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WASHING MACHINE



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Field of the Invention

5 The present invention relates to a washing machine for performing washing, rinsing, and water-extracting processes in a rotary drum having a substantially horizontal or slanted rotational axis.

10 Background of the Invention

 A conventional drum-type washing machine includes a rotary drum for accommodating laundry therein. The rotary drum is installed in a water tub such that it rotates about
15 a horizontal axis. Further, formed at the front portion of the water tub is a laundry loading/unloading opening, which is opened and closed by a door. After putting laundry in the rotary drum through the laundry loading/unloading opening, the washing machine performs washing, rinsing and
20 water-extracting processes by controlling water supply/drain into/from the water tub and also by controlling the rotation of the rotary drum. Further, by forming an air circulation channel for discharging air from the water tub and running it through a dehumidification unit and a heating unit prior
25 to re-circulating the air back into the water tub, the washing machine can also have the function of drying laundry

in the rotary drum. One example of washing machines of this type is disclosed in Japanese Patent Laid-Open Application No. 1998-211393 (pp. 3 and 4, Fig. 1).

5 With regard to the conventional type washing machine as described, when impurities or contaminants such as detergent residues are stuck on the outer cylindrical surface of the rotary drum rotably installed in the water tub, it has been difficult to remove them. Particularly, since detergent residues are lipophilic and highly cohesive
10 materials, they often remain on the cylindrical surface of the rotary drum once stuck thereon.

When such impurities or contaminants dry up, they become hardened so that their removal becomes more difficult. Further, once contaminants are stuck on the drum surface,
15 they tend to grow bigger by attracting more contaminants, causing an obnoxious cycle. In addition, detergent residues may cause the growth of microorganism, bacteria and/or the like. There is also a concern that molds would grow in the water tub inside of which is highly humid by promoting the
20 spread of germs. Accordingly, there has been a need to come up with a method to remove promptly the impurities or contaminants stuck on the outer cylindrical surface of the rotary drum.

Summary of the Invention

It is, therefore, an object of the present invention to provide a washing machine capable of flushing out
5 impurities or contaminants such as detergent residues stuck on the outer cylindrical surface of a rotary drum by strong water currents created as a result of rotating the rotary drum at a high speed, thereby maintaining the outer cylindrical surface of the rotary drum hygienic.

10 In accordance with a preferred embodiment of the present invention, there is provided a washing machine including: a rotary drum having an approximately horizontal or a slanted rotational axis; a water tub elastically supported in a washing machine main body and accommodating
15 the rotary drum therein; a motor for rotating the rotary drum; an inverter having one or more switching devices for supplying an electric power to the motor; and a controller for controlling an operation of the motor by way of controlling one or more of the switching devices, wherein
20 the controller executes a rotary drum cleaning operation by using water collected in the water tub by way of controlling a rotational speed of rotary drum to be equal to a first rotational speed, the first rotational speed being greater than a rotational speed which makes laundry in the rotary
25 drum to stick to the inner surface of the rotary drum but smaller than a normal rotational speed which is required for

extracting water from the laundry.

Brief Description of the Drawings

5 The above and other objects and features of the present invention will become apparent from the following description of a preferred embodiment given in conjunction with the accompanying drawings, in which:

10 Fig. 1 is a circuit diagram of a washing machine in accordance with a preferred embodiment of the present invention, wherein some components are represented by blocks;

 Fig. 2 is a vertical cross sectional view of the washing machine in Fig. 1;

15 Fig. 3 is a cross sectional view of a major component of the washing machine in Fig. 1;

 Fig. 4 is a magnified view of a console and a display unit of the washing machine in Fig. 1;

20 Fig. 5 is a flowchart that describes the operation of a main component of the washing machine in Fig. 1;

 Fig. 6 is a time chart that outlines the number of rotations of a rotary drum and changes in electric current of a motor of the washing machine in Fig. 1;

25 Fig. 7 is a flow chart to illustrate a subroutine which controls the rotational speed of the rotary drum and the electric current of the motor of the washing machine in

Fig 1.; and

Fig. 8 is a cross sectional view showing a main component of the washing machine, to illustrate the flow of water supplied into a water tub.

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Detailed description of the Preferred Embodiments

Hereinafter, a preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings. However, it is to be noted that the present invention is not limited thereto.

As shown in Fig. 2, cylindrical rotary drum 1 having a base is rotatably installed in water tub 3. Rotary drum 1 is provided with multiple drum perforations 2 on its cylindrical surface and with rotating shaft (central axis of rotation) 4 at its center of rotation while rotary drum 1 is disposed such that its central axis of rotation is declined toward the rear portion of the washing machine. Motor 5 installed at the rear side of water tub 3 is connected to rotating shaft 4 to make rotary drum 1 to rotate in forward and reverse direction. Further, a number of agitation blades 6 are disposed on the inner wall of rotary drum 1.

An opening formed at the inclined surface of water tub 3's front portion which faces upward is opened and closed by door 7. By opening door 7, laundry can be loaded into or unloaded from rotary drum 1 through laundry

loading/unloading opening 8. Since door 7 is installed in the inclined surface, the loading/unloading of laundry can be performed without a user having to bend down.

Water tub 3 is suspended in washing machine main body 9 by springs (not shown) so that it can rock back and forth. Connected to the lower portion of water tub 3 is one end of water drain conduit 10, and the other end of water drain conduit 10 is coupled to water drain valve (water draining means) 11 to drain wash water from water tub 3. Water supply valve (water supplying means) 12 is used to fill water in water tub 3 via water supply conduit 13.

Water outlet 14 is formed at the bottommost portion of water tub 3 such that it is perpendicular to the rotational direction of rotary drum 1. As shown in Fig. 3, sidewall 14a of water outlet 14 is formed such that it crosses the direction of water current.

Further, in this embodiment, although rotary drum 1 having rotating shaft 4 at its center of rotation is installed such that its central axis of rotation is declined toward the rear portion of the washing machine in this preferred embodiment, rotary drum 1 with rotating shaft 4 may be set up such that the central axis of rotation is approximately horizontally oriented.

Fig. 1 shows the configuration of control unit 15. As shown therein, control unit 15 includes controller 16 with a microcomputer for controlling a series of operations

including washing, rinsing, and water-extracting processes in sequence as well as controlling the operation of motor 5, water drain valve 11, water supply valve 12, and so forth. As for controller 16, it registers an input signal from
5 input setting unit 17 for setting an operation course, while it informs a user of the input information through display unit 18. Concurrently, once an operation is set to start by input setting unit 17, controller 16 monitors the operation of water drain valve 11 and water supply valve 12 via load
10 driving unit 20 based on input data transmitted from water level detector 19 for detecting the water level in water tub 3, and so forth, thereby carrying out a washing operation.

At this time, controller 16 controls the rotation of motor 5 by controlling inverter 23 via inverter driving
15 circuit 22 based on data transmitted from position detecting unit 21, which detects the position of motor 5's rotor. Though not shown, motor 5 is a brushless DC motor including a stator with three-phase windings and a rotor with a bipolar permanent magnet disposed on a ring. The stator is
20 made up of three-phase windings including first winding 5a, second winding 5b and third winding 5c wound around an iron core provided with slots.

Inverter 23 includes switching devices each being made up of a parallel circuit of a power transistor (e.g.,
25 insulated gate bipolar transistor("IGBT")) and a reverse conducting diode. Specifically, inverter 23 includes a

serial circuit of first and second switching devices 23a and 23b; a serial circuit of third and forth switching devices 23c and 23d; and a serial circuit of fifth and sixth switching devices 23e and 23f, wherein the serial circuits
5 are connected to each other in parallel.

Here, both ends of each of the serial circuits serve as input terminals and are coupled to a DC power supply. Further, respectively coupled to a junction of the two switching devices in each serial circuit are output
10 terminals, which are in turn connected to a U terminal, a V terminal and a W terminal of the three-phase windings, respectively. The U, V and W terminals are controlled as a positive voltage, a zero voltage and a floating state, respectively, by a combination of on-off operations of the
15 two switching devices in each serial circuit.

The on-off operations of the switching devices are controlled by controller 16 based on data from three position detectors 21a to 21c, which are made up of hall IC's. Position detectors 21a to 21c are disposed at the
20 stator by an interval of an electrical angle of 120 degrees to face the permanent magnet provided in the rotor.

While the rotor makes one revolution, each of three position detectors 21a to 21c outputs a pulse by the interval of the electrical angle of 120 degrees. Controller
25 16 monitors changes in the state of signals from at least one of three position detectors 21a to 21c. When a change

is detected, controller 16 changes the on-off states of the switching devices 23a to 23f based on the signals from position detectors 21a to 21c, thereby setting the U, V and W terminals as a positive voltage, a zero voltage and a floating state, respectively. A magnetic field is formed by supplying thus controlled electric power to first, second and third windings 5a to 5c of the stator, thereby rotating the rotor.

Further, each of switching devices 23a, 23c and 23e is subjected to pulse width modification (PWM), and the number of rotations of the rotor is controlled by, for example, repeatedly controlling a duty ratio at a frequency of 10 kHz. Every time the state of signals from at least one of three position detectors 21a to 21c is changed, controller 16 detects the period thereof, calculates the number of rotations (rotational speed) of the rotor within the period; and then performs the PWM control of switching devices 23a, 23c and 23e such that the rotor makes as many rotations as the set rotation number. At this time, switching devices 23b, 23d and 23f are not subjected to the PWM control.

Current detector 24 includes resistor 25 connected to an input terminal of one side of inverter 23 and current detecting circuit 26 coupled to resistor 25. Current detector 24 detects an input current of inverter 23, i.e., an electric current of motor 5; converts the detected current into a voltage signal; and inputs the voltage signal

to controller 16. Subsequently, controller 16 performs an A/D conversion on the inputted voltage signal; processes thus A/D converted voltage signal as digital data; and controls the motor 5 such that its current is maintained at
5 less than or equal to a predetermined value.

In case motor 5 is a brushless DC motor, its torque is substantially proportional to the input current. Thus, the torque of motor 5 can be detected by way of detecting the value of the input current of inverter 23 by current
10 detecting circuit 26 connected to resistor 25.

Laundry amount detector 27 detects the amount of laundry in rotary drum 1. Specifically, laundry amount detector 27 calculates the amount of laundry in rotary drum based on a signal transmitted from current detector 24 when
15 rotary drum 1 is driven to rotate at a specific rotational speed (e.g., 200 rpm).

Commercial power source 28 is connected to inverter 23 via a DC power converter made up of diode bridge 29, choke coil 30 and smoothing capacitor 31 for example. It is to be
20 noted that the configuration described above with respect to Fig. 1 is only one example. Thus, the configurations of brushless DC motor 5 and inverter 23 are not limited thereto.

As shown in Fig. 4, input setting unit 17 includes washing time setting switch 17a for setting a washing time
25 period, rinsing number setting switch 17b for setting the number of rinsing operations, water-extracting time setting

switch 17c for setting a water-extracting time period, course setting switch 17d, start/pause switch 17e, power-on switch 17f, power-off switch 17g, and so forth. Display unit 18 includes washing time display unit 18a, rinsing
5 number display unit 18b, water-extracting time display unit 18c, course set display unit 18d, detergent amount indicator lamp 18e, residual operating time indicator lamp 18f, number display unit 18g, and so forth.

Here, controller 16 performs a rotary drum cleaning
10 operation while water is collected in water tub 3 by way of rotating rotary drum 1 at a first rotational speed (e.g., 400 rpm). In particular, the first rotational speed is greater than a rotational speed that makes laundry to stick to the inner surface of rotary drum 1 but is smaller than a
15 normal rotational speed for a water-extracting operation. Such rotary drum cleaning operation is performed during the water-extracting operation.

Further, during the rotary drum cleaning operation, controller 16 maintains drain valve 11 closed and operates
20 water supply valve 12 to feed water into water tub 3. At this time, the operating time of water supply valve 12 is determined based on the amount of laundry detected by laundry amount detector 27, as shown in Table 1.

Table 1

Laundry Amount	Water Supply Period
0 to 2 kg	15 seconds
2 to 4 kg	10 seconds
4 to 6 kg	5 seconds
6 to 8 kg	0 second

Further, controller 16 performs a laundry balancing operation and a laundry balance monitoring operation in order before the rotary drum cleaning operation is carried out. More specifically, in the laundry balancing operation, from a stopped condition controller 16 rotates rotary drum at a second rotational speed (e.g., 90 rpm) slower than the first rotational speed (400 rpm), thereby making laundry to stick to the inner surface of rotary drum 1. In the laundry balance monitoring operation, controller 16 screens the balance state of laundry by rotating rotary drum 1 approximately at the second rotational speed. If it is determined in the laundry balance monitoring operation that laundry is not balanced properly, the laundry balancing operation is repeated.

The washing machine's operation having the above-described configuration will now be described with reference to Figs. 5 to 7. After loading laundry into rotary drum 1, power-on switch 17f is turned on and an operation course is selected by using course setting switch 17d depending on the

type of laundry. Then, once start/pause switch 17e is pressed, the operation of the washing machine is started as follows. First, controller 16 rotates rotary drum 1 and detects the amount of laundry in rotary drum 1 by means of laundry amount detector 27. Thereafter, controller 16 displays a required amount of detergent on number display unit 18g based on the detected amount of laundry while detergent amount indicator lamp 18e is on. When the required amount of detergent is added into a detergent dispenser (not shown) installed in water supply conduit 13 in accordance with the displayed amount of detergent, a residual operating time of the washing machine is displayed on number display unit 18g while residual operating time indicator lamp 18f is on.

Subsequently, a washing operation is initiated. Water supply valve 12 is opened, and fresh water flows into water tub 3 through water supply conduit 13 while dissolving detergent added from the detergent dispenser. When the water reaches a predetermined level, motor 5 is driven to rotate rotary drum 1, thereby performing the washing operation. By the rotation of rotary drum 1, laundry in rotary drum 1 is lifted up in the drum's rotational direction by being caught by agitation blades 6 disposed on the inner cylindrical surface of rotary drum 1 and dropped when reaching a specific height. As the laundry is repeatedly agitated in the drum, it is subject to pounding

motions and is therefore washed. After a predetermined washing time is passed, water drain valve 11 is opened and soiled washing water is drained via water drain conduit 10. Then, wash water absorbed in the laundry is extracted by spinning rotary drum 1 at a high speed.

Afterward, water supply valve 12 is opened to supply fresh water, and a rinsing operation is started. During the rinsing operation, the laundry undergoes the agitation motions again, i.e. being lifted up by agitation blades 6 and dropped by the rotation of rotary drum 1, as in the washing operation. When the rinsing operation is finished, a water-extracting operation is started by spinning rotary drum 1 at a high speed.

Referring to Fig. 5, if the water-extracting operation is started in step 100, data initialization ($N=1$) is performed in step 101 and water drain valve 11 is opened in step 102. Then, a laundry balancing operation is performed by rotating rotary drum 1 forwardly at a rotational speed (rotation number) of 90 rpm by means of motor 5, while controlling the balance of the laundry in rotary drum 1 in step 103.

Here, detailed description will be provided with reference to Fig. 6. Further, in Fig. 6, curves "a" and "c" represent the rotational speed of rotary drum 1 and the current of motor 5, respectively, when the load exerted on motor 5 is small, while curves "b" and "d" represent the

drum rotational speed and the current of motor 5, respectively, when the load exerted on motor 5 is great.

As shown in Fig. 6, motor 5 is driven to rotate rotary drum 1 at a rotational speed of 40 rpm at time t1 and then keeps rotating rotary drum 1 at the rotational speed of 40 rpm during the time period from t1 through t2, to thereby stabilize the rotational speed of rotary drum 1. During the subsequent time period from t2 through t3, motor 5 rotates rotary drum 1 at a second rotational speed (90 rpm) so that laundry would stick to the inner surface of rotary drum 1. Namely, by gradually increasing the rotational speed of rotary drum 1 from a substantially stopped state of rotary drum 1 up to the second rotational speed (90 rpm), centrifugal force becomes greater than the gravity exerted on the laundry so that the laundry would stick to the inner surface of rotary drum 1. For example, for the first 5 seconds, the rotational speed of rotary drum 1 is regulated at 40 rpm and then is accelerated every second by 3 rpm until it reaches 90 rpm.

Subsequently, during a laundry balance monitoring operation in step 104 (during the time period from t3 through t4), the balance state of laundry in rotary drum 1 is estimated by rotating rotary drum 1 approximately at the second rotational speed (about 90 rpm). Namely, while applying a fixed voltage level to motor 5 such that the rotational speed of rotary drum 1 can be maintained at 90

rpm, a change in the rotational speed is detected. In case there is a considerable change in the rotational speed, it is interpreted as having a poor sticking and balancing condition of laundry in the rotary drum.

5 In the balance state of laundry in step 104 is found to be in an unbalance state, the process goes to step 105 where it is determined whether N equals 10. If N is under 10, the process proceeds to step 106 and stops rotary drum 1. Then, by adding 1 to N in step 107, the process is returned
10 to step 103 and the laundry balancing operations from steps 103 through 107 are repeated. Here, if the number of repetitions of the laundry balancing operation reaches a predetermined value, i.e., if N equals 10 in step 105, the process moves on to step 108 and reports an abnormality.

15 If it is determined in step 104 that the balance state of laundry is good, the rotational speed of rotary drum 1 is increased from the second rotational speed (90 rpm) up to 150 rpm during the time period from t4 through t5 shown in Fig. 6 in step 109. Then, the rotational speed of 150 rpm
20 is maintained during the time period from t5 through t6 (e.g., 1 minute). Accordingly, the laundry can be water extracted to some extent, so that the load exerted on motor 5 can be reduced during the subsequent control of rotating rotary drum 1.

25 Thereafter, step 110 is carried out and the rotational speed of rotary drum 1 is increased from 150 rpm to the

first rotational speed (400 rpm) during the time period from t6 through t7 in Fig. 6, to thereby start a rotary drum cleaning operation. Since water drain valve 11 is closed in step 111, the water extracted from the laundry articles can be collected during the rotary drum cleaning operation, it is possible to collect water in water tub 3 without using a special means therefor.

Thereafter, timer I is initialized in step 112, and an initial value for set rotational speed R of rotary drum 1 is set as the first rotational speed (400 rpm) in step 113 (at time t7 in Fig. 6). Then, the process proceeds to step 114 where a drum rotation control and a motor current control are executed.

The drum rotation control and the motor current control will be described in detail with reference to a subroutine shown in Fig. 7

Referring to Fig. 7, the control of drum rotational speed is started in step 120 and timer II is initialized in step 121. Then, a feedback control for regulating the rotational speed of rotary drum 1 to be equal to the set rotational speed R (initial value of 400 rpm) is performed in step 122. After 5 seconds in step 123, the process proceeds to step 124 so that a motor current I detected by current detector 24 is input, and in step 125, it is determined whether the motor current I is greater than or equal to a predetermined value I_c . If 5 seconds has not yet

passed in step 123, the process returns to step 122.

5 If the load exerted on motor 5 is small and the motor current I is smaller than the predetermined value I_c as represented by the curve "c" shown in Fig. 6, step 115 is performed, whereas, if the load exerted on motor 5 is great and the motor current I is equal to or greater than the predetermined value I_c as represented by the curve "d" shown in Fig. 6, step 126 is carried out to reduce the set rotational speed R by 5 rpm and then step 115 is executed.

10 Accordingly, the rotational speed of rotary drum 1 is regulated to be equal to the first rotational speed (400 rpm) during the time period from t_7 through t_{10} when the load exerted on motor 5 is small, as shown by the curve "a" in Fig. 6. When the load exerted on motor 5 is great,
15 however, rotary drum 1 is first driven to rotate at the first rotational speed (400 rpm) during the time period from t_7 through t_8 and, after 5 seconds, the set rotational speed R is reduced by 5 rpm at the time t_8 such that rotary drum 1 is driven to rotate at a rotational speed of 395 rpm. Then,
20 after another 5 seconds has elapsed, the set rotational speed R is reduced again by 5 rpm at time t_9 , so that rotary drum 1 is driven to rotate at a rotational speed of 390 rpm until time t_{10} .

25 By controlling motor 5 as described, when the load exerted on motor 5 is light, the rotational speed of rotary drum 1 is controlled to be less than or equal to the

predetermined value I_c during the time period from t_7 through t_{10} , as represented by the curve "c" shown in Fig. 6. In case the load exerted on motor 5 is heavy, on the other hand, the rotational speed of rotary drum 1 is reduced at time t_9 to be maintained at or below the predetermined value I_c , as shown by the curve "d" shown in Fig. 6.

Then, the process proceeds to step 115. In step 115, water supply valve is turned on and water is fed into water tub 3. As a result, even in case the amount of laundry is small so that the amount of water extracted therefrom is small, water can certainly be collected in water tub 3. Further, since water is supplied based on the amount of laundry detected by laundry amount detector 27 in accordance with, for example, the operating time shown in Table 1, a substantially same amount of water can always be collected in water tub 3 regardless of the amount of laundry.

Referring back to Fig. 5, after timer I indicates that 30 seconds has elapsed in step 116 and it reaches time t_{10} shown in Fig. 6, step 117 is performed to open water drain valve 11 and a water-extracting operation is performed in step 118, during which the laundry in rotary drum 1 is water extracted by rotating rotary drum 1 while accelerating the rotational speed thereof. Referring back to step 116, if 30 seconds has not yet passed, step 114 is executed again.

Here, while water is still collected in water tub 3, by performing the rotary drum cleaning operation by

rotating rotary drum 1 at the first rotational speed (for example, 400 rpm) greater than the rotational speed which makes laundry to stick to the inner surface of rotary drum 1 but lower than the normal rotational speed for the water-extracting operation, water discharged through drum perforations 2 of rotary drum 1 which rotates at the first rotational speed, gets reflected by sidewall 14a of water outlet 14 to thereby contact the outer cylindrical wall of rotary drum 1, as shown in Fig. 3. As a result, impurities or contaminants such as detergent residues sticking to the outer cylindrical surface of rotary drum 1 can be flushed out by the water bouncing off, so that the outer cylindrical surface of rotary drum 1 can be kept clean and the growth of germs or molds in rotary drum 1 can be prevented. Therefore, more hygienic laundry washing can be achieved.

Further, by supplying water into water tub 3 during the rotary drum cleaning operation by way of operating water supply valve 12, the water supplied via water supply conduit 13 flows to water outlet 14 along the inner surface of water tub 3 and is bounced off by sidewall 14a of water outlet 14, as shown in Fig. 8. Concurrently, turbulent water currents are generated due to an air pressure from the rotation of the rotary drum 1. By water bounced off and turbulent water currents, the outer cylindrical surface of rotary drum 1 can be flushed out by clean water. As a result, the outer cylindrical surface of rotary drum 1 can be kept more

hygienic.

As described above, controller 16 performs the rotary drum cleaning operation such that water is collected in water tub 3 by way of rotating rotary drum 1 at the first rotational speed (for example, 400 rpm) greater than the rotational speed which makes laundry to stick to the inner surface of rotary drum 1 but smaller than the normal rotational speed for the water-extracting operation. Therefore, impurities or contaminants such as detergent residues sticking to the outer cylindrical surface of rotary drum 1 can be flushed out by vigorous water currents generated by high-speed rotation of rotary drum 1. Therefore, the outer cylindrical surface of rotary drum 1 can be kept clean and the impurities or contaminants such as detergent residues can be prevented from sticking again to rotary drum 1.

Further, controller 16 controls the washing, rinsing, and water-extracting operations and performs the rotary drum cleaning operation during the water-extracting operation. Since rotary drum 1 is controlled to rotate at a specific rotational speed (for example, 400 rpm) by using the water collected in water tub 3 after sufficiently rinsing laundry in the rotary drum, the problem that is associated with a great deal of foams generated due to residual detergent left in water tub 3, in which condition the rotational speed of rotary drum 1 cannot increase, i.e., in bubble constraint

state, can be solved.

Further, since current detector 24 for detecting a current of motor 5 is prepared and controller 16 controls motor 5 in response to a signal from current detector 24 such that the current of motor 5 is smaller than or equal to a predetermined value, abnormal overheating of motor 5 resulting from a high load can be prevented by controlling the current of motor 5 even in case the amount of laundry is large, or when much of laundry having fabrics that can trap a considerable amount of water, otherwise, when a large amount of water is in water tub 3. Therefore, safety can be improved.

Further, since controller 16 closes water drain valve 11 during the rotary drum cleaning operation, the water extracted from laundry during the rotary drum cleaning operation can be collected, so that it becomes possible to collect water in water tub 3 without needing a special means therefor, thereby contributing to a cost saving and an improvement in the washing machine's hygiene.

Further, since controller 16 opens water supply valve 12 to feed fresh water into water tub 3 during the rotary drum cleaning operation, water can be certainly collected in water tub 3 even in case the amount of water extracted is small given that only a small mount of laundry is loaded while the outer cylindrical surface of rotary drum 1 can be washed by fresh water, and thus, the surface can be kept

more hygienic.

Further, since the operating time of water supply valve 12 is set based on the amount of laundry detected by laundry amount detector 27, a substantially same amount of water can always be collected in water tub 3 regardless of the amount of laundry, thereby contributing a cost saving and the improvement of the washing machine's hygiene.

Further, controller 16 performs the laundry balancing operation and the laundry balance monitoring operation in order before the rotary drum cleaning operation. In the laundry balancing operation, from a substantially stopped condition, controller 16 rotates rotary drum 1 at the second rotational speed (e.g., 90 rpm) lower than the first rotational speed (400 rpm), thereby making laundry to stick to the inner surface of rotary drum 1. In the laundry balance monitoring operation, controller 16 checks the balance state of the laundry by rotating rotary drum 1 at approximately the second rotational speed. Therefore, by gradually making the laundry to stick to the inner surface of rotary drum 1 during the laundry balancing operation, the laundry balance state can be changed, and the rotary drum cleaning operation can be controlled to be performed by rotating rotary drum 1 at the first rotational speed only when the laundry balance state is good. Further, since abnormal vibration of rotary drum 1 and/or water tub 3 due to unbalanced laundry can be eliminated, safety of the

washing machine can be enhanced.

Still further, controller 16 repeats the laundry balancing operation when it detect the condition of unbalanced laundry in the laundry balance monitoring operation. Specifically, when laundry is found to be unbalanced, the laundry is made fall off from rotary drum 1 by stopping rotary drum 1, and the balance state of the laundry can be changed by performing the laundry balancing operation again to thereby gradually allow the laundry to stick to the inner surface of rotary drum 1. Further, since the rotary drum cleaning operation can be performed by way of rotating rotary drum 1 at the first rotational speed only when the laundry balance state is good, abnormal vibration of rotary drum 1 and/or water tub 3 due to the unbalance of the laundry articles can be eliminated, resulting in improved safety.

Further, although the rotary drum cleaning operation is executed during the water-extracting operation preceded by the washing and rinsing operations in accordance with the preferred embodiment of the present invention, the rotary drum cleaning operation can be conducted during a so-called intermediate water-extracting action between the washing and the rinsing operations or during an intermediate water-extracting action in the rinsing operation. In both cases, the same functions and effects as in the preferred embodiment can be obtained.

Further, though the preferred embodiment has been described with reference to a washing machine without having a laundry drying function, the present invention can also be applied to a washing machine having the laundry drying
5 function by way of blowing warm air into water tub 3. In such a case, the same functions and effects as in the preferred embodiment can also be obtained.

Since the washing machine in accordance with the present invention is capable of flushing out impurities or
10 contaminants such as detergent residues sticking on the outer cylindrical surface of a rotary drum by vigorous water currents generated by rotating the rotary drum at a high rotational speed, the outer cylindrical surface of the rotary drum can be kept hygienic. Thus, the present
15 invention can offer advantages when it is applied to a washing machine for performing washing, rinsing and water-extracting operations in a rotary drum having a substantially horizontal or slanted rotational axis.

While the invention has been shown and described with
20 respect to the preferred embodiment of the present invention, it will be understood by those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A washing machine comprising:

5 a rotary drum having an approximately horizontal or a slanted rotational axis;

a water tub elastically supported in a washing machine main body and accommodating the rotary drum therein;

a motor for rotating the rotary drum;

10 an inverter having one or more switching devices for supplying an electric power to the motor; and

a controller for controlling an operation of the motor by way of controlling one or more of the switching devices,

15 wherein the controller executes a rotary drum cleaning operation by using water collected in the water tub by way of controlling a rotational speed of rotary drum to be equal to a first rotational speed, the first rotational speed being greater than a rotational speed which makes laundry in the rotary drum to stick to the inner surface of the rotary drum but smaller than a normal rotational speed which is
20 required for extracting water from the laundry.

2. The washing machine of claim 1, wherein the controller controls washing, rinsing and water-extracting operations and executes the rotary drum cleaning operation during the
25 water-extracting operation.

3. The washing machine of claim 1 or 2, further comprising a current detector for detecting a current of the motor and for transmitting a signal based on the detected current to the controller, wherein the controller controls
5 the motor such that a current thereof is not greater than a specific value regardless of the signal from the current detector.

4. The washing machine of any one of claims 1 to 3,
10 further comprising a water drain valve for draining water from the washing machine, wherein the controller closes the water drain valve during the rotary drum cleaning operation.

5. The washing machine of any one of claims 1 to 4,
15 further comprising a water supply valve for supplying water into the water tub, wherein the controller operates the water supply valve to feed the water into the water tub.

6. The washing machine of claim 5, further comprising a
20 laundry amount detector for detecting an amount of laundry in the rotary drum, wherein the controller determines an operation time of the water supply valve based on the amount of the laundry detected by the laundry detector.

25 7. The washing machine of any one of claims 1 to 5, wherein the controller executes the rotary drum cleaning

operation after performing a laundry balancing operation and
a laundry balance monitoring operation in order, the laundry
balancing operation being carried out when the rotary drum
is substantially in a stopped state by rotating the rotary
5 drum at a second rotational speed high enough to make the
laundry in the rotary drum to stick to the inner surface of
the rotary drum but lower than the first rotational speed
and the laundry balance monitoring operation being carried
out by monitoring a balance state of the laundry by way of
10 rotating the rotary drum approximately at the second
rotational speed.

8. The washing machine of claim 7, wherein the controller
repeats the laundry balancing operation when unbalanced
15 laundry in the rotary drum is detected in the laundry
balance monitoring operation.