S205. If command rotational speed ωs is lower (NO), a shift is made to step S201. At step S205, the acceleration control in the clothing quantity detection ends.

[0059] FIG. 9 is a flowchart for constant-speed control in the clothing quantity detection of the washing machine according to the first exemplary embodiment.

[0060] At step S300, the constant-speed control in the clothing quantity detection starts. At step S301, ON term timer T_ontm is cleared to 0.

[0061] At step S302, a determination is made whether reverse count n is 0. If reverse count n is 0 (YES), a shift is made to step S303. If reverse count n is not 0 (NO), a shift is made to step S305. At step S303, cumulative Iq Iq_integral is cleared to 0. At step S304, cumulation count integral_n is cleared to 0. At step S305, a shift is made to the motor speed control routine (described in detail later). At step S306, a time (e.g., 1 ms) taken for processing the motor speed control is added to ON term timer T_ontm.

[0062] At step S307, a determination is made whether a value of ON term timer T_ontm is smaller than cumulation delay T_delay (e.g., 0.3 s). If the value is smaller (YES), a shift is made to step S310. If the value is larger or equal (NO), a shift is made to step S308. At step S308, an Iq is added to cumulative Iq Iq_integral. At step S309, cumulation count integral_n is incremented by 1. At step S310, a determination is made whether the value of ON term timer T_ontm is larger than ON term T_on. If the value is larger (YES), a shift is made to step S311. If the value is smaller or equal (NO), a shift is made to step S305. At step S311, the constant-speed control in the clothing quantity detection ends.

[0063] FIG. 10 is a flowchart for deceleration control in the clothing quantity detection of the washing machine according to the first exemplary embodiment.

[0064] At step S400, the deceleration control in the clothing quantity detection starts. At step S401, a determination is made whether reverse count n is 0. If reverse count n is 0 (YES), a shift is made to step S402. If reverse count n is not 0 (NO), a shift is made to step S404.

[0065] At step S402, OFF term timer T_offtm is cleared to 0. At step S403, cumulative rotation angle θ_integral is cleared to 0. At step S404, a shift is made to a pause control routine (described in detail later) for the motor speed. At step S405, a determination is made whether motor rotation angle θ (where the term "angle" hereinafter refers to the motor's electrical angle) is smaller than angle threshold θ_limit. If angle threshold θ_limit is larger (YES), a shift is made to step S406. If motor rotation angle θ is larger or equal (NO), a shift is made to step S407. At step S406, a time (e.g., 1 ms) taken for processing

the motor pause control is added to OFF term timer T_offtm. At step S407, a shift is made to "A" (refer to FIG. 7).

[0066] At step S408, a determination is made whether motor rotational speed ω is lower than minimum rotational speed ω_min (e.g., 100 r/min) to be detected. If motor rotational speed ω is lower (YES), a shift is made to step S410. If motor rotational speed ω is higher or equal (NO), a shift is made to step S409. At step S409, motor rotation angle θ is added to cumulative rotation angle θ_integral. At step S410, a determination is made whether a value of OFF term timer T_offtm is larger than OFF term T_off. If the value is larger (YES), a shift is made to step S411. If the value is smaller or equal (NO), a shift is made to step S404. At step S411, the deceleration control in the clothing quantity detection ends.

[0067] FIG. 11 is a flowchart for determination output in the clothing quantity detection of the washing machine according to the first exemplary embodiment.

[0068] At step S500, the determination output in the clothing quantity detection starts. At step S501, an average Iq is calculated using Formula 5.

[0069] Formula 5

$$I_{\text{q_average}} = \frac{I_{q_integral}}{\text{integral_n}}$$

[0070] At step S502, a determination value is output. A detailed description of determination methods is provided with reference to FIGS. 12A and 12B, and Tables 1 to 3. At step S503, the determination output in the clothing quantity detection ends.

[0071] FIG. 12A illustrates a relationship between the average Iq from the determination output in the clothing quantity detection of the washing machine according to the first exemplary embodiment and the clothing quantity determination value. FIG. 12B illustrates a relationship between the cumulative rotation angle from the determination output in the clothing quantity detection of the washing machine according to the first exemplary embodiment and the clothing quantity determination value. Points in each of FIGS. 12A and 12B are evaluation values (in terms of average Iq or cumulative rotation angle) corresponding respectively to clothing quantities (e.g., 2 kg, 4 kg, 6 kg, 8 kg, and 10 kg), and a dashed line is an approximate line connecting these points. As double arrowed lines indicate, thresholds to be used in determining clothing quantity determination values (respectively indicating, for example, 0 to 3 kg, 3 to 5 kg, 5 to 7 kg, 7 to 9 kg, and 9 kg or more) are determined from the evaluation values. For each of the clothing quantities,

[0082] As illustrated in part (b) of FIG. 13, the Iq cumulation starts after elapse of the cumulation delay in the constant-speed control and ends when the constant-speed control terminates (refer to a shadow area). The average Iq to be used for the determination in the clothing quantity detection is calculated from cumulative $Iq_integral$. Since the Iq easily fluctuates due to changes in the rotational speed, the Iq is measured after the cumulation delay here for restrained fluctuation, thus also restraining fluctuation of the average Iq.

[0083] As illustrated in part (a) of FIG. 13, the rotation angle cumulation is performed in the deceleration control until the minimum rotational speed to be detected is reached (refer to a shadow area). Since rotation angles during lower speed rotation where the rotational speed detection is not easy are excluded, the minimum rotational speed to be detected serves as a limit of the rotation angle cumulation to make the cumulative rotation angle more accurate.

[0084] In the drawing, the determination is made after the agitation takes only a single round in one of the directions; however, the average Iq and the cumulative rotation angle are more accurate after an even number of (e.g., four) Iq and rotation angle cumulations through changes in the rotation direction because of a reduced effect of the rotation direction.

[0085] FIG. 14 is a flowchart for the motor speed control in the washing machine according to the first exemplary embodiment.

[0086] At step S600, the motor speed control starts. At step S601, a determination is made whether motor rotational speed ω is higher than command rotational speed ωs for motor 4. If motor rotational speed ω is higher (YES), a shift is made to step S602. If motor rotational speed ω is lower or equal (NO), a shift is made to step S603. At step S602, δ-axis command current $I\delta s$ is reduced. At step S603, δ-axis command current $I\delta s$ is increased. Speed error amplifier 26 that performs steps S601 to 603 normally performs proportional-integral control that includes an integral element such as averaging when setting δ-axis command current $I\delta s$, because a variable element is significant enough to cause unstable control.

[0087] At step S604, current control timer Te_tm is cleared to 0. At step S605, a shift is made to a current control routine (described in detail later). At step S606, a time (e.g., 0.1 ms) taken for processing the current control is added to current control timer Te_tm. At step S607, a determination is made whether a value of current control timer Te_tm is larger than current control period Te_cycle. If the value is larger (YES), a shift is made to step

S608. If the value is smaller or equal (NO), a shift is made to step S605. At step S608, the motor speed control ends.

[0088] FIG. 15 is a flowchart for the motor pause control in the washing machine according to the first exemplary embodiment. At step S700, the motor pause control starts. At step S701, 0 or a fixed value is substituted for δ-axis command current Iδs. There is a method of using 0 as δ-axis command current Iδs to cause no torque. There is also a method of using a negative fixed value as δ-axis command current Iδs to cause brake torque to such a degree that regenerative voltage is not problematic for achieving a shorter braking time period, and a method of using a slightly positive fixed value as δ-axis command current Iδs to widen a cumulative rotation angle variation with slight driving torque that more reliably effects a pause than, for example, frictional force that acts to decelerate the rotation for facilitating the determination in the clothing quantity detection. An easy-to-use method to be selected depends on the clothing quantity or how the washing machine is configured.

[0089] Thereafter, steps that are the same as steps S604 to S608 of the motor speed control in FIG. 14 are performed. At step S702, current control timer Te_tm is cleared to 0. At step S703, a shift is made to the current control routine (described in detail later). At step S704, a time (e.g., 0.1 ms) taken for processing the current control is added to current control timer Te_tm. At step S705, a determination is made whether a value of current control timer Te_tm is larger than current control period Te_cycle. If the value is larger (YES), a shift is made to step S706. If the value is smaller or equal (NO), a shift is made to step S703. At step S706, the motor pause control ends.

[0090] FIG. 16 is a flowchart for motor current control in the washing machine according to the first exemplary embodiment.

[0091] At step S800, the motor current control starts. At step S801, current detection unit 18 detects phase currents Iu, Iv, and Iw. At step 802, a determination is made whether any one of phase currents Iu, Iv, and Iw is smaller than phase current threshold I_limit. If phase current Iu, Iv, or Iw is smaller (YES), a shift is made to step S803. If phase current Iu, Iv, or Iw is larger or equal (NO), a shift is made to step S804.

[0092] At step S803, three-phase to two-phase converter 22 calculates δ-axis current Iδ, using Formula 1. At step S804, a shift is made to "A" (refer to FIG. 7). At step S805, a determination is made whether δ-axis current Iδ is larger than δ-axis command current Iδs. If δ-axis current Iδ is larger (YES), a shift is made to step S806. If δ-axis current Iδ is

sensorless detection of the rotation angle is enabled by inertia rotation in which PWM output is not brought to a complete stop.

[0114] A quantity of laundry may be detected from a rotation angle from when a period of the pause control starts until an actual rotational speed reaches a specified rotational speed.

[0115] In this configuration, rotation angle cumulation is performed only in a higher speed rotation range that enables the rotational speed detection to be accurate. Therefore, the clothing quantity detection is enabled to be accurate.

[0116] The control unit may terminate clothing quantity detection and determine that a quantity of laundry is maximum when a current in the electric motor is larger than or equal to a predetermined value or when a rotation angle is smaller than a predetermined value.

[0117] This configuration enables the determination of the larger or largest clothing quantity with no need to perform the entire clothing quantity detection sequence and thus enables a time- and energy-saving clothing quantity detection sequence.

[0118] OTHER EXEMPLARY EMBODIMENTS

Each of the first and second exemplary embodiments has been described above as being illustrative of the technique of the present disclosure. However, the above techniques are not restrictive of the present disclosure.

[0119] Exemplary embodiments below are given as other illustrations.

[0120] The washing machine used as an example in the description of each of the first and second exemplary embodiments is the top-loading type that uses speed reducer and clutch 6 for connection to pulsator 1 or washing and spin-drying tub 2, with motor pulley 31 and impeller pulley 32 connected by belt 5; however, even with a direct drive washing machine that has a washing and spin-drying tub coaxial with a motor, a clothing quantity is easily and accurately detectable.

[0121] The washing machine used as the example in the description of each of the first and second exemplary embodiments is the top-loading type that uses the pulsator; however, even with a top-loading washing machine that uses an agitator, a clothing quantity is easily and accurately detectable.

[0122] THIRD EXEMPLARY EMBODIMENT

A description is hereinafter provided of water flow review control in a washing machine according to the third exemplary embodiment.

[0123] The washing machine according to the third exemplary embodiment has the same configuration as the washing machine according to the first exemplary embodiment that is

illustrated in FIGS. 1 to 6B and thus has the same reference characters, which will not be described.

[0124] The water flow review control in the configuration of the washing machine according to the third exemplary embodiment is described with reference to FIGS. 19 to 27.

[0125] FIG. 19 is a flowchart for the water flow review control in the washing machine according to the third exemplary embodiment.

[0126] At step S1100, the water flow review control starts. At step S1101, reverse count n is cleared to 0. At step S1102,command rotational speed ωs for motor 4 is cleared to 0. At step S1103, a shift is made to an acceleration control routine (described in detail later) in a water flow review. At step S1104, a shift is made to a constant-speed control routine (described in detail later) in the water flow review. At step S1105, a shift is made to a deceleration control routine (described in detail later) in the water flow review. At step S1106, reverse count n is incremented by 1. At step S1107, a determination is made whether reverse count n is larger than preset count ns (e.g., 22) for the determination. If reverse count n is larger (YES), a shift is made to step S1108. If reverse count n is smaller or equal(NO), a shift is made to step S1109. At step S1108, a shift is made to a determination output routine (described in detail later) in the water flow review control. At step S1109, the rotation is changed from CW to CCW or vice versa. Step S1110 serves as a transition from "B" in another routine. At step S1111, a maximum determination value (indicating, for example, a weakestwater flow) is output in the water flow review control. At step S1112, the water flow review control ends.

[0127] FIG. 20 is a flowchart for acceleration control in the water flow review of the washing machine according to the third exemplary embodiment.

[0128] At step S1200, the acceleration control in the water flow review starts. At step S1201, motor acceleration α (e.g., 3000 (r/min)/s) is called. At step S1202, command rotational speed ωs for motor 4 is incremented in accordance with motor acceleration α. At step S1203, a shift is made to a motor speed control routine (described in detail later). At step S1204, a determination is made whether command rotational speed ωs for motor 4 is higher than or equal to maximum command rotational speed ωmax (e.g., 2160 r/min) for motor 4. If command rotational speed ωs is higher or equal (YES), a shift is made to step S1205. If command rotational speed ωs is lower (NO), a shift is made to step S1201. At step S1205 ,the acceleration control in the water flow review ends.

[0129] FIG. 21 is a flowchart for constant-speed control in the water flow review of the washing machine according to the third exemplary embodiment.

[0130] At step S1300, the constant-speed control in the water flow review starts. At step S1301, ON term timer T_ontm is cleared to 0. At step S1302, a shift is made to the motor speed control routine (described in detail later). At step S1303, a time (e.g., 1 ms) taken for processing the motor speed control is added to ON term timer T_ontm. At step S1304, a determination is made whether a value of ON term timer T_ontm is larger than ON term T_on. If the value is larger (YES), a shift is made to step S1305. If the value is smaller or equal (NO), a shift is made to step 302. At step S1305 ,the constant-speed control in the water flow review ends.

[0131] FIG. 22 is a flowchart for deceleration control in the water flow review of the washing machine according to the third exemplary embodiment.

[0132] At step S1400, the deceleration control in the water flow review starts. At step S1401, a determination is made whether reverse count n is 0. If reverse count n is 0 (YES), a shift is made to step S1402. If reverse count n is not 0 (NO), a shift is made to step S1404. At step S1402, OFF term timer T_offtm is cleared to 0. At step S1403, cumulative rotation angle θ_integral is cleared to 0. At step S1404, a shift is made to a pause control routine (described in detail later) for the motor speed. At step S1405, a determination is made whether angle threshold θ_limit (where the term “angle” hereinafter refers to the motor’s electrical angle) is larger than motor rotation angle θ. If angle threshold θ_limit is larger (YES), a shift is made to step S1406. If angle threshold θ_limit is smaller or equal (NO), a shift is made to step S1407. At step S1406, a time (e.g., 1 ms) taken for processing the motor pause control is added to OFF term timer T_offtm. At step S1407, a shift is made to "B" (refer to FIG. 19).

[0133] At step S1408, a determination is made whether motor rotational speed ω is lower than minimum rotational speed ω_min (e.g., 100 r/min) to be detected. If motor rotational speed ω is lower (YES), a shift is made to step S1410. If motor rotational speed ω is higher or equal (NO), a shift is made to step S1409. At step S1409, motor rotation angle θ is added to cumulative rotation angle θ_integral. At step S1410, a determination is made whether a value of OFF term timer T_offtm is larger than OFF term T_off. If the value is larger (YES), a shift is made to step S1411. If the value is smaller or equal (NO), a shift is made to step S1404. At step S1411 ,the deceleration control in the water flow review ends.

[0134] FIG. 23 illustrates a relationship between the cumulative rotation angle from determination output in the water flow review control of the washing machine according to the third exemplary embodiment and the water flow to be determined in the water flow review control.

[0135] Points in FIG. 23 are evaluation values (in terms of cumulative rotation angle) corresponding respectively to water flows (e.g., the weakest water flow, a weaker water flow, and a standard water flow) at a constant water level, and a dashed line is an approximate line connecting these points. As double arrowed lines indicate, thresholds to be used in determining water flow determination values (respectively indicating, for example, the weakest water flow, the weaker water flow, and the standard water flow at the water level of 65 L) are determined from the evaluation values. For each of the water flows, evaluation is performed multiple times so that the threshold setting takes into consideration variations in the evaluation value.

[0136] Table 4 shows the water flows that are each determined from the cumulative rotation angle from the determination output in the water flow review control of the washing machine according to the third exemplary embodiment.

[0137] Table 4

Cumulative Rotation Angle	Water Flow to be Determined
at least 130 revs	Weakest Water Flow
75 to 130 revs	Weaker Water Flow
below 75 revs	Standard Water Flow

[0138] As in FIG. 23, the cumulative rotation angle is nearly in inverse proportion to the water flow determination value from the water flow review control. Therefore, for the standard water flow at the constant water level, there is a narrower variation in the cumulative rotation angle with the thresholds closer together; however, for the weaker water flow, there is a wider variation in the cumulative rotation angle that facilitates the threshold setting. Therefore, the cumulative rotation angle enables the setting of, for example, the water flow determination values in Table 4 in the water flow review control.

[0139] Table 5 shows examples of respective terms of the water flows to be determined. For example, the term of the standard water flow is 1.4 s ON/1.0 s OFF, the term of the weaker water flow is 1.0 s ON/1.2 s OFF, and the term of the weakest water flow is 0.5 s ON/1.2 s OFF.

[0140] Table 5

At step S1507, a determination is made whether a value of current control timer Te_tm is larger than current control period Te_cycle. If the value is larger (YES), a shift is made to step S1508. If the value is smaller or equal (NO), a shift is made to step S1505. At step S1508, the motor speed control ends.

[0148] FIG. 26 is a flowchart for the motor pause control in the washing machine according to the third exemplary embodiment.

[0149] At step S1600, the motor pause control starts. At step S1601, 0 or a fixed value is substituted for δ-axis command current Iδs. There is a method of using 0 as δ-axis command current Iδs to cause no torque. There is also a method of using a negative fixed value as δ-axis command current Iδs to cause brake torque to such a degree that regenerative voltage is not problematic for achieving a shorter braking time period, and a method of using a slightly positive fixed value as δ-axis command current Iδs to widen a cumulative rotation angle variation with slight driving torque that more reliably effects a pause than, for example, frictional force that acts to decelerate the rotation for facilitating the determination in water splashing detection. An easy-to-use method to be selected depends on the clothing quantity or how the washing machine is configured.

[0150] Thereafter, steps that are the same as steps S1504 to S1508 of the motor speed control are performed. At step S1602, current control timer Te_tm is cleared to 0. At step S1603, a shift is made to the current control routine (described in detail later). At step S1604, a time (e.g., 0.1 ms) taken for processing the current control is added to current control timer Te_tm. At step S1605, a determination is made whether a value of current control timer Te_tm is larger than current control period Te_cycle. If the value is larger (YES), a shift is made to step S1606. If the value is smaller or equal (NO), a shift is made to step S1603. At step S1606, the motor pause control ends.

[0151] FIG. 27 is a flowchart for motor current control in the washing machine according to the third exemplary embodiment.

[0152] At step S1700, the motor current control starts. At step S1701, current detection unit 18 detects phase currents Iu, Iv, and Iw. At step S1702, three-phase to two-phase converter 22 calculates δ-axis current Iδ, using Formula 1. At step S1703, a determination is made whether δ-axis current Iδ is larger than δ-axis command current Iδs. If δ-axis current Iδ is larger (YES), a shift is made to step S1704. If δ-axis current Iδ is smaller or equal (NO), a shift is made to step S1705. At step S1704, δ-axis command voltage Vδs is reduced. At step S1705, δ-axis command voltage Vδs is increased.

CLAIMS

1. A washing machine comprising:

an impeller rotatable in a washing and spin-drying tub;

an electric motor including a permanent magnet and a winding;

a power supply circuit that supplies a current to the electric motor;

a current detection unit that detects a current in the electric motor;

a transmission mechanism that transmits torque of the electric motor to the impeller;

a rotational speed control unit that controls the electric motor to obtain a specified rotational speed; and

a control unit that performs a set of controls on the electric motor a predetermined number of times, the set of controls including at least one of acceleration control, constant-speed control, and pause control which are performed one after another in sequence, the set of controls being performed alternately for clockwise rotation and counterclockwise rotation of the impeller, wherein

the control unit includes a clothing quantity detection unit that detects a quantity of laundry from an average current value in a period of the constant-speed control or a rotation angle in a period of the pause control.

2. The washing machine according to claim 1, wherein the clothing quantity detection unit detects a quantity of laundry from both an average current value in a period of the constant-speed control and a rotation angle in a period of the pause control.

3. The washing machine according to claim 1 or 2, wherein the clothing quantity detection unit detects a quantity of laundry from an average current value between elapse of a predetermined time period that follows a shift to a period of the constant-speed control and termination of a period of the constant-speed control.

4. The washing machine according to claim 1 or 2, wherein the clothing quantity detection unit detects a quantity of laundry from an average current value between elapse of a predetermined time period that follows complete settlement of a difference between a target rotational speed and an actual rotational speed in a predetermined value range in a

period of the constant-speed control and termination of a period of the constant-speed control.

5. The washing machine according to claim 1 or 2, wherein the clothing quantity detection unit detects a quantity of laundry from a rotation angle while torque is set at zero or a constant value in a period of the pause control.

6. The washing machine according to claim 1 or 2, wherein the clothing quantity detection unit detects a quantity of laundry from a rotation angle from when a period of the pause control starts until an actual rotational speed reaches a specified rotational speed.

7. The washing machine according to claim 5, wherein the clothing quantity detection unit detects a quantity of laundry from a rotation angle from when a period of the pause control starts until an actual rotational speed reaches a specified rotational speed.

8. The washing machine according to claim 1 or 2, wherein the control unit terminates clothing quantity detection and determines that a quantity of laundry is maximum when a current in the electric motor is larger than or equal to a predetermined value or when a rotation angle is smaller than a predetermined value.

9. A washing machine comprising:

an impeller rotatable in a washing and spin-drying tub;

an electric motor including a permanent magnet and a winding;

a power supply circuit that supplies a current to the electric motor;

a current detection unit that detects a current in the electric motor;

a transmission mechanism that transmits torque of the electric motor to the impeller;

a rotational speed control unit that controls the electric motor to obtain a specified rotational speed; and

a control unit that performs a set of controls on the electric motor a predetermined number of times, the set of controls including at least one of acceleration control, constant-speed control, and pause control which are performed one after another in sequence, the set of controls being performed alternately for clockwise rotation and counterclockwise rotation of the impeller, wherein

during washing, the control unit performs water flow review control based on a rotation angle in a period of the pause control.

10. The washing machine according to claim 9, wherein the control unit changes a water flow during washing on a basis of a rotation angle from when a shift to a period of the pause control in the water flow review control is made until an actual rotational speed reaches a specified rotational speed.

11. The washing machine according to claim 9, wherein the control unit changes a water flow during washing on a basis of a rotation angle from when a period of the pause control in the water flow review control starts until a predetermined time period elapses.

12. The washing machine according to any one of claims 9 to 11, wherein the control unit changes a water flow during washing on a basis of a rotation angle while torque is set at zero or a constant value in a period of the pause control in the water flow review control.

13. The washing machine according to any one of claims 9 to 11, wherein the control unit terminates a review of a water flow to be changed and effects a weaker water flow when a rotation angle is greater than or equal to a predetermined value in the water flow review control.

14. The washing machine according to claim 12, wherein the control unit terminates a review of a water flow to be changed and effects a weaker water flow when a rotation angle is greater than or equal to a predetermined value in the water flow review control.