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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 (see, for example, Japanese Patent Laid-Open Application No. H10-211393 (pp. 3 and 4, Fig. 1)).

 With the above configuration, however, laundry tends
25 to float in wash water even when the rotary drum is rotated if the amount of the laundry in the rotary drum is

relatively small compared to the amount of wash water in the water tub. If such a condition is present, mechanical force cannot be properly applied to the laundry, so that it becomes difficult to effectively remove dirt from laundry.

5 Particularly, the above problem most frequently occurs when the laundry is made of a material such as synthetic fibers which does not absorb water very well, thereby making difficult to remove dirt from it.

10 Summary of the Invention

 It is, therefore, an object of the present invention to provide a washing machine capable of removing dirt from laundry by having an optimum washing operation regardless of
15 the amount or fabric types of laundry being washed.

 In accordance with 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 accommodating the rotary drum therein; a motor for
20 rotating the rotary drum; a current detector for detecting a current of the motor; and a controller for controlling an operation of the motor and a series of washing operations, wherein the controller detects a state of laundry in the rotary drum based on a value of current in the motor during
25 a washing operation.

Brief Description of the Drawings

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

Fig. 1 is a schematic cross sectional view of a washing machine in accordance with a first preferred embodiment of the present invention;

10 Fig. 2 shows a circuit diagram of the washing machine in accordance with the first embodiment of the present invention, wherein some of its components are represented by blocks;

15 Fig. 3 is a front view of an input setting unit and a display unit of the washing machine in accordance with the first embodiment of the present invention;

Fig. 4A is a chart plotting motor current against time during normal rotation (i.e., when the laundry is properly agitated by the rotation of rotary drum);

20 Fig. 4B is a similar chart as 4A representing motor current against time during free rotation (i.e., when the laundry is not agitated by the rotation of rotary drum);

25 Figs. 5A and 5B are a flow chart that controls a washing operation of the washing machine in accordance with the first embodiment of the present invention;

Fig. 6 is a flow chart that illustrates a subroutine

for calculating the average current value of the motor of the washing machine in accordance with the first embodiment of the present invention;

5 Figs. 7A and 7B are a flow chart that describes a subroutine for detecting a small amount of laundry in the washing machine in accordance with the first embodiment of the present invention;

10 Figs. 8A and 8B are a flow chart that illustrates a subroutine for controlling the water draining procedure when the laundry amount is found to be small in the washing machine in accordance with the first embodiment of the present invention;

15 Fig. 9 shows a timing chart of the motor during a washing operation of the washing machine in accordance with the first embodiment of the present invention;

Figs. 10A and 10B are a flow chart that controls washing operation of a washing machine in accordance with a second preferred embodiment of the present invention;

20 Fig. 11 is a flow chart that describes a subroutine for calculating the current amplitude of the washing machine in accordance with the second embodiment of the present invention;

25 Figs. 12A and 12B are a flow chart that illustrates a subroutine for detecting small laundry amount in the washing machine in accordance with the second embodiment of the present invention;

Figs. 13A and 13B are a flow chart that describes a control procedure during washing operation of a washing machine in accordance with a third preferred embodiment of the present invention;

5 Figs. 14A and 14B are a flow chart that illustrates a subroutine for calculating the average current value and the current amplitude of a motor of the washing machine in accordance with the third embodiment of the present invention; and

10 Figs. 15A and 15B are a flow chart that describes a subroutine for detecting a small amount of laundry in the washing machine in accordance with the third embodiment of the present invention.

15 Detailed Description of the Preferred Embodiments

Preferred embodiments of the present invention will now be described in connection with the accompanying drawings. It is to be noted, however, that the present invention is not limited to the preferred embodiments discussed below.

First embodiment

25 Hereinafter, a washing machine in accordance with a first preferred embodiment of the present invention will be described with reference to Figs. 1 to 9.

Fig. 1 is a schematic cross sectional view of the washing machine in accordance with the first embodiment of the present invention.

Washing machine main body 9 includes water tub 3 and
5 cylindrical rotary drum 1 disposed in water tub 3. Rotary drum 1 having a bottom surface is provided with multiple drum perforations 2 on its cylindrical surface and with rotating shaft (central axis of rotation) 4 at its center of
10 rotation while rotary drum 1 is arranged 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 so that it is capable of making rotary drum 1 to rotate in a forward and reverse direction. Further, multiple agitation blades 6
15 are disposed on the inner cylindrical wall of rotary drum 1.

Opening 3a 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
20 loading/unloading opening 8. Since door 7 is installed in the slopped surface, loading/unloading of laundry can be done without a user having to bend down considerably.

Water tub 3 is suspended in washing machine main body 9 by springs (not shown) such that is allowed to vibrate or
25 shake therein. 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 connected to water drain valve (water draining unit) 11 to drain wash water from water tub 3. Water supply valve (water supplying unit) 12 is used to fill water in water tub 3 via water supply conduit 13.

5 Further, 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 can also be arranged up such that its central axis of
10 rotation is approximately horizontal.

The configuration of control unit 14 for controlling each electric component will now be described with reference to the circuit diagram in Fig. 2.

As shown in Fig. 2, control unit 14 includes
15 controller 15 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 15, it receives
20 an input signal from input setting unit 16 for setting an operation course, while it informs user of the input information through display unit 17. Concurrently, once an operation is set and ready to start by input setting unit 16, controller 15 monitors the operation of water drain valve 11,
25 water supply valve 12 and switching unit 20 via switching unit driving circuit 19 based on the input data transmitted

from water level detector 18 for detecting the water level in water tub 3, and so forth, thereby carrying out a washing operation.

At this time, controller 15 controls the rotation of motor 5 by controlling inverter 23 via inverter driving circuit 22 based on the 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 composed 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 composed of a parallel circuit of a power transistor (e.g., 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 fourth switching devices 23c and 23d; and a serial circuit of fifth and sixth switching devices 23e and 23f, wherein the serial circuits are connected to each other in parallel.

Here, the 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

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 two switching devices in each serial circuit.

The on-off operations of the switching devices are controlled by controller 15 based on the data from three position detectors 21a to 21c, which are composed of hall IC's. Position detectors 21a to 21c are disposed at the stator by an interval of 120 degrees in electrical angle to face the permanent magnet provided in the rotor.

While the rotor makes one revolution, each of three position detectors 21a to 21c generates a pulse by the interval of 120 degrees in electrical angle. Controller 15 monitors changes in the state of signals from at least one of three position detectors 21a to 21c. When a change is detected, controller 15 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 high and low 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 15 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 transmits the voltage signal to controller 15. Subsequently, controller 15 performs an A/D conversion of the received voltage signal; processes thus A/D converted voltage signal as digital data; and controls the motor 5.

In case motor 5 is a brushless DC motor, its torque is substantially proportional to its input current. Thus, the torque of motor 5 can be detected by measuring the value of the input current of inverter 23 by current 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 1 based on a signal transmitted from current detector 24 when rotary drum 1 is driven to rotate at a predetermined rotational speed (e.g., 200 r/min).

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 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.

Next, examples of input setting unit 16 and display unit 17 will be described with reference to Fig. 3.

As shown in Fig. 3, input setting unit 16 includes washing time setting switch 16a for setting a washing time period, rinsing number setting switch 16b for setting the number of rinsing operations, water-extracting time setting switch 16c for setting a water-extracting time period, course setting switch 16d, start/pause switch 16e, power-on switch 16f, power-off switch 16g, and so forth. Display unit 17 includes washing time display unit 17a, rinsing number display unit 17b, water-extracting time display unit 17c, course setting display unit 17d, detergent amount indicator lamp 17e, residual operating time indicator lamp

17f, number display unit 17g, and so forth.

Here, while water is filled in water tub 3, controller 15 performs a cleaning (washing) operation by applying mechanical force to laundry in rotary drum 1 by rotating rotary drum 1. That is, by applying rotational force or frictional force to laundry, dirt is removed.

Further, during the cleaning operation, controller 15 operates water supply valve 12 to feed water into water tub 3. At this time, the amount of water supplied into water tub 3 is determined based on the amount of laundry detected by laundry amount detector 27.

The water level in water tub 3 is detected by water level detector 18. Controller 15 regulates the water level to be reached in water tub 3 during the cleaning operation based on the amount of laundry detected by laundry amount detector 27, as shown in Table 1.

Table 1

Laundry Amount	Amount of Water Supplied
0 to 2 kg	50 mm
2 to 4 kg	100 mm
4 to 6 kg	130 mm
6 to 8 kg	150 mm

Here, the amount of water supplied represents the depth from the lowermost point of rotary drum 1.

If laundry amount is detected to be large, the soiled

laundry can be washed more effectively by using a large amount of wash water. If the laundry amount is small, on the other hand, the washing process can be performed by using only a small amount of wash water. Therefore, the water level is set to be low when the laundry amount is also small.

Further, controller 15 can detect the rotational state of laundry in water tub 3 by using a current value of motor 5 which is detected by current detector 24 during the cleaning operation. In case motor 5 is a brushless DC motor, a torque exerted to motor 5 is substantially proportional to the motor current value. Thus, if the current value of motor 5 transmitted to controller 15 is high, it indicates that a high load (torque) is exerted on motor 5. If the current value of motor 5 transmitted to controller 15 is low, on the other hand, it indicates that a small load (torque) is applied on motor 5.

When the current value of motor 5 is high, it may be taken as having a large amount (for example, 6 kg to 8 kg) of laundry in water tub 3 or having a laundry type which is capable of absorbing wash water greatly even though the amount (for example, 2 kg to 3 kg) of laundry itself is not so large. The laundry type which is capable of absorbing water to a great extent becomes much heavier than its own weight because it can absorb so much wash water. Thus, a greater torque becomes necessary to rotate such laundry

containing a considerable amount of water.

In contrast, when the current value of motor 5 is low, it may be taken as having a small amount (for example, not greater than 2 kg) of laundry in water tub 3 or otherwise as experiencing a condition where laundry is floating in water while it is being agitated during washing. Herein, a laundry floating state refers to a condition where laundry does not contact agitation blades 6 even though rotary drum 1 is rotated, so that only the rotary drum 1 rotates while the laundry is floating near the surface of wash water. In this state, it becomes difficult to apply mechanical forces on such laundry, thereby making it difficult to effectively remove dirt from the laundry.

The laundry floating state occurs when the amount of wash water is greater than the optimum level or when the laundry is made of a fabric type which does not absorb water very well. However, it is sometimes possible to have an unusual case where the current value of motor 5 is low even though the amount of laundry in rotary drum 1 is large. For example, such aberration occurs when laundry rotates synchronous with the rotation of rotary drum 1. If laundry rotates together with rotary drum 1, the laundry is subject to minimal agitation necessary to wash it effectively, that is, laundry articles' forms and positions are not changed with respect to rotary drum 1 during the rotation. As a result, the load exerted on motor 5 becomes smaller and the

current value of motor 5 is reduced. This synchronous rotation of laundry with the rotary drum is not a usual phenomenon when the laundry amount is large, but its occurrence depends on how to laundry put into rotary drum 1 or on the types or qualities of laundry.

As described, the rotational state of laundry in rotary drum 1 can be assessed based on the value of current in motor 5 during the washing process. Further, by considering the laundry amount detected by laundry amount detector 27 as well when initiating the washing operation, the rotational state of laundry in rotary drum 1 can be more accurately assessed. Table 2 shows assessment examples of the rotational state of laundry in rotary drum 1 based on the data detected by laundry amount detector 27 and the current value of motor 5 (at this time, the water level is regulated according to the amount of the laundry as shown in Table 1).

Table 2

		Amount of Laundry [kg]			
		8 to 6	6 to 4	4 to 2	2 to 0
Current	4.0~	Normal	Normal	----	----
Value		Rotation	Rotation		
of	3.0 to 4.0	Normal	Normal	Normal	----
Motor		Rotation	Rotation	Rotation	

A	2.0 to 3.0	Normal Rotation	Normal Rotation	Normal Rotation	----
	1.5 to 2.0	Synchronous Rotation	Normal Rotation	Normal Rotation	Normal Rotation
	1.0 to 1.5	Synchronous Rotation	Synchronous Rotation	Normal Rotation	Normal Rotation
	0.5 to 1.0	----	Synchronous Rotation	Normal Rotation	Normal Rotation
	0.0 to 0.5	----	----	Normal Rotation	Normal Rotation

Detection of laundry floating state, which causes deterioration of cleaning efficiency in removing dirt from laundry, is important in monitoring the rotational state of laundry. By detecting the laundry floating state, a control for correcting the laundry floating state can be executed, to thereby enhance the removal of dirt from the laundry. As described above, laundry floats near the surface of wash water under at least one of two conditions. First, the laundry floating state is caused when the amount of wash water in water tub 3 is greater than an optimum level with respect to the amount of laundry. Second, the laundry floating state can also occur when laundry is made of a material such as synthetic fibers having a poor water absorbing property. If the current value of the motor is found to be low with respect to the amount of laundry, it means that at least one of the above two conditions has been

satisfied. Thus, the shaded portions in Table 2 may indicate the laundry floating states where the agitation blades do not effectively contact the laundry being washed.

The possibility of having laundry floating state due to the first condition is greatly affected by the detection accuracy of laundry amount detector 27. For example, if laundry detector 27 estimates the laundry amount as 2 to 4 kg despite the actual amount is actually smaller (0 to 2 kg), wash water is supplied up to 100 mm as shown in Table 1. This amount is even greater than that actually required. As a result, the laundry floats in the wash water. As such, by considering the detection accuracy of laundry amount detector 27, if the laundry amount is detected to be 2 to 4 kg but if the motor current value is low, it is assessed as having a laundry floating state.

Laundry floating state due to the second condition frequently occurs when washing clothes which are made of, for example, synthetic fibers and the laundry amount ranges from 0 to 2 kg approximately. In this case, the occurrence of laundry floating state is determined by considering the current value of motor 5 within such range of laundry amount. That is, if the laundry amount ranges from 0 to 2 kg and the current value of motor 5 is below a predetermined value, it could indicate the existent of laundry floating state.

Further, controller 15 can access the rotational state of laundry accommodated in water tub 3 based on fluctuations

in the values of motor current detected by current detector 24 during the washing process. In case motor 5 is a brushless DC motor, a torque exerted on motor 5 is substantially proportional to the current value of motor 5.

5 Thus, if the current value of the motor 5 transmitted to controller 15 is high, it indicates that a large load (torque) is exerted on motor 5. Conversely, if the current value of the motor 5 transmitted to controller 15 is low, it indicates that a small load (torque) is applied on motor 5.

10 Thus, based on the fluctuations in the current of motor 5 which is rotating, the rotational state of laundry can be determined. Alternatively, the rotational state of laundry can be assessed by using the amplitude of motor 5 current as shown in Figs. 4A and 4B.

15 As shown in Fig. 4B, if the fluctuation in the motor current value is small, it may imply that the change in the state of load exerted on motor 5 is also small, which also means that the laundry in rotary drum 1 is rotating while maintaining its current state without changing forms and

20 positions relative to rotary drum 1 or only the rotary drum 1 is rotating while laundry is floating in wash water, as discussed previously. If the motor current value has great amplitude synchronous with the rotation of rotary drum 1 as shown in Fig. 4A, it may indicate that the laundry in rotary

25 drum 1 is properly rotating to be properly subject to washing motion of the rotary drum. As described, by

detecting the amplitude level of the motor current synchronous with the rotation of rotary drum 1, the rotational state of the laundry can be assessed and, particularly, the laundry floating state, which is important factor in the washing operation, can be properly detected. A relationship between the laundry amount, the amplitude of motor current and the rotational state of the laundry is illustrated in Table 3.

Table 3

		Amount of Laundry [kg]			
		8 to 6	6 to 4	4 to 2	2 to 0
Amplitude A	2.0 ~	Normal Rotation	Normal Rotation	Normal Rotation	----
	1.5 to 2.0	Normal Rotation	Normal Rotation	Normal Rotation	----
	1.0 to 1.5	Synchronous Rotation	Normal Rotation	Normal Rotation	Normal Rotation
	0.5 to 1.0	----	Synchronous Rotation	Normal Rotation	Normal Rotation
	0.0 to 0.5	----	----	Flower Wash air dried	Flower Wash liquid

Further, controller 15 can determine the state of laundry in rotary drum 1 more accurately by detecting both the absolute value and amplitude level of the motor current during the washing process. Moreover, the laundry floating

state where the laundry floats in the wash water can be more accurately detected when both of the two conditions, namely, the small absolute value and small amplitude level of the motor current value are satisfied. In fact, consideration of the both conditions are required for an accurate detection of the laundry floating state because of a case where laundry rotates while being stuck on rotary drum 1 if the absolute value of the motor current is below a predetermined value although the amplitude thereof is small or a case where a small amount of laundry is properly rotating while being washed in case the amplitude level is above a predetermined level despite the absolute value of the motor current is below the predetermined value.

When the laundry floating state in rotary drum 1 is detected by the current detector 24 during the washing process, controller 15 drains a predetermined amount of wash water from water tub 3 by opening water drain valve 11 in order to allow an optimum amount of wash water in water tub 3. The amount of the drained water is controlled based on the water level detected by water level detector 18. For example, about 50 mm of wash water is drained by lowering the water level in water tub 3 from 150 mm to 100 mm. Alternatively, the amount of the drained water is controlled by controlling the time period for draining water based on the current water level as shown in Table 4.

Table 4

Amount of Laundry	Time Period for Water Drain
0 to 2 kg	10 seconds
2 to 4 kg	20 seconds
4 to 6 kg	30 seconds
6 to 8 kg	40 seconds

Further, if the presence of the laundry floating state is detected again based on the current value of motor 5 obtained by current detector 24 after performing the water draining procedure, water drain valve 11 is opened again so that some of remaining wash water is drained from water tub 3. That is, by executing the water draining operation multiple times in case the free rotational state of the rotary drum where laundry does not contact agitation blades properly (hereinafter the condition is referred to as "free rotational state"), is not corrected by performing the water draining operation once, it is possible to make sure that the free rotational state of the laundry is corrected. In each of the water draining procedures, the amount of water drained is controlled by the same method as employed in the first water draining operation. That is, the amount of water drained is controlled by on-off operating the water drain valve at specific water levels detected by the water level detector 18 such that the water level is reduced from, for example, 100 mm down to 80 mm. Alternatively, the amount of water drained can be controlled by regulating the

time period for operating water drain valve 11. When draining water for a predetermined time period, the amount of water drained is different depending on, e.g., the condition in which the water drain is being done. Therefore, there is an upper limit in the number of multiple draining procedures to avoid the wash water in water tub 3 from being completely drained, as illustrated in Table 5.

Table 5

Amount of Laundry	Repetition Number of Water Draining Operation
0 to 2 kg	1
2 to 4 kg	2
4 to 6 kg	3
6 to 8 kg	4

Operation of the washing machine configured as described above will now be described with reference to Figs. 5 to 9. After loading laundry into rotary drum 1, power-on switch 16f is turned on and an operation course is selected by using course setting switch 16d depending on the laundry type. Then, once start/pause switch 16e is pressed in step 100, the operation of the washing machine is started. First, controller 15 rotates rotary drum 1 and detects the amount of laundry in rotary drum 1 by using laundry amount detector 27 in step 101.

In step 102, ranking of the detected laundry amount is determined from 0 to 3 by every 2 kg. The amount from 0 to

2 kg is ranked as 0; 2 to 4 kg as 1; 4 to 6 kg as 2; and 6 to 8 kg as 3. Then, based on the detected laundry amount, a required amount of detergent is displayed on number display unit 17g while detergent amount indicator lamp 17e is on, and then the washing operation is performed. For example, the water amount (actually controlled by the level of water) supplied in water tub 3 during the washing operation is set based on the detected laundry amount as shown in Table 1.

A washing cycle is initiated from step 103 in which water supply valve 12 is opened, so that wash water is filled in water tub 3 up to a predetermined water level as illustrated in Table 1. When the laundry amount is large, the water level is set to be high while it is set to be low when the laundry amount is small. In step 104, motor 5 is driven to rotate rotary drum 1, thereby initiating the washing (cleaning) operation. During the cleaning operation, motor 5 is rotated in a clockwise and counterclockwise direction alternately according to a timing chart shown in Fig. 9, to thereby rotate rotary drum 1 while alternating the rotational direction thereof.

In step 105, operation of motor 5 is started. Then, in step 106, it is checked whether a predetermined time period (for example, 3 seconds) has passed after starting the operation of motor 5. If the predetermined time period has elapsed, the process proceeds to step 106 where the current of motor 5 is detected by current detector 24. Since the

starting operation of motor 5 requires a torque (starting torque) greater than that needed to rotate motor 5 while running, a greater amount of current flows in motor 5 when starting motor 5. Figs. 4A and 4B describe the relationships between the time elapsed after the starting operation of motor 5 and the current flowing in motor 5 during the rotation of motor 5, respectively. Since there exists an overshoot in the current flowing in motor 5 for a predetermined time period (for example, 3 seconds) after the starting operation of motor 5, the current can be stabilized after passing of a predetermined time period (3 seconds).

The level and the time of the overshoot vary depending on the starting control method of motor 5. Thus, the time required to stabilize the current of motor 5 would also differ depending on the starting control method. Accordingly, the time for the stabilization of the motor current is set through a trial experiment or the like after determining the starting control method. In order to detect the rotational state of laundry in rotary drum 1 during the rotation of motor 5, the current of motor 5 should not be detected until the predetermined time period has elapsed because the current value of motor 5 during the starting control does not always accurately reflect the rotational state of laundry in rotary drum 1.

In step 107, the average current value I_{mo_avg} that flows during the rotation of motor 5 is detected. It

sometimes happens that the value of the current flowing in motor 5 suddenly changes under various conditions (noise delivered to the detection circuit, minute change in the rotational state of laundry, etc.). Further, as shown in Figs. 4A and 4B, the current value flowing in motor 5 is changed synchronous with the rotational period of rotary drum 1 (laundry returns to its initial state after rotary drum 1 makes one revolution). Accordingly, the rotational state of laundry in rotary drum 1 can be evaluated by using the mean value of the current of motor 5 during a predetermined time period (for example, 2 seconds, or time period required for motor 5 to make one revolution).

A method for obtaining the average current value I_{mo_avg} will be described hereinafter with reference to a flow chart in Fig. 6. In step 120, it is determined whether it is time to detect the current of motor 5. If the current of motor 5 is set to be detected every 0.1 second, it is determined whether 0.1 second has passed after the previous detection. If 0.1 second has elapsed, the process proceeds to step 121 to detect the current flowing in motor 5. Before passing of 0.1 second, however, the detection of current is not performed and step 127 is executed to terminate the current subroutine.

In step 121, a voltage signal corresponding to a current value of motor 5 detected by current detector 24 is transmitted to controller 15, and controller 15 calculates a

motor current value I_{mo} from the input voltage signal. In step 122, controller 15 then adds the detected motor current value to the summation of motor current values I_{sum} for use in obtaining an average current value. At this time, 1 is added to the summation count C_t for counting the number of summation steps. Then, in step 123, it is determined whether it is time to calculate the average current value.

For example, if the average current value is set to be obtained every 2 seconds as described above, it is first determined whether 2 seconds has passed after the estimation of the previous average current value. If it is found that 2 seconds has elapsed, the process then proceeds to step 124 where an average current value of motor I_{mo_avg} is calculated again. Prior to the lapse of 2 seconds, however, step 127 is conducted and the current subroutine is terminated.

In step 124, an average current value of motor I_{mo_avg} is calculated from the summation of motor current values I_{sum} and the number of summation steps C_t by using a formula: $I_{mo_avg} = I_{sum}/C_t$. After obtaining the average current value of motor I_{mo_avg} in step 124, the summation of motor current values I_{sum} and the number of summation steps C_t are cleared in step 125 in order to obtain a next average current value of motor. Thereafter, a small laundry amount assessment 1 timing F indicating timing for a small laundry amount assessment is set by obtaining the average current

value of motor in step 126. Then, the current subroutine is terminated.

After the flow chart in Fig. 6 for obtaining the mean value of the motor current is finished, the process goes back to the flow chart in Figs. 5A and 5B, and a small laundry amount assessment 1 judgment is performed in step 108. A flow chart for a small laundry amount assessment 1 judgment is shown in Figs. 7A and 7B. In step 130, it is determined whether the termination of a small laundry amount assessment F is set. If the termination of a small laundry amount assessment F is set, it is interpreted that laundry's state of having a small amount has been already detected and laundry floating state is being corrected by draining wash water from water tub 3 several times, that is, that a small laundry amount assessment need not be performed again.

If the termination of a small laundry amount assessment F is set, the process goes to step 142 and the current subroutine is terminated; if otherwise, step 131 is performed. In step 131, laundry's state of having a small amount is detected and it is determined whether draining of wash water is now being performed to correct the laundry floating state. In case draining of wash water is now being carried out, the process proceeds to step 142 to end the current subroutine, draining for a small laundry amount F is set and during which the small laundry amount assessment is not necessary during this time.

If draining of water is not being performed, it is determined in step 132 whether a small laundry amount assessment 1 timing F is set. A small laundry amount assessment 1 timing F is a flag representing that an average
5 current value of motor Imo_avg has been obtained. If the flag is set, it means that a new average current value of motor Imo_avg has been obtained, so that the process goes to step 133 in order to perform a small laundry amount assessment 1.

10 In step 133, a small laundry amount assessment 1 timing F is cleared for next detection. Then, 1 is added to a total number of assessment representing the total assessment numbers of a small laundry amount assessment 1 (i.e., repetition number of the step of detecting a average
15 current value of motor Imo_avg) in step 134. Thereafter, in step 135, it is determined whether the currently obtained average current value of motor Imo_avg is lower than a predetermined value (for example, a peak value of a average current value of motor Imo_avg is equal to or less than 1.0
20 A). In case the laundry amount is small relative to the amount of wash water and, thus, the laundry floats on the wash water, a load (torque) exerted on motor 5 and a current flowing in motor 5 are both reduced. Accordingly, if the average current value of motor Imo_avg is lower than a
25 predetermined value, it may imply that laundry is floating on wash water. In such case, 1 is added to the number of

small laundry amount assessment CT in step 136.

5 In step 137, it is determined whether the total number of assessment CT is greater than a predetermined value (for example, 20). Since the amplitude of the average current value of motor is different according to the rotational state of laundry, it may be difficult to decide the occurrence of laundry floating state by measuring a current value only once (for example, measuring a current value during 2 seconds) and there is a concern that the laundry's state is wrongly estimated in such a case. Therefore, the rotational state of laundry can be more accurately detected by detecting motor current, for example, 20 times (i.e., 20 revolutions in case of detecting a current value every 2 seconds with motor 5 at a rotational speed of 30 r/min). If 10 a assessment of a predetermined number has been performed, it is determined in step 138 whether the laundry floats on the wash water. If the number of assessment has not been reached, however, the current subroutine is terminated and the detection of motor current is continued.

20 In step 138, it is determined whether the number of small laundry amount assessment CT is greater than a predetermined value (for example, 19). If the average current value of motor is found to be below a predetermined level more than a predetermined number of times with respect to the total number of assessment, it is determined that a 25 laundry floating state occurs. Here, by considering, e.g.,

a detection error, it is determined that a laundry floating state occurs if the average current value of motor is found to be lower than a predetermined level more than 19 times among 20 times of the total number of assessment. If the laundry floating state is detected, a small laundry amount F is set in step 139. If the laundry floating state is not detected, step 139 is skipped and step 140 is performed. In steps 140 and 141, in order to detect a next small laundry amount assessment, the number of small laundry amount assessment CT and the total number of assessment CT are cleared, respectively.

After the completion of a small laundry amount assessment 1 judgment, the process goes back to the flow chart in Figs. 5A and 5B and a water drain control process is performed in step 109. Referring to Figs. 8A and 8B, there is provided a flow chart that describes the water drain control process. In case the small laundry amount assessment is carried out, a predetermined amount of wash water in water tub 3 is drained such that the laundry floating state is corrected.

In step 150, it is checked whether the termination of the small laundry amount assessment F is set. If the termination of the small laundry amount assessment F is set, the water drain control process is ended. Then, it is determined in step 151 whether draining for small laundry amount F is set. If draining of water is being performed by

detecting laundry's state of having a small amount, the process proceeds to step 156 to continue the water draining operation. If draining of water is not being performed, on the other hand, step 152 is executed to determine whether a
5 small laundry amount F is set. If the small laundry amount F is set, steps after step 153 are performed to initiate a draining operation. If the small laundry amount F is not set, however, the current subroutine is terminated.

In step 153, the small laundry amount F is cleared and
10 in step 154, draining for small laundry amount F indicating that draining of water is now being performed is set. Thereafter, in step 155, water drain valve 11 is on-operated by controller 15, thereby starting a water draining operation. In step 156, controller 15 keeps operating water
15 drain valve 11 to thereby continue the water draining operation. Then, in step 157, it is determined whether a third predetermined time period set for the water draining operation has passed. With the lapse of the third predetermined time period, the water draining operation is
20 terminated.

The third predetermined time period is set based on the amount of laundry detected by laundry amount detector 27, as shown in Table 5. For example, when water is supplied to a high level because the laundry amount is detected to be
25 great, a greater amount of wash water needs to be drained, so that the third predetermined time period is set to be 30

seconds. On the other hand, in case the laundry amount is detected to be small, there is a concern that little wash water would remain if the amount of the drained water is excessively large, so that the third predetermined time
5 period is set to be shorter, e.g., 10 seconds.

After the passing of the third predetermined time period, the water draining operation is finished, and 1 is added to draining count CT for counting the repetition number of water drain controls triggered by the small
10 laundry amount assessment in step 158. Afterward, in step 159, draining for small laundry amount F is cleared. If draining count CT is determined to have reached a predetermined value (which value is set based on the laundry amount as shown in Table 4) in step 160, the termination of
15 the small laundry amount assessment F indicating that no more small laundry amount assessment is to be performed is set in step 161. Since there frequently occur cases where the laundry floating state cannot be corrected by performing the water drain control only once, such determination is
20 made in order to execute the water draining operation several times. Further, setting of an upper limit in the repetition number of the water drain control is required in order to prevent an excessive amount of wash water from being drained, resulting in a failure to perform washing
25 operation. Then, in step 162, the subroutine for the water drain control is terminated, and the process goes back to

step 110 in the flow chart shown in Figs. 5A and 5B.

Referring back to the flow chart in Figs. 5A and 5B, it is determined in step 110 whether a time for driving motor 5 has elapsed. As described above, since the washing operation is performed by rotating the motor in the clockwise and the counterclockwise direction alternately according to the timing chart in Fig. 9, it assesses whether a complete operation cycle has been reached. If the motor driving time has not been reached, the process goes back to step 107 to perform a small laundry amount assessment. When the motor driving time has passed, on the other hand, motor 5 is turned off in step 111. If the passing of the time for stopping motor 5 is detected in step 112, it is determined in step 113 whether the washing time (for example, 30 minutes) for the washing operation has passed. With the lapse of the washing time, step 114 is performed so that the next process (rinsing process after draining wash water) is performed. If the washing time has not been reached yet, the process goes back to step 105 in which motor 5 is driven to continue the washing operation and the existence of laundry floating state is checked.

As described above, the state where the amount of laundry is small and the laundry is in the free rotation state in rotary drum 1 is detected by using the current value of motor 5 which is detected by current detector 24. If the laundry's such state is detected, a predetermined

amount of wash water is drained from water tub 3, so that a washing operation appropriate for the laundry's current state can be performed while fully removing dirt from the laundry.

5

Second embodiment

A washing machine in accordance with a second preferred embodiment of the present invention will now be described with reference to Figs. 10 to 12, in which
10 components identical to those described in the first embodiment will be assigned same reference numerals and description thereof will be omitted.

The important technical feature of the second embodiment is in the fact that the rotational state of
15 laundry in rotary drum 1 is determined based on the amplitude of a current value of motor 5 detected by current detector 14. Hereinafter, operation of the washing machine in accordance with the second embodiment will be described in conjunction with Figs. 10 to 12.

20 After loading laundry into rotary drum 1, power-on switch 16f is turned on and an operation course is selected by using course setting switch 16d depending on the type of laundry. Then, once start/pause switch 16e is pressed in step 200, the operation of the washing machine is started.
25 First, controller 15 rotates rotary drum 1 and detects the laundry amount in rotary drum 1 using laundry amount

detector 27 in step 201. Then, in step 202, ranking of the detected laundry amount is set from 0 to 3 by every 2 kg. That is, the amount from 0 to 2 kg is ranked as 0; 2 to 4 kg as 1; 4 to 6 kg as 2; and 6 to 8 kg as 3.

5 Then, based on the detected laundry amount, a required amount of detergent is displayed on number display unit 17g while detergent amount indicator lamp 17e is on, and the, washing operation is performed. For example, the water amount (actually controlled by water level) supplied in
10 water tub 3 during a washing operation is set based on the detected laundry amount as shown in Table 1. Thereafter, a washing cycle is initiated from step 203.

 In step 203, water supply valve 12 is turned on, so that wash water is fed into water tub 3 up to a set water
15 level as illustrated in Table 1. When the laundry amount is large, the water level is set to be high while it is set to be low when the laundry amount is small. In step 204, motor
20 5 is driven to rotate rotary drum 1, thereby initiating the washing (cleaning) operation. During the cleaning operation, motor 5 is rotated in a clockwise and a counterclockwise
 direction alternately according to a timing chart shown in Fig. 9, to thereby rotate rotary drum 1 while reversing the rotational direction thereof.

 In step 205, operation of motor 5 is started. Then, in
25 step 206, it is checked whether a predetermined time period (for example, 3 seconds) has passed after starting motor 5.

If the predetermined time period has elapsed, the process proceeds to step 207 where the current of motor 5 is detected by current detector 24. Since starting the operation of motor 5 requires a torque (starting torque) greater than that needed to rotate motor 5 in a running state, a greater amount of current has to flow in motor 5 when starting motor 5.

Figs. 4A and 4B describe the relationships between the time elapsed after the starting operation of motor 5 and the current flowing in motor 5 during the rotation of motor 5, respectively. Since there exists an overshoot in the current flowing in motor 5 for a predetermined time period (for example, 3 seconds) after the starting operation of motor 5, it takes the predetermined time period (3 seconds) for the current of motor 5 to be stabilized. Here, the level and the time of the overshoot vary depending on the starting control method of motor 5. Thus, the time required to stabilize the current of motor 5 would also differ depending on the starting control method. Accordingly, the time for the stabilization of the motor current is set through a trial experiment or the like after determining the starting control method. In order to detect the rotational state of laundry in rotary drum 1 during the rotation of motor 5, the value of current in motor 5 should not be detected until the predetermined time period has elapsed from the starting operation of the motor because a current

value of motor 5 measured during the starting control does not always reflect the rotational state of laundry in rotary drum 1.

In step 207, a current amplitude Imo_amp is detected.
5 Since the value of current in motor 5 is changed synchronous with the rotational cycle of rotary drum 1 (laundry returns to its initial state after rotary drum 1 makes one revolution), the rotational state of laundry in rotary drum 1 can be estimated by using the difference between the
10 maximum motor current value and the minimum motor current value which are obtained during a predetermined time period (for example, 2 seconds, or time period required for motor 5 to make one revolution).

A method for obtaining a current amplitude Imo_amp
15 will be described hereinafter with reference to a flow chart in Fig. 11.

In step 220, it is determined whether it is time to detect the current of motor 5. If the motor current is set to be detected every 0.1 second, it is determined whether
20 0.1 second has passed after the previous detection. If 0.1 second has elapsed, the process goes to step 221 to detect current. Before the lapse of 0.1 second, however, the detection of current is not performed and step 228 is executed to terminate the current subroutine.

25 In step 221, a voltage signal corresponding to a current value of motor 5 detected by current detector 24 is

transmitted to controller 15, and controller 15 calculates a motor current value I_{mo} from the input voltage signal. In step 222, controller 15 overwrites the maximum motor current value I_{mo_max} for use in obtaining the amplitude of motor current. Then, the maximum motor current value I_{mo_max} , which represents the highest value among motor current values detected so far, is compared with the presently obtained motor current value I_{mo} . If the motor current value I_{mo} is higher than the maximum motor current value I_{mo_max} , the present motor current value I_{mo} is set as a new maximum motor current value I_{mo_max} .

In step 223, controller 15 overwrites a minimum motor current value I_{mo_min} for obtaining the amplitude of motor current. Then, the minimum motor current value I_{mo_min} , which represents the lowest value among motor current values detected so far, is compared with the presently obtained motor current value I_{mo} . If the motor current value I_{mo} is lower than the minimum motor current value I_{mo_min} , the present motor current value I_{mo} is set as a new minimum motor current value I_{mo_min} .

In step 224, it is determined whether it is time to detect a current amplitude value. For example, if the current amplitude value is set to be obtained every 2 seconds as described above, it is determined whether 2 seconds has passed after the calculation of the previous current amplitude value. If it is found that 2 seconds has

elapsed, the process then proceeds to step 225 where a current amplitude value Imo_amp ($=Imo_max - Imo_min$) is calculated.

Before the passing of 2 seconds, however, step 228 is performed and the current subroutine is terminated. The time interval of 2 seconds between every detection of the current amplitude value is the time required to allow rotary drum to make one revolution in case of rotating rotary drum 1 (motor 5) at a rotational speed of 30 r/min. The current amplitude during the 2 seconds reflects the rotational state of laundry in rotary drum 1.

In step 226, the minimum motor current value Imo_min and the maximum motor current value Imo_max are cleared in order for the next detection of the current amplitude of motor current. Thereafter, a small laundry amount assessment 2 timing F indicating timing for small laundry amount assessment is set by obtaining the current amplitude of motor current in step 227. Then, the current subroutine is terminated in step 228.

After the flow chart in Fig. 11 for obtaining current amplitude value is finished, the process goes back to the flow chart in Figs. 10A and 10B, and a small laundry amount assessment 2 judgment is performed in step 208. A flow chart for small laundry amount assessment 2 judgment is shown in Figs. 12A and 12B.

In step 230, it is determined whether the termination

of small laundry amount assessment F is set. If the termination of small laundry amount assessment F is set, it is interpreted that the state of having only a small amount of laundry has been already detected and laundry floating state is being corrected by draining wash water from water tub 3 for a predetermined number of times, that is, that small laundry amount assessment of laundry need not be performed again. If the termination of small laundry amount assessment F is set, the process goes to step 242 and the current subroutine is terminated; if otherwise, step 231 is performed. In step 231, it is determined whether the state of having only a small amount of laundry has been detected and draining of wash water is now being performed to correct the laundry floating state. If draining of wash water is now being carried out, the process proceeds to step 242 to end the current subroutine, for draining for small laundry amount F is set while the draining is being performed, during which the small laundry amount assessment is not necessary. If draining of water is not being performed, it is determined in step 232 whether a small laundry amount assessment 2 timing F is set.

The small laundry amount assessment 2 timing F is a flag indicating that a current amplitude value Imo_amp of motor current has been obtained. If the flag is set, it means that a new current amplitude value Imo_amp has been obtained, so that the process goes to step 233 in order to

perform small laundry amount assessment 2.

In step 233, the small laundry amount assessment 2 timing F is cleared for next detection. Then, 1 is added to a total number of assessment CT representing the total
5 number of small laundry amount assessment 2 (i.e., repetition number of the step of calculating a current amplitude value Imo_amp) in step 234. Thereafter, in step 235, it is determined whether a just obtained current
10 amplitude value Imo_amp is lower than a predetermined value (for example, 0.5 A). In case the laundry amount is small relative to the amount of wash water and, thus, the laundry floats in the wash water, a load (torque) exerted on motor 5 is reduced and a change in load is also reduced while rotary drum 1 (motor 5) makes one revolution. Accordingly, if the
15 amplitude value of motor current is lower than a predetermined value, it may imply that laundry is in the free rotation state with no load exerted thereon. In such case, it is determined that the laundry floats in the wash water and therefore, 1 is added to the number of small
20 laundry amount assessment CT in step 236.

In step 237, it is determined whether the total number of assessment CT is greater than a predetermined value (for example, 20). In order to improve the accuracy of detection, the rotational state of laundry is determined after
25 performing the detection multiple times. Specifically, if the total number of assessment reaches a predetermined value,

it is determined that the laundry floats in wash water. If the total number of assessment does not reach the predetermined value, however, the current subroutine is terminated in step 242 because the detection is continued.

5 In step 238, it is determined whether the number of small laundry amount assessment CT is greater than a predetermined value (for example, 19). If the amplitude value of motor current is detected to be below a predetermined level more than a predetermined number of
10 times with respect to the total number of assessment, it is determined that the laundry floats in wash water. If the laundry floating state is detected, the small laundry amount F is set in step 239; if not, step 239 is skipped and step 240 is performed. In steps 240 and 241, the small laundry
15 amount assessment CT and the total number of assessment CT are cleared, respectively.

 After completing small laundry amount assessment 2 judgment in step 242, the process goes back to the flow chart in Figs. 10A and 10B and a water drain control process
20 is performed in step 209. Here, the water drain control process is identical to that described in Figs. 8A and 8B in accordance with the first embodiment, thus its description will be omitted. By reducing the amount of wash water through the water drain control, the free rotation state of
25 laundry can be corrected.

 After finishing the water drain control according to

the flow chart in Figs. 8A and 8B, the process goes back to step 210 in the flow chart shown in Figs. 10A and 10B. In step 210, it is determined whether a time for driving motor 5 has elapsed. As described above, since washing operation is conducted by rotating the motor in the clockwise and the counterclockwise direction alternately according to the timing chart in Fig. 9, whether a complete operation cycle has been reached. If the motor driving time has not passed yet, the process goes back to step 207 to perform small laundry amount assessment again. When the motor driving time has passed, on the other hand, motor 5 is turned off in step 211.

If the lapse of the time for off-operating motor 5 is detected in step 212, it is determined in step 213 whether the washing time (for example, 30 minutes) for the washing operation has passed. With the lapse of the washing time, step 214 is performed so that the next process (rinsing process after draining wash water) is performed. If the washing time has not passed yet, the process goes back to step 205 in which motor 5 is started again to continue the washing operation and the existence of laundry floating state is checked.

As described above, the state where the laundry amount is small and the laundry is in the free rotation state in rotary drum 1 is detected by using the amplitude of current value of motor 5 which is detected by current detector 24.

If the free rotation state of laundry is detected, a predetermined amount of wash water is drained from water tub 3, so that a washing operation adequate for the laundry's current state can be performed, while fully removing dirt
5 from the laundry.

Third embodiment

A washing machine in accordance with a third preferred embodiment of the present invention will now be described
10 with reference to Figs. 13 to 15, in which components identical to those described in the first or the second embodiment will be assigned same reference numerals and description thereof will be omitted.

After loading laundry into rotary drum 1, power-on
15 switch 16f is turned on and an operation course is selected by using course setting switch 16d depending on the type of the laundry. Then, once start/pause switch 16e is pressed in step 300, the operation of the washing machine is started.

First, controller 15 rotates rotary drum 1 and detects
20 the laundry amount in rotary drum 1 by using laundry amount detector 27 in step 301. Then, in step 302, ranking of the detected laundry amount is determined from 0 to 3 by every 2 kg. That is, the amount from 0 to 2 kg is ranked as 0; 2 to 4 kg as 1; 4 to 6 kg as 2; and 6 to 8 kg as 3. Then, based
25 on the detected laundry amount, a required amount of detergent is displayed on number display unit 17g while

detergent amount indicator lamp 17e is on, and then, washing operation is performed.

For example, the water amount (controlled by water level) supplied in water tub 3 during a washing operation is set based on the detected laundry amount as shown in Table 1. Thereafter, a washing cycle is initiated from step 303. In step 303, water supply valve 12 is turned on, so that wash water is fed into water tub 3 up to a set water level as illustrated in Table 1. When the laundry amount is large, the water level is set to be high while it is set to be low when the laundry amount is small. In step 304, motor 5 is driven to rotate rotary drum 1, thereby initiating the washing (cleaning) operation. During the cleaning operation, motor 5 is rotated in a clockwise and counterclockwise direction alternately according to a timing chart shown in Fig. 9, to thereby rotate rotary drum 1 while reversing its rotational direction.

In step 305, operation of motor 5 is started. Then, in step 306, it is checked whether a predetermined time period (for example, 3 seconds) has passed after starting the operation of motor 5. If the predetermined time period has elapsed, the process goes to step 307 where the current of motor 5 is detected by current detector 24. Since a torque (starting torque) greater than that needed to rotate motor 5 in a running state is required to start motor 5, a greater amount of current flows in motor 5 when starting motor 5.

Figs. 4A and 4B describe the relationships between the time elapsed after starting motor 5 and the current flowing in motor 5 during the rotation of motor 5, respectively. Since there exists an overshoot in the current flowing in motor 5 for a predetermined time period (for example, 3 seconds) after starting motor 5, it takes a predetermined time period (3 seconds) for the current of motor 5 to be stabilized. Here, the level and the time of the overshoot vary depending on the starting control method of motor 5. Thus, the time required to stabilize the current of motor 5 would also differ depending on the starting control method. Accordingly, the time for the stabilization of motor current is set through a trial experiment or the like after determining the starting control method. In order to detect the rotational state of laundry in rotary drum 1 during the rotation of motor 5, a current value of motor 5 should not be detected until the predetermined time period elapses because a current value of motor 5 measured at a time of starting motor 5 does not always reflect the rotational state of laundry in rotary drum 1.

In step 307, an average current value of motor I_{mo_avg} and a current amplitude I_{mo_amp} of the current value are detected. There sometimes occurs a case where the current value of motor 5 instantaneously changes under various conditions (noise delivered to a detection circuit, minute change in the rotational state of laundry, etc.). Further,

as shown in Figs. 4A and 4B, since a current value of motor 5 is changed synchronous with the rotational cycle of rotary drum 1 (laundry returns to its initial state after rotary drum 1 makes one revolution), the rotational state of laundry in rotary drum 1 can be estimated by using an average current value of motor I_{mo_avg} which is obtained during a predetermined time period (for example, 2 seconds, or time period required for motor 5 to make one revolution).

Moreover, since a current value of motor 5 is changed synchronous with the rotational cycle of rotary drum 1 (laundry returns to its initial state after rotary drum 1 makes one revolution), the rotational state of laundry in rotary drum 1 can be assessed by using a difference between a maximum motor current value and a minimum motor current value which are obtained during a predetermined time period (for example, 2 seconds, or time period required for motor 5 to make one revolution). By detecting such two states together, a more accurate detection of the rotational state of laundry in rotary drum 1 can be made.

A method for obtaining an average current value of motor I_{mo_avg} and a current amplitude I_{mo_amp} will be described hereinafter with reference to a flow chart in Figs. 14A and 14B. In step 320, it is determined whether it is time to detect the current of motor 5. For example, if the motor current is set to be detected every 0.1 second, it is determined whether 0.1 second has passed after the previous

detection. If 0.1 second has elapsed, the process goes to step 321 to detect the current. Before the lapse of 0.1 second, however, the detection of current is not performed and step 331 is executed to terminate the current subroutine

5 In step 321, a voltage signal corresponding to a current value of motor 5 detected by current detector 24 is transmitted to controller 15, and controller 15 calculates a motor current value I_{mo} from the input voltage signal. In step 322, controller 15 then adds the currently obtained
10 motor current value I_{mo} to a summation of motor current values I_{sum} for obtaining an average current value. At this time, 1 is added to the summation count C_t for counting the number of summation steps.

15 In step 323, controller 15 overwrites a maximum motor current value I_{mo_max} for obtaining the amplitude of motor current. Then, the maximum motor current value I_{mo_max} , which represents the highest value among motor current values detected so far, is compared with the motor current value I_{mo} just obtained. If the motor current value I_{mo} is
20 higher than the maximum motor current value I_{mo_max} , the latest motor current value I_{mo} is set as a new maximum motor current value I_{mo_max} .

25 In step 324, controller 15 overwrites a minimum motor current value I_{mo_min} for use in obtaining the amplitude of motor current. Then, the minimum motor current value I_{mo_min} , which represents the lowest value among motor

current values detected so far, is compared with the motor current value I_{mo} just obtained. If the motor current value I_{mo} is lower than the minimum motor current value I_{mo_min} , the latest motor current value I_{mo} is set as a new minimum motor current value I_{mo_min} . In step 325, it is determined whether it is time to detect an average current value of motor and a current amplitude value. For example, the average current value of motor and the current amplitude value are set to be obtained every 2 seconds for the reason as described above. If it is determined that a predetermined time (2 seconds) has passed after the previous detection, the process then proceeds to step 326.

In step 326, average current value of motor I_{mo_avg} is calculated from the summation of motor current values I_{sum} and the number of summation steps Ct by using a formula:
$$I_{mo_avg} = I_{sum}/Ct.$$
After obtaining the average current value of motor I_{mo_avg} , the summation of motor current values I_{sum} and the number of summation steps Ct are cleared in step 327 in order to obtain the next average current value of motor I_{mo_avg} .

In step 328, after calculating a current amplitude value I_{mo_amp} ($=I_{mo_max} - I_{mo_min}$), the minimum motor current value I_{mo_min} and the maximum motor current value I_{mo_max} are cleared for next detection of the current amplitude of motor current in step 329. In step 330, the mean value and the current amplitude value of motor current

are obtained and a small laundry amount assessment 3 timing F indicating a timing for small laundry amount assessment is set. Thereafter, the current subroutine is terminated in step 331.

5 After the flow chart in Figs. 14A and 14B for obtaining the mean value and the amplitude value of motor current is finished, the process goes back to the flow chart in Figs. 13A and 13B, and small laundry amount assessment 3 judgment is performed in step 308. A flow chart for the
10 small laundry amount assessment 3 judgment is shown in Figs. 15A and 15B.

 In step 340, it is determined whether the termination of small laundry amount assessment F is set. If the termination of small laundry amount assessment F is set, it
15 is interpreted that a state of having a small amount of laundry has been already detected and laundry floating state is being corrected by draining wash water from water tub 3 for a predetermined number of times, that is, that small laundry amount assessment of laundry need not be performed
20 again. Therefore, the process goes to step 356 to terminate the current subroutine.

 If the termination of small laundry amount assessment F is not set, on the other hand, the process goes to step 341 in which it is determined whether the state of having a
25 small amount of laundry has been detected and draining of wash water is now being performed to correct the laundry

floating state. If draining of wash water is now being carried out, the process proceeds to step 356 to end the current subroutine, for draining for small laundry amount F is set while the draining is being performed, during which
5 the small laundry amount assessment is not necessary.

If draining of water is not being performed, it is determined in step 342 whether the small laundry amount assessment 3 timing F is set. As described before, the small laundry amount assessment 3 timing F is a flag
10 indicating that an average current value of motor Imo_avg and a current amplitude value Imo_amp have been obtained. If the flag is set, it means that a new average current value of motor Imo_avg and a new current amplitude value Imo_amp have been obtained, so that the process goes to step
15 343 in order to perform small laundry amount assessment 3.

In step 343, the small laundry amount assessment 3 timing F is cleared for next detection. Then, 1 is added to a total number of assessment CT representing the total number of small laundry amount assessment 3 (i.e.,
20 repetition number of the step of calculating an average current value of motor Imo_avg and an current amplitude value Imo_amp) in step 344.

Thereafter, in step 345, it is determined whether the currently obtained average current value of motor Imo_avg is
25 lower than a predetermined value (for example, a peak value of the average current value of motor Imo_avg is equal to or

less than 1.0 A). In case the laundry amount is small relative to the amount of wash water and, thus, the laundry floats in the wash water, load (torque) exerted on motor 5 and current flowing in motor 5 are both reduced.

5 Accordingly, if the average current value of motor `Imo_avg` is lower than a predetermined value, it may imply that laundry is floating in wash water. In such case, 1 is added to the number of average current assessment CT in step 346.

10 Further, in step 347, it is determined whether the currently obtained current amplitude value `Imo_amp` is lower than a predetermined value (for example, 0.5 A). In case the laundry amount is small relative to the amount of wash water and, thus, the laundry floats in the wash water, load (torque) exerted on motor 5 is reduced and a change in load
15 is also reduced while rotary drum 1 (motor 5) makes one revolution. Accordingly, if the current amplitude value `Imo_amp` is lower than a predetermined value, it may imply that laundry is in free rotation with no load exerted thereon. In such case, it is determined that the laundry
20 floats on the wash water and 1 is added to the number of amplitude assessment CT in step 348.

In step 349, it is determined whether the total number of assessment CT is greater than a predetermined value (for example, 20). In order to improve the accuracy of detection,
25 the rotational state of laundry is determined after performing the detection of the current amplitude multiple

times. Specifically, if the total number of assessment reaches a predetermined value, it is determined that the laundry really floats in the wash water. If the total number of assessment does not reach the predetermined value, however, the current subroutine is terminated in step 356 to continue the detection of the current amplitude.

In step 350, it is determined whether a number of average current assessment CT is greater than a predetermined value (for example, 19). If the average current value of motor is found to be below a predetermined level more than a predetermined number of times with respect to the total number of assessment, it is determined that a laundry floating state is present. In case of detecting the laundry floating state, detection of laundry's state is performed again through the use of current amplitude in step 351. In step 351, it is whether the number of amplitude assessment CT is greater than a predetermined value (for example, 19). If the current amplitude value is detected to be below a predetermined level more than a predetermined number of times with respect to the total number of assessment, it is determined that the laundry floats on the wash water.

As described above, since laundry floating state is determined only when the both mean and amplitude values of motor current are below predetermined values in accordance with the third embodiment of the present invention described

above, the probability of inaccurately detecting laundry floating state can be reduced, allowing more accurate detection of laundry's rotational state.

5 If laundry floating state is detected in both of steps 350 and 351, the small laundry amount F is set in step 352; if otherwise, step 352 is skipped and step 353 is performed. In steps 353, 354 and 355, the number of average current assessment CT, the number of amplitude assessment CT and the total number of assessment CT are cleared to perform a next
10 small laundry amount assessment, respectively.

After finishing small laundry amount assessment 3 judgment in step 356, the process goes back to the flow chart in Figs. 13A and 13B and a water drain control process is performed in step 309. Here, the water drain control
15 process is identical to that described in Figs. 8A and 8B in accordance with the first embodiment, and description thereof will be omitted. By reducing the amount of wash water through the water drain control, the free rotation state of laundry can be corrected.

20 After finishing the flow chart in Figs. 8A and 8B, the process goes back to step 310 in the flow chart shown in Figs. 13A and 13B. In step 310, it is determined whether a time for driving motor 5 has elapsed. As described above, since washing operation is conducted by rotating the motor
25 in the clockwise and counterclockwise direction alternately according to the timing chart in Fig. 9, whether a complete

operational cycle has been reached. If the motor driving time has not passed yet, the process goes back to step 307 to perform small laundry amount assessment again. When the motor driving time has passed, on the other hand, motor 5 is
5 turned off in step 311.

If the lapse of the time for off-operating motor 5 is detected in step 312, it is determined in step 313 whether a washing time (for example, 30 minutes) for the washing operation has passed. With the lapse of the washing time,
10 step 314 is performed so that a next process (a rinsing process after draining wash water) is conducted. If the washing time has not passed yet, the process goes back to step 305 in which motor 5 is started again to continue the washing operation and the presence of laundry floating state
15 is checked.

As described above, the state where the laundry amount is small and the laundry is in free rotation in rotary drum 1 is detected by using a current value of motor 5 and amplitude thereof which are detected by current detector 24
20 and, if the free rotation state of laundry is detected, a predetermined amount of wash water is drained from water tub 3, so that a washing operation adequate for the laundry's current state can be performed, while fully removing soils from the laundry.

25 Moreover, since controller 15 detects laundry's state in rotary drum 1 by using a current value of motor 5

detected by current detector 24 during a washing operation, a laundry floating state in which laundry floats on wash water and mechanical force is not properly applied to the laundry can be detected. Further, by performing an optimum
5 washing operation based on the amount or the types of laundry after correcting the laundry floating state, dirt can be removed from the laundry sufficiently.

Further, since controller 15 determines laundry's state in rotary drum 1 by using a current value of motor 5
10 which is detected by current detector 24 after a predetermined time period passes after motor 5 is started, a motor starting current containing overshoot during the starting of the motor can be ignored, thereby allowing more accurate detection of laundry's state in rotary drum 1.

15 Furthermore, controller 15 determines that the laundry amount in rotary drum 1 is small and laundry is in the free rotation therein when a current value of motor 5 detected by current detector 24 is below a predetermined value. Thus, by performing a washing operation adequate for the laundry's
20 state thereafter, removal of dirt from laundry can be carried out sufficiently. Moreover, since the detection of the current flowing in motor 5 is equivalent to the direct detection of the state of load exerted on motor 5, laundry's state in rotary drum 1 can be accurately and simply detected
25 by detecting an absolute value of motor current.

Further, controller 15 determines that the amount of

laundry in rotary drum 1 is small and laundry is in the free rotation state therein in case the fluctuation range of the current value of the motor 5 detected by current detector 24 during a washing operation is below a predetermined value.

5 Thereafter, since washing operation corresponding to different laundry types can be performed, dirt of laundry are fully removed from the laundry. Moreover, if the fluctuation range of the current value of the motor is small, it can be estimated that laundry in rotary drum 1 is not
10 accurately rotated, thereby detecting the rotational state of laundry in rotary drum.

Furthermore, controller 15 determines that the amount of laundry in rotary drum 1 is small and laundry is the free rotation state therein when a current value of motor 5
15 detected by current detector 24 during a washing operation is below a predetermined value and a fluctuation range of the current value of the motor detected by current detector 24 is below a predetermined level as well. As a result, more accurate detection of laundry's state in rotary drum 1
20 can be carried out.

Further, when it is detected that the amount of laundry in rotary drum 1 is small and laundry is in the free rotation state therein, controller 15 drains a predetermined amount of wash water from water tub 3 by opening water drain
25 valve 11, thereby mitigating the free rotation state of laundry while fully removing dirt from the laundry.

As described above, the washing machine in accordance with the present invention is capable of effectively removing dirt from laundry by performing an optimum washing operation regardless of the amount or the types of laundry.

5 The present invention can be applied to various apparatuses or equipment including a cleaning apparatus or a washing machine for performing washing, rinsing and water-extracting processes by using a rotary drum having an approximately horizontal or slanted rotational axis.

10 A washing machine in accordance with the present invention can determine laundry's state in a rotary drum regardless of the amount or the types of laundry, thereby making it possible to fully remove dirt from laundry.

15 While the invention has been shown and described with respect to the preferred embodiments, 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.

20

What is claimed is:

1. A washing machine comprising:

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

a water tub accommodating the rotary drum therein;

a motor for rotating the rotary drum;

a current detector for detecting a current of the
motor; and

10 a controller for controlling an operation of the motor
and a series of washing operations,

wherein the controller detects a state of laundry in
the rotary drum based on a value of current in the motor
during a washing operation.

15 2. The washing machine of claim 1, wherein the controller
controls the state of laundry in the rotary drum by using a
current value of the motor detected by the current detector
after a predetermined time period after starting the motor.

20 3. The washing machine of claim 1 or 2, wherein the
controller determines that the laundry is in a free rotation
state where the contact between the rotary drum and the
laundry is minimal in the rotary drum if the current value
25 of the motor detected by the current detector is below a
predetermined value.

4. The washing machine of claim 1 or 2, wherein the controller determines that the laundry is in a free rotation state where the contact between the rotary drum and the laundry is minimal in the rotary drum if a fluctuation range of a current value of the motor is below a predetermined value.

5. The washing machine of claim 1 or 2, wherein the controller determines that the laundry is in a free rotation state where the contact between the rotary drum and the laundry is minimal in the rotary drum if the current value of the motor detected by the current detector is below a predetermined value and a fluctuation range of the current value is below a predetermined value.

6. The washing machine of any one of claims 3 to 5, further comprising a water draining unit for draining wash water from the water tub, wherein a predetermined amount of wash water is drained from the water tub by using the water draining unit when the controller determines that laundry is in the free rotation state in the rotary drum and the amount of the drained wash water is controlled by directly regulating the amount of wash water drained from the water tub or by controlling a time period for draining wash water.