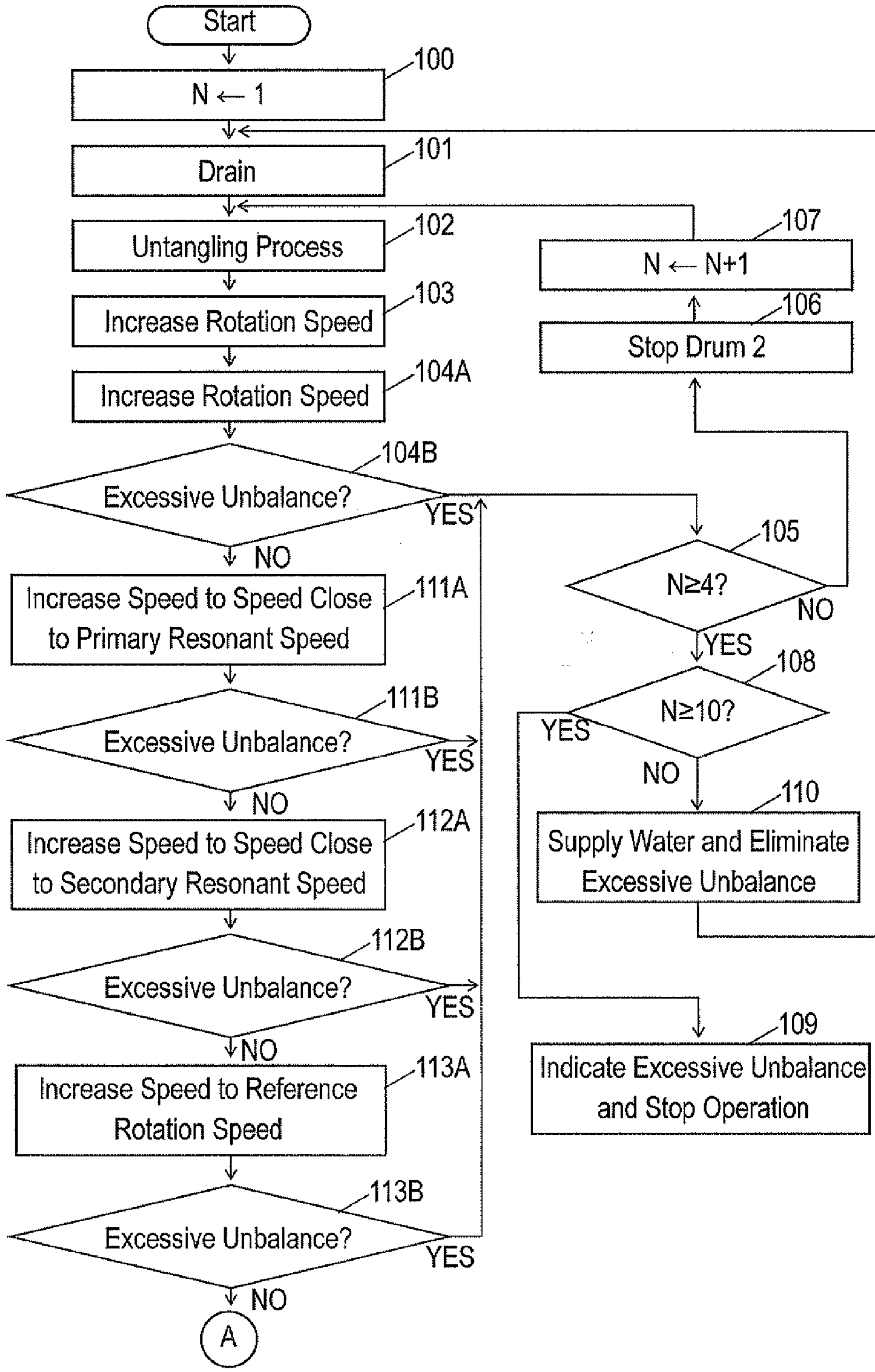

Start
N ← 1
100
Drain
101
Untangling Process
102
Increase Rotation Speed
103
Increase Rotation Speed
104A
Excessive Unbalance?
104B
YES
NO
Increase Speed to Speed Close to Primary Resonant Speed
111A
Excessive Unbalance?
111B
YES
NO
Increase Speed to Speed Close to Secondary Resonant Speed
112A
Excessive Unbalance?
112B
YES
NO
Increase Speed to Reference Rotation Speed
113A
Excessive Unbalance?
113B
YES
NO
A
N ← N+1
107
Stop Drum 2
106
N≥4?
105
NO
YES
N≥10?
108
YES
NO
Supply Water and Eliminate Excessive Unbalance
110
Indicate Excessive Unbalance and Stop Operation
109

FIG. 6B

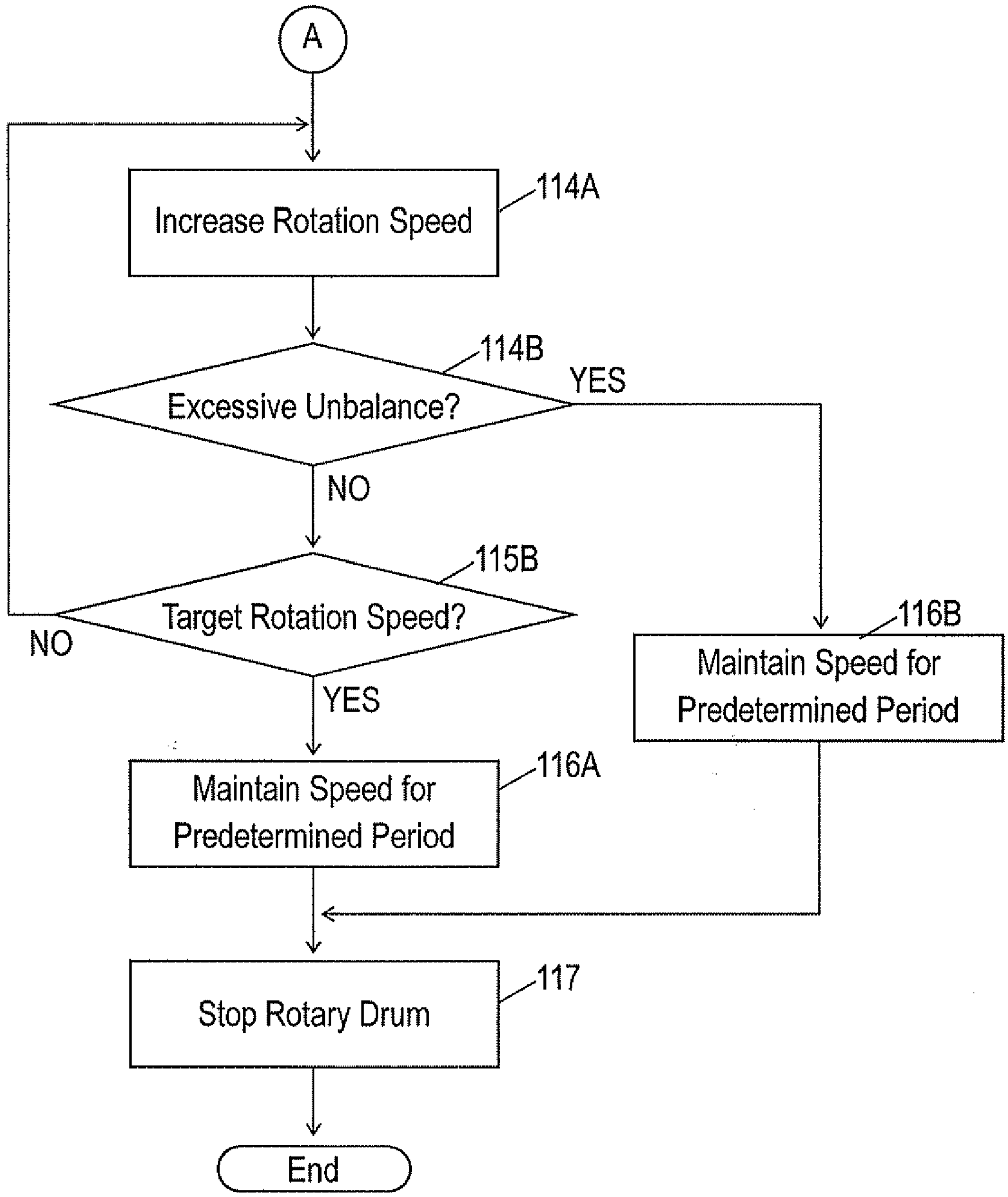
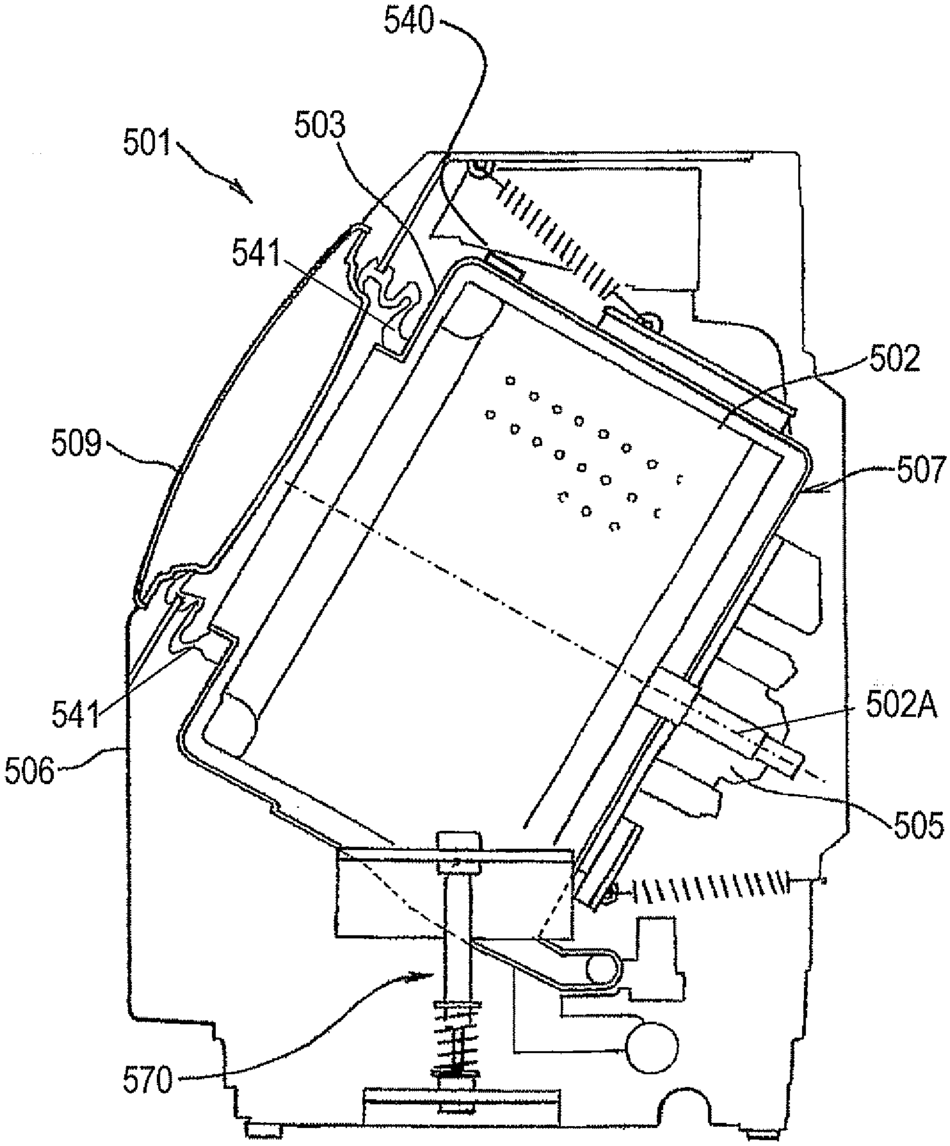

A
Increase Rotation Speed
114A
Excessive Unbalance?
114B
YES
NO
Target Rotation Speed?
115B
NO
YES
Maintain Speed for Predetermined Period
116B
Maintain Speed for Predetermined Period
116A
Stop Rotary Drum
117
End

FIG. 7



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EUROPEAN SEARCH REPORT

Application Number
EP 09 15 0519

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X	EP 1 857 583 A (WHIRLPOOL CO [US]) 21 November 2007 (2007-11-21) * paragraph [0034] - paragraph [0054]; figures 6-9 *	1-5	INV. D06F37/20
A	EP 1 607 729 A (DIEHL AKO STIFTUNG GMBH & CO [DE]) 21 December 2005 (2005-12-21) * abstract *	1-5	
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A	US 2004/154351 A1 (KIM JONG SEOK [KR] ET AL) 12 August 2004 (2004-08-12) * abstract *	1-5	
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D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 June 2009	Hannam, Martin

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			JP	2006075467	A	23-03-2006
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			RU	2300591	C1	10-06-2007
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