

DESCRIPTION

WASHING MACHINE

5 TECHNICAL FIELD

[0001] The present disclosure relates to a washing machine.

BACKGROUND ART

[0002] Conventionally, in this type of washing machine, the rotational position of the
10 motor is detected as follows. Rotational position detection is to detect the electric angle of
the motor, and a Hall element, a rotary encoder, or the like is used as a rotation sensor.
However, when it is not possible to provide a rotation sensor due to cost and structural
restrictions, there are methods of detecting the rotational position without a rotation sensor,
including a method using an induced voltage and a method using inductance.

15 [0003] When an induced voltage is used, the induced voltage proportional to the rotation
speed of the motor is calculated from the input voltage and current to the motor, and the
rotational position is detected from this induced voltage. This detection method enables
accurate rotational position detection in the region where the rotation speed of the motor is
high because the induced voltage is large, but cannot perform correct rotation detection in
20 the region where the rotation speed of the motor is low when starting or stopping because
the induced voltage is small.

[0004] When an inductance is used, the inductance of the motor is calculated from the
input voltage and current to the motor, and the rotational position is detected by utilizing
the fact that the inductance fluctuation cycle is twice the electric angle of the motor. This
25 detection method is limited to a motor having a magnetic salient polarity, and a voltage is
applied to the motor at a cycle different from the rotation cycle of the motor (see, for
example, PTL 1).

Citation List

Patent Literature

30 [0005] PTL 1: Unexamined Japanese Patent Publication No. 2001-169590

SUMMARY OF THE INVENTION

[0006] However, such a conventional washing machine uses a control method that does

not feed back phase information because it is difficult to perform phase estimation in a region where the rotation speed is low in a motor having a magnetic non-salient polarity. In this case, since the phase is uncertain, the torque is not correctly transmitted to the motor, and there is a problem that the motor fails to start and enters a lock state. Even if a

restarting operation is performed for an unlocking operation in the same manner by the starting method, the lock state is not released, resulting in a failure to start.

[0007] The present disclosure provides a washing machine that can easily release the lock state by changing the starting method when starting fails and the lock state is reached.

[0008] The washing machine according to the present disclosure includes a rotating object that comes into contact with laundry, an electric motor having a permanent magnet and windings, a power supply circuit that supplies current to the electric motor, a transmission mechanism that transmits the torque of the electric motor to the rotating object, and a controller that executes a washing control operation. Further, the controller can execute the first control process of energizing the windings regardless of the position of the permanent magnet and the second control process of energizing the windings in accordance with according to the position of the permanent magnet. Further, the controller can execute a lock detection process of detecting motor lock when the permanent magnet is not rotated at a predetermined rotation speed after transition from the first control process to the second control process. Upon detecting that the motor is locked in a lock detection process, the controller performs phase fixed control in different phases a plurality of times at the start of driving by the first control process.

[0009] The washing machine according to the present disclosure can easily release the lock state by changing the starting method when the machine fails to start and enters the lock state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a sectional view of the main part of a washing machine according to a first exemplary embodiment.

Fig. 2 is a block diagram of a drive system of a motor of the washing machine according to the first exemplary embodiment.

Fig. 3 is an equivalent circuit diagram of the motor of the washing machine according to the first exemplary embodiment.

Fig. 4 is a control block diagram at the time of phase estimation of the motor of

the washing machine according to the first exemplary embodiment.

Fig. 5 is a detailed block diagram of a velocity phase estimator of the motor of the washing machine according to the first exemplary embodiment.

Fig. 6A is a vector diagram in which estimated coordinates at the time of phase estimation of the motor of the washing machine according to the first exemplary embodiment are delayed.

Fig. 6B is a vector diagram in which the estimated coordinates at the time of phase estimation of the motor of the washing machine according to the first exemplary embodiment are advanced.

Fig. 7 is a control block diagram of the motor of the washing machine during an open loop according to the first exemplary embodiment.

Fig. 8A is a flowchart of a sensorless control process for the motor of the washing machine according to the first exemplary embodiment.

Fig. 8B is a flowchart of another sensorless control process for the motor of the washing machine according to the first exemplary embodiment.

Fig. 9 is a flowchart of a sensorless open loop acceleration control process for the motor of the washing machine according to the first exemplary embodiment.

Fig. 10 is a vector diagram of initial phase fixed control of a sensorless open loop acceleration control for the motor of the washing machine according to the first exemplary embodiment.

Fig. 11 is a graph showing the command rotation speed of sensorless open loop acceleration control for the motor of the washing machine according to the first exemplary embodiment.

Fig. 12 is a flowchart of a sensorless phase estimation control process for the motor of the washing machine according to the first exemplary embodiment.

Fig. 13 is a flowchart of a velocity control process for the motor of the washing machine according to the first exemplary embodiment.

DESCRIPTION OF EMBODIMENTS

[0011] Exemplary embodiments of the present disclosure will be described below with reference to the accompanying drawings. The present disclosure is not limited to the exemplary embodiments described herein.

[0012] (First exemplary embodiment)

Fig. 1 is a sectional view of the main part of a washing machine according to a first exemplary embodiment.

5 [0013] Washing and dehydrating tank 2 in which pulsator 1 for stirring clothes is placed on the bottom so as to be rotatable left and right is placed inside water receiving tank 3 so as to be able to perform dehydration rotation. Motor 4 is fixed to the outer bottom of water receiving tank 3. The rotation of motor 4 causes pulsator 1 or washing and dehydrating tank 2 to rotate via motor pulley 31, belt 5, impeller pulley 32, and speed reduction mechanism and clutch 6 or stopped by braking. In addition to the method of controlling braking so as to apply reverse torque to motor 4, there is also a method of mechanically
10 braking washing and dehydrating tank 2 by actuating geared motor 7 and bringing brake belt 8 into contact with the rotating portion. Lid 11 is placed on the upper surface of panel 10 placed above washing machine outer frame 9 so as to be openable and closable. Control device 13 that controls an overall washing machine process and has display 12 is placed inside the front part of the panel.

15 [0014] Control device 13 includes controller 20 including a microcomputer that controls the operations of motor 4, water supply valve 14, drain valve 15, and the like and sequentially controls a series of processes such as washing, rinsing, and dehydration. Based on information from an input setter with which the user performs operations such as setting a desired washing course, starting an operation, and pausing an operation, controller
20 20 informs the user of the progress of a process or various types of information by display with display 12 composed of light emitting elements such as light emitting diodes (LEDs) and liquid crystal displays (LCDs). When the user sets operation start with the input setter, the operations of geared motor 7, water supply valve 14, and drain valve 15 are controlled according to data from a water level detector and the like to perform a washing operation.

25 [0015] Fig. 2 is a block diagram of a drive system of the motor of the washing machine according to the first exemplary embodiment.

[0016] An AC power supply applies AC power to rectifier circuit 16. Rectifier circuit 16 is composed of a voltage doubler rectifier circuit and applies a voltage doubler DC voltage to inverter circuit 17. Inverter circuit 17 is composed of a three-phase full-bridge inverter
30 circuit composed of six power switching semiconductors and antiparallel diodes. The three-phase full-bridge inverter circuit is usually composed of an insulated gate bipolar transistor (IGBT), an antiparallel diode, and an intelligent power module (hereinafter referred to as IPM) incorporating its drive circuit and protection circuit. Further, motor 4 is

connected to the output terminal of inverter circuit 17 to be driven.

[0017] Current detector 18 detects phase currents I_u , I_v , and I_w of motor 4 based on the input current of inverter circuit 17 calculated from the voltage across the shunt resistor connected between the negative voltage terminal of inverter circuit 17 and the negative voltage terminal of rectifier circuit 16. Since the DC voltage applied to inverter circuit 17 is sometimes superimposed by the regenerative energy generated by the rotation of the motor in addition to an input from an AC power supply, the DC voltage is always detected.

[0018] Pulse width modulation (PWM) controller 19 controls a PWM signal that switches the IGBT of inverter circuit 17 according to the three-phase motor drive control voltage commands V_{us} , V_{vs} , and V_{ws} from controller 20, thereby driving motor 4 using output voltages V_u , V_v , and V_w of the inverter circuit.

[0019] Fig. 3 is an equivalent circuit diagram of the motor of the washing machine according to the first exemplary embodiment.

[0020] In this case, for the sake of simplicity, a bipolar configuration is used in which one mechanical angle rotation corresponds to one electric angle rotation. When the number of poles changes to 4 poles, 8 poles, ..., one mechanical angle rotation sequentially corresponds to two electric angle rotations, four electric angle rotations, ... Motor 4 is a three-phase synchronous motor and is composed of an equivalent circuit having three-phase windings 4a, 4b, and 4c of U, V, and W and permanent magnet 4d, which is a rotor that rotates about the rotation axis. In this equivalent circuit, an axis penetrating the permanent magnet with the N pole side as the positive direction is defined as the d-axis (direct-axis), and an axis orthogonal to the d-axis is defined as the q-axis (quadrature-axis). With this definition, the magnetic field in the q-axis direction mainly dominates the torque of the motor. A phase (electrical angle) is rotation angle θ between an axis penetrating the U-phase winding and the d-axis. Hereinafter, all the phases described are electric angles. The inductance of the winding when a voltage is applied so as to generate a magnetic field in the d-axis direction is represented by L_d , and the inductance in the q-axis direction is represented by L_q .

[0021] The embedded magnet type three-phase synchronous motor has a relation of $L_d < L_q$. Since controller 20 to be described later cannot accurately detect the position of the rotor at first, it is assumed that phase θ_c is set as shown in Fig. 3, and error $\Delta\theta$ occurs with respect to actual phase θ . That is, the axes controlled by the microcomputer assuming phase θ_c are the γ -axis (estimated d-axis) and the δ -axis (estimated q-axis) with respect to

the d-axis and q-axis of the actual motor. Subsequently, a current component corresponding to the torque in the microcomputer is δ -axis current I_δ , a current component corresponding to the magnetic flux in the microcomputer is γ -axis current I_γ , a voltage component corresponding to the torque in the microcomputer is command δ -axis voltage V_δ s, and a voltage component corresponding to the magnetic flux in the microcomputer is command γ -axis voltage V_γ s.

[0022] Fig. 4 is a control block diagram at the time of phase estimation of the motor of the washing machine according to the first exemplary embodiment.

[0023] Controller 20 includes a microcomputer, an inverter control timer (timer) built in the microcomputer, A/D conversion, and a memory circuit. Controller 20 includes velocity phase estimator 21, three-phase two-phase converter 22, I_δ error amplifier 23, I_γ error amplifier 24, two-phase three-phase converter 25, velocity error amplifier 26, and field weakening setter 27. Controller 20 performs inverter control as follows.

[0024] The details of velocity phase estimator 21 will be described later. Velocity phase estimator 21 receives δ -axis current I_δ , γ -axis current I_γ , and command γ -axis voltage V_γ s and outputs velocity (electric angular velocity) ω and estimated phase θ . The velocities described below are all electric angular velocities.

[0025] Three-phase two-phase converter 22 computes γ -axis current I_γ and δ -axis current I_δ according to mathematical expression (1) based on electric angle θ , phase currents I_u , I_v , and I_w , and the sinusoidal data (sin and cos data) required for conversion from the static coordinate system to a rotational coordinate system.

[0026] [Mathematical expression 1]

$$\begin{bmatrix} I_\gamma \\ I_\delta \end{bmatrix} = \sqrt{\frac{2}{3}} \times \begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2}{3}\pi\right) & \cos\left(\theta - \frac{4}{3}\pi\right) \\ -\sin\theta & -\sin\left(\theta - \frac{2}{3}\pi\right) & -\sin\left(\theta - \frac{4}{3}\pi\right) \end{bmatrix} \times \begin{bmatrix} I_u \\ I_v \\ I_w \end{bmatrix}$$

[0027] I_δ error amplifier 23 receives error ΔI_δ with respect to command value I_δ s of the δ -axis current based on δ -axis current command I_δ s obtained by velocity error amplifier 26 and δ -axis current I_δ obtained by three-phase two-phase converter 22 and outputs command δ -axis voltage V_δ s as the sum of a proportional component and an integration component.

[0028] Similarly, I_γ error amplifier 24 receives error ΔI_γ with respect to command value

I_{γs} of the γ-axis current based on γ-axis current command I_{γs} obtained by field weakening setter 27 and γ-axis current I_γ obtained by three-phase two-phase converter 22 and outputs command γ-axis voltage V_{γs} as the sum of a proportional component and an integration component.

- 5 **[0029]** δ-axis current I_δ and γ-axis current I_γ are controlled independently, and hence this control is called vector control.

[0030] Two-phase three-phase converter 25 computes sinusoidal command three-phase voltage V_{us}, V_{vs}, and V_{ws} according to mathematical expression (2) from phase θ, command δ-axis voltage V_{δs}, command γ-axis voltage V_{γs}, and sinusoidal data (sin and cos data) required for inverse conversion from a rotational coordinate system to the static coordinate system.

[0031] [Mathematical expression 2]

$$\begin{bmatrix} V_{us} \\ V_{vs} \\ V_{ws} \end{bmatrix} = \sqrt{\frac{2}{3}} \times \begin{bmatrix} \cos\theta & -\sin\theta \\ \cos\left(\theta - \frac{2}{3}\pi\right) & -\sin\left(\theta - \frac{2}{3}\pi\right) \\ \cos\left(\theta - \frac{4}{3}\pi\right) & -\sin\left(\theta - \frac{4}{3}\pi\right) \end{bmatrix} \times \begin{bmatrix} V_{\gamma s} \\ V_{\delta s} \end{bmatrix}$$

- [0032]** Velocity error amplifier 26 receives error Δω with respect to velocity command ω_s based on velocity command ω_s and velocity ω computed by velocity phase estimator 21 and outputs δ-axis current command I_{δs} which is the sum of a proportional component and an integral component.

- [0033]** Field weakening setter 27 computes γ-axis current command I_{γs} in the negative direction from velocity ω computed by velocity phase estimator 21 and DC voltage V_{dc} input to the inverter circuit and performs magnetic flux weakening control.

[0034] Fig. 5 is a detailed block diagram of the velocity phase estimator of the motor of the washing machine according to the first exemplary embodiment.

[0035] Estimated phase θ is calculated using resistance values R_a and inductance values L of windings 4a, 4b, and 4c, which are the parameters of motor 4.

- 25 **[0036]** Velocity phase estimator 21 includes γ-axis induced voltage calculator 28 and γ-axis induced voltage error amplifier 29.

[0037] Note that γ-axis induced voltage calculator 28 computes γ-axis induced voltage V_γ from inductance value L, resistance value R_a, δ-axis current I_δ, γ-axis current I_γ,

command γ -axis voltage $V_{\gamma s}$, and estimated velocity ω according to mathematical expression (3).

[0038] [Mathematical expression 3]

$$V_{e\gamma} = V_{\gamma s} - (R_a \times I_{\gamma} - \omega \times L \times I_{\delta})$$

5 [0039] With γ -axis induced voltage command $V_{e\gamma s} = 0$, error $\Delta V_{e\gamma}$ with respect to γ -axis induced voltage command $V_{e\gamma s}$ is input to γ -axis induced voltage error amplifier 29.

[0040] Note that γ -axis induced voltage error amplifier 29 outputs estimated velocity ω computed from integral gain $K\omega$, adds estimated velocity ω to the value computed from proportional gain $K\theta$, performs time integration by an integrator, and outputs estimated
10 phase θ .

[0041] However, γ -axis induced voltage calculator 28 is not necessarily limited to the one using mathematical expression (3), and may perform computation according to mathematical expression (4) to which a time derivative term is added.

[0042] [Mathematical expression 4]

$$V_{e\gamma} = V_{\gamma s} - (R_a \times I_{\gamma} + L \times (dI_{\gamma}/dt) - \omega \times L \times I_{\delta})$$

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[0043] For inductance L in each mathematical expression given above, the same L value can be used if motor 4 has a characteristic defined by $L_d = L_q$. However, inductance L can be computed as a constant L value ($= L_q$) even for motor 4 with $L_d \neq L_q$.

[0044] Fig. 6A is a vector diagram of a state in which the estimated coordinates at the
20 time of phase estimation of the motor of the washing machine according to the first exemplary embodiment are delayed ($\gamma\delta$ coordinates (estimated dq coordinates) are slightly delayed with respect to the dq coordinates of motor 4). Fig. 6B is a vector diagram of a state in which the estimated coordinates at the time of phase estimation of the motor of the washing machine according to the first exemplary embodiment are advanced ($\gamma\delta$
25 coordinates (estimated dq coordinates) are slightly advanced with respect to the dq coordinates of motor 4).

[0045] In the vector diagram, γ -axis induced voltage error $\Delta V_{e\gamma}$ is the γ -axis component of estimated induced voltage vector $V_e (= \omega \times \Psi_a)$ obtained by subtracting the drop of the current flowing through R_a and ωL from input voltage V_a of motor 4. Since induced
30 voltage vector V_e is always on the q-axis, when estimated phase error $\Delta\theta$ (assuming that a

state in which the $\gamma\delta$ coordinates come counterclockwise with respect to the dq coordinates is positive) is 0, the q-axis coincides with the δ -axis. With reference to Fig. 6A, estimated phase error $\Delta\theta$ is negative ($\Delta\theta < 0$). With reference to Fig. 6B, estimated phase error $\Delta\theta$ is positive ($\Delta\theta > 0$).

5 **[0046]** Note that γ -axis induced voltage error amplifier 29 increases estimated velocity ω to advance θ in the case of Fig. 6A and decreases estimated velocity ω to delay θ in the case of Fig. 6B, thereby performing feedback control so as to eliminate γ -axis induced voltage error $\Delta V_{e\gamma}$ and estimated phase error $\Delta\theta$.

10 **[0047]** As described above, since phase estimation is premised on the motor rotation state with induced voltage V_e , the phase estimation is not stable in a low velocity region at the time of starting or stopping when the induced voltage is low. Accordingly, open loop control without phase estimation will be described next.

[0048] Fig. 7 is a control block diagram of the motor of the washing machine during an open loop according to the first exemplary embodiment.

15 **[0049]** The microcomputer in controller 20, inverter control timer (timer) built in the microcomputer, the A/D conversion, the memory circuit, three-phase two-phase converter 22, I_δ error amplifier 23, I_γ error amplifier 24, and two-phase three-phase converter 25 are common to Fig. 4.

20 **[0050]** Phase computing unit 30 obtains phase θ by integrating the phase per unit time based on initial phase θ_{init} and velocity command ω_s set for each unit time. At this time, since velocity estimation is not performed in an open loop, control is performed with velocity command ω_s being directly treated as velocity ω . Further, δ -axis current command I_δ^s and γ -axis current command I_γ^s , set for each unit time, are respectively input to I_δ error amplifier 23 and I_γ error amplifier 24.

25 **[0051]** In the open loop, this method performs control using only initial phase θ_{init} , velocity command ω_s set for each unit time, δ -axis current command I_δ^s , and γ -axis current command I_γ^s , and hence is normally used as a drive method limited to at the time of starting and braking in a low velocity region where the phase estimation is not stable. In this case, an example of current control using δ -axis current command I_δ^s and γ -axis current command I_γ^s is described. However, this control can be replaced by either voltage control with command δ -axis voltage V_δ^s and command γ -axis voltage V_γ^s set for each unit time or voltage control with only the degree of modulation set for each unit time.

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[0052] In the above configuration, an operation will be described with reference to Figs. 8A to 12 and Table 1.

[0053] Fig. 8A is a flowchart of a sensorless control process for the motor of the washing machine according to the first exemplary embodiment. Fig. 8B is a flowchart of another sensorless control process for the motor of the washing machine according to the first exemplary embodiment.

[0054] As shown in Fig. 8A, a sensorless control process is started in step S100, and a sensorless open loop acceleration control process routine is performed from the motor stopped state in step S101. When a phase estimation flag is set in step S102, the process shifts to the sensorless phase estimation control process routine in step S103. After information of velocity ω and phase θ is inherited, velocity control including acceleration and deceleration is performed according to the sequence. When the phase estimation flag is cleared in step S104, the process shifts to the sensorless open loop deceleration control process routine in step S105. After information of velocity ω and phase θ is inherited, deceleration control is performed. When velocity ω becomes 0 in step S106 and the motor stops, sensorless control is terminated in step S107.

[0055] In this case, steps S105 and S106 shown in Fig. 8A can be replaced with S105a and S106a as shown in Fig. 8B. The motor is stopped by braking such as short-circuit braking or mechanical braking in step S105a. The stoppage of the motor is determined in step S106a based on the elapse of predetermined time T1 from time T at the start of braking instead of velocity ω . In step S107, sensorless control is terminated.

[0056] The activation of sensorless open loop acceleration control of the motor of the washing machine according to the first exemplary embodiment will be described with reference to Figs. 9 to 11.

[0057] Fig. 9 is a flowchart of a sensorless open loop acceleration control process for the motor of the washing machine according to the first exemplary embodiment.

[0058] The sensorless open loop acceleration control process is started in step S200, and it is checked in step S201 whether the restart is due to motor lock. If restart is not performed, normal parameters are input in step S202. If restart is performed, motor lock time parameters corresponding to the number of restarts are input in step S203.

[0059] Table 1 shows parameter settings at the time of starting the motor of the washing machine according to the first exemplary embodiment.

[0060] [Table 1]

Parameter		In normal time	First restart after motor lock		Second restart after motor lock	
Initial phase fixed control	Phase fixed time T2	0s	0 to 1s	1 to 2s	0 to 2s (>0 to 1s)	2 to 4s (>1 to 2s)
	Command δ -axis current $I_{\delta s}$	–	–1A	0A	2A (> –1A)	0A
	Command γ -axis current $I_{\gamma s}$	–	0A	1A	0A	1A (>2A)
	Fixed phase θ_{fix}	–	270°	0°	90° ($\neq 270^\circ$)	0°
Set velocity control	Rotation direction	CW	CCW (Opposite to CW)		CW (Opposite to CCW)	
	Acceleration α	100 rpm/s	50 rpm/s (<100 rpm/s)		25 rpm/s (<50 rpm/s)	
	Command δ -axis current $I_{\delta s}$	1A	2A (>1A)		3A (>2A)	
	Command γ -axis current $I_{\gamma s}$	0A	0A		0A	

[0061] The parameters include phase fixed time T2 for initial phase fixed control, fixed phase θ_{fix} , command δ -axis current I_{δ} , command γ -axis current I_{γ} , a rotation direction for set velocity control, acceleration α , command δ -axis current I_{δ} , and command γ -axis current I_{γ} . These are examples of settings, and the settings are changed depending on a sequence such as stirring and dehydration and the amount of laundry.

[0062] In the initial phase fixed control performed in step S204, a constant phase DC voltage is applied to converge the rotor position to fixed phase θ_{fix} (for example, 270° or 90°). Further, performing initial phase fixed control again with phase θ_{fix} (for example, 0°) shifted by 90° will facilitate converging the rotor position to an arbitrary phase (for example, 0°). This control is continued until the elapse of predetermined time T2 in step S205. In order to quicken the startup, T2 = 0s may be set and the process may immediately proceed to step S206.

[0063] In the set velocity control performed in step S206, velocity ω is not detected and is accelerated in an open loop in which velocity ω is treated as equivalent to set velocity ω_s . If it is determined in step S207 that set velocity ω_s exceeds ω_1 (for example, 100 rpm) set based on a velocity enabling phase estimation, the phase estimation flag is set in step S208, and the sensorless open loop acceleration control process is terminated in step S209.

[0064] Fig. 10 is a vector diagram of the initial phase fixed control of the motor of the washing machine according to the first exemplary embodiment. Fig. 11 is a graph showing the command rotation speed of sensorless open loop acceleration control for the motor of the washing machine according to the first exemplary embodiment.

5 [0065] As shown in Fig. 10, phase θ_{fix} is set using the fixed coordinates of initial phase fixed control $\omega_s = 0$ rpm, with γ -axis direction set by the microcomputer as 0° and the δ -axis direction as 90° .

[0066] With reference to Fig. 11, the operations of the first restart after motor lock is detected and the second restart after motor lock is detected in a normal state will be
10 described.

[0067] Normally, phase fixed time $T2 = 0$ s is set, and initial phase fixed control is not performed. The velocity is accelerated to ω_1 with set velocity control in the CW direction from the initial stage of startup, acceleration α_1 (for example, 100 rpm/s: acceleration that rises to 100 rpm per second), and current setting (for example, $I_{\delta s} = 1$ A, $I_{\gamma s} = 0$ A). Since
15 initial phase fixed control is not performed as in an operation at the time of motor lock described below, no extra time is generated at startup. Since acceleration α of set velocity control is large and the acceleration time is short with respect to the operation at the time of motor lock, quick startup control can be performed. In addition, since the current is suppressed with respect to the operation at the time of motor lock, energy saving operation
20 can be performed.

[0068] In the first restart after motor lock is detected, initial phase fixed control during the period from 0 to $T2_1/2$ (for example, 1s) is performed with current setting (for example, $I_{\delta s} = -1$ A, $I_{\gamma s} = 0$ A, $\theta_{fix} = 270^\circ$), and initial phase fixed control during the period from $T2_1/2$ to $T2_1$ (for example, 2s) is performed with current setting (for
25 example, $I_{\delta s} = 0$ A, $I_{\gamma s} = 1$ A, $\theta_{fix} = 0^\circ$), thereby converging the rotor position to 0° . After $T2$ (for example, 2s), set velocity control is performed in the CCW direction, at acceleration α_2 (for example, 50 rpm/s), and with current setting (for example, $I_{\delta s} = 2$ A, $I_{\gamma s} = 0$ A) so as to rotate the motor in the CCW direction opposite to the CW direction at the time of normal operation in which the velocity is accelerated to ω_1 , thereby facilitating
30 releasing the lock state due to the uneven distribution of clothes at the start of stirring. The acceleration is reduced as compared with the normal operation (for example, 100 rpm/s $\rightarrow$ 50 rpm/s) to make step-out due to sudden acceleration less likely to occur, and the

command current is increased (for example, $I_{\delta s} = 1 \text{ A} \rightarrow 2 \text{ A}$ and $I_{\gamma s} = 0 \text{ A}$) to increase the torque, thereby making it easy to release the motor lock. For the second restart operation described below, the initial phase fixed control is short, acceleration α is large, and the acceleration time is short, so that quick startup control can be performed. In addition, since
5 the current is suppressed with respect to the second startup operation, energy saving operation can be performed.

[0069] In the second restart after motor lock is detected, initial phase fixed control during the period from 0 to $T2_2/2$ (for example, 2s) is performed with current setting (for example, $I_{\delta s} = -2 \text{ A}$, $I_{\gamma s} = 0 \text{ A}$, $\theta_{\text{fix}} = 90^\circ$), and initial phase fixed control during the
10 period from $T2_2/2$ to $T2_2$ (for example, 4s) is performed with current setting (for example, $I_{\delta s} = 0 \text{ A}$, $I_{\gamma s} = 2 \text{ A}$, $\theta_{\text{fix}} = 0^\circ$), thereby converging the rotor position to 0° . By changing fixed phase θ_{fix} in the period from 0 to $T2/2$ from 270° for the first restart to 90° , the phase can be easily converged even when the phase is locked for the first time around 90° . In addition, more rotational torque is generated by increasing command current ($I_{\delta s}$,
15 $I_{\gamma s}$), and the phase fixed time is increased (for example, $2\text{s} \rightarrow 4\text{s}$) to secure the time for the phase to converge. After $T2$ (for example, 4s), set velocity control is performed in the CW direction, at acceleration α_2 (for example, 25 rpm/s), and with current setting (for example, $I_{\delta s} = 3 \text{ A}$, $I_{\gamma s} = 0 \text{ A}$) to accelerate the velocity to ω_1 .

[0070] Rotating the motor in the CW direction opposite to the CCW direction at the first
20 restart will make it easy to release the lock state due to the uneven distribution of clothes at the start of stirring. The acceleration is reduced as compared with the first restart operation (for example, $50 \text{ rpm/s} \rightarrow 25 \text{ rpm/s}$) to make step-out due to sudden acceleration less likely to occur, and the command current is increased (for example, $I_{\delta s} = 2 \text{ A} \rightarrow 3 \text{ A}$ and $I_{\gamma s} = 0 \text{ A}$) to increase the torque, thereby making it easy to release the motor lock.

[0071] In the above explanation, motor applied voltages (V_{us} , V_{vs} , V_{ws}) are computed with currents ($I_{\delta s}$, $I_{\gamma s}$). However, motor applied voltages (V_{us} , V_{vs} , V_{ws}) can also be
25 computed by setting voltages ($V_{\delta s}$, $V_{\gamma s}$).

[0072] Fig. 12 is a flowchart of a sensorless phase estimation control process for the motor of the washing machine according to the first exemplary embodiment.

[0073] The sensorless phase estimation control process is started in step S300, and it is
30 determined in step S301 whether or not motor lock has occurred. In this determination, the motor lock is detected when velocity ω or induced voltage V_e calculated by phase

estimation is extremely low with respect to set velocity ω_s . If no motor lock has occurred, the process advances to step S302. If motor lock has occurred, the process advances to step S305. If the duration of the lock state is less than predetermined time T3 (for example, 5s) in step S305, the process advances to step S302. If the duration exceeds T3, the process
5 advances to step S306.

[0074] In step S302, final velocity ω and phase θ in sensorless open loop acceleration control are used as initial values to perform velocity control. The process then advances to step S303.

[0075] In order to rotate the motor at set velocity ω_s determined by the sequence, δ -axis
10 current command $I_{\delta s}$ is set according to velocity ω . This operation will be described in detail with reference to Fig. 13 illustrated below. If velocity ω becomes less than ω_2 (for example, 100 rpm) set based on the velocity at which phase estimation is impossible in step S303, the process advances to step S308. If velocity ω becomes larger than ω_2 , the process returns to the lock state check in step S301.

[0076] In step S306, the number of times of motor locking is checked. If the number of
15 times of motor locking is less than predetermined number n1 (for example, 16), the process advances to step S308 to restart the motor by sensorless open loop acceleration control. If the number of times of motor locking is predetermined number n1 or more, it is determined in step S307 that the motor lock state is not cleared, and abnormality is informed.

[0077] The phase estimation flag is cleared in step S308, and the sensorless phase
20 estimation control process is terminated in step S309.

[0078] Fig. 13 is a flowchart of a velocity control process for the motor of the washing machine according to the first exemplary embodiment.

[0079] A velocity control process is started in step S400, and command velocity ω_s is
25 computed according to the acceleration or deceleration sent from the sequence unit of the washing machine in step S401. In step S402, velocity ω is computed from velocity phase estimator 21. In step S403, it is checked whether velocity ω is larger than command velocity ω_s . If velocity ω is greater than command velocity ω_s (YES) in step S403, command $I_{\delta s}$ is reduced and the acceleration torque is reduced in step S404. If velocity ω
30 is smaller than command velocity ω_s (NO) in step S403, since it indicates that the torque is insufficient, command $I_{\delta s}$ is increased in step S405 to increase the torque.

[0080] The velocity loop portion in steps S401 to S405 is repeated at regular intervals

(for example, every 1 ms).

[0081] In step S406, the phase currents (I_u , I_v , I_w) detected by current detector 18 and estimated phase θ computed by velocity phase estimator 21 are subjected to three-phase to two-phase conversion to compute δ -axis current I_δ . It is checked in step S407 if I_δ is greater than command I_δ s. If I_δ is greater than command I_δ s (YES), command V_δ s is reduced in step S408. If I_δ is less than command I_δ s (NO), command V_δ s is increased in step S409.

[0082] In step S410, in the case of I_γ , similar to the case of I_δ , phase currents (I_u , I_v , I_w) detected by current detector 18 and estimated phase θ computed by velocity phase estimator 21 are subjected to three-phase to two-phase conversion to compute γ -axis current I_γ . It is checked in step S411 if I_γ is greater than command I_γ s. If I_γ is greater than command I_γ s (YES), command V_γ s is reduced in step S412. If I_γ is less than command I_γ s (NO), command V_γ s is increased in step S413.

[0083] Subsequently, in step S414, command V_δ s and command V_γ s, and estimated phase θ computed by velocity phase estimator 21 are subjected to two-phase to three-phase conversion to compute applied voltages V_{us} , V_{vs} , and V_{ws} , which are then applied to the motor in step S415.

[0084] The current minor loop portion in steps S406 to S415 is repeated at regular intervals (for example, every 0.1 ms) faster than the speed loop portion.

[0085] Finally, in step S416, the velocity control process is terminated.

[0086] In the velocity loop portion in steps S401 to S405, ω is compared with command ω s and command I_δ s is output. In this case, since the fluctuation factor is large and the control is unstable, PI control to which an integration factor such as averaging is added is performed.

[0087] Similarly, in the current minor loop in steps S406 to S415, I_δ and I_γ are respectively compared with command I_δ s and command I_γ s and command V_δ s and command V_γ s are output. In this case, since the fluctuation factor is large and the control is unstable, PI control to which an integration factor such as averaging is added is performed.

[0088] (Action, etc.)

As described above, the washing machine according to the present exemplary embodiment includes pulsator 1 that is a rotating object configured to come into contact with laundry and to stir clothes, motor 4 that is an electric motor having permanent magnet

4d and windings 4a, 4b, and 4c, inverter circuit 17 that is a power supply circuit configured to supply current to motor 4, motor pulley 31, belt 5, impeller pulley 32, and speed reduction mechanism and clutch 6 that constitute a transmission mechanism configured to transmit the torque of motor 4 to pulsator 1, and controller 20 that executes a washing
5 control operation. Controller 20 executes a sensorless open loop acceleration control process that is the first control process of energizing windings 4a, 4b, and 4c regardless of the position of permanent magnet 4d and a sensorless phase estimation control process that is the second control process of energizing windings 4a, 4b, and 4c in accordance with the position of permanent magnet 4d. Controller 20 executes a sensorless phase estimation
10 control process of detecting that motor lock has occurred when permanent magnet 4d is not rotated at a predetermined rotation speed after transition from the sensorless open loop acceleration control process to the sensorless phase estimation control process. In the sensorless phase estimation control process, when motor 4 is detected to be locked, controller 20 performs phase fixed control in different phases a plurality of times at the
15 start of driving by the sensorless open loop acceleration control process.

[0089] With this configuration, the rotor position can be easily converged to an arbitrary phase, the torque at the time of initial drive can be easily transmitted to the motor, and the lock state can be easily released.

[0090] As in the present exemplary embodiment, controller 20 may change the phase of
20 phase fixed control by a sensorless open loop acceleration control process when motor 4 is detected to be locked in a sensorless phase estimation control process.

[0091] This configuration facilitates transmitting the torque at the time of initial drive to the motor regardless of the rotor position where the motor is locked, thus easily releasing the lock state.

[0092] As in the present exemplary embodiment, the controller may reverse the drive
25 rotation direction by a sensorless open loop acceleration control process when motor 4 is detected to be locked in a sensorless phase estimation control process in a stirring or rinsing sequence.

[0093] With this configuration, even if the clothes are stuck in either the left or right
30 direction of the rotation of the pulsator and the motor cannot be started, the clothes can be loosened by starting the motor in the direction opposite to the lock rotation direction once, thus easily releasing the lock state in the lock rotation direction.

[0094] The present exemplary embodiment includes pulsator 1 that is a rotating object

configured to come into contact with laundry and to stir clothes, motor 4 that is an electric motor having permanent magnet 4d and windings 4a, 4b, and 4c, inverter circuit 17 that is a power supply circuit configured to supply current to motor 4, motor pulley 31, belt 5, impeller pulley 32, and speed reduction mechanism and clutch 6 that constitute a
5 transmission mechanism configured to transmit the torque of motor 4 to pulsator 1, and controller 20 that executes a washing control operation. Controller 20 executes a sensorless open loop acceleration control process that is the first control process of energizing windings 4a, 4b, and 4c regardless of the position of permanent magnet 4d and a sensorless phase estimation control process that is the second control process of energizing windings
10 4a, 4b, and 4c in accordance with the position of permanent magnet 4d. Controller 20 executes a sensorless phase estimation control process of detecting that motor lock has occurred when permanent magnet 4d is not rotated at a predetermined rotation speed after transition from the sensorless open loop acceleration control process to the sensorless phase estimation control process. Controller 20 may reduce the drive rotation speed
15 acceleration by a sensorless open loop acceleration control process when motor 4 is detected to be locked in a sensorless phase estimation control process.

[0095] This configuration can suppress step-out due to acceleration at the time of motor lock and transmit torque to the motor, thereby easily releasing the lock state.

[0096] As in the present exemplary embodiment, controller 20 may increase the current or voltage controlled by a sensorless open loop acceleration control process when motor 4
20 is detected to be locked in a sensorless phase estimation control process.

[0097] This configuration can easily release the lock state by transmitting strong torque to the motor.

[0098] As in the present exemplary embodiment, the controller may reverse the drive rotation direction by a sensorless open loop acceleration control process when motor 4 is
25 detected to be locked in a sensorless phase estimation control process in a stirring or rinsing sequence.

[0099] With this configuration, even if the clothes are stuck in either the left or right direction of the rotation of the pulsator and the motor cannot be started, the clothes can be
30 loosened by starting the motor in the direction opposite to the lock rotation direction once, thus easily releasing the lock state in the lock rotation direction.

[0100] (Other exemplary embodiments)

The first exemplary embodiment has been described above as an example of the

present disclosure. However, the technique according to the present disclosure are not limited to this.

[0101] Therefore, other exemplary embodiments will be described below as examples.

[0102] The first exemplary embodiment has exemplified the pulsator type vertical washing machine in which motor pulley 31 and impeller pulley 32 are connected to each other through belt 5 and joined to pulsator 1 or washing and dehydrating tank 2 through speed reduction mechanism and clutch 6. However, even in a direct drive type washing machine in which the washing and dehydrating tank and the motor are coaxial, when the washing machine fails to start and becomes locked, the lock state can be easily released.

[0103] Further, the first exemplary embodiment has exemplified a pulsator type vertical washing machine. However, even a drum type washing machine can be configured to easily release a lock state when the motor fails to start and becomes locked.

INDUSTRIAL APPLICABILITY

[0104] The present disclosure can easily release the lock state by changing the starting method when the machine fails to start and enters the lock state. More specifically, the present disclosure is applicable to a pulsator type vertical washing machine and a drum type washing machine.

REFERENCE MARKS IN THE DRAWINGS

- | | | |
|--------|----|---|
| [0105] | 1 | pulsator (rotating object) |
| | 2 | washing and dehydrating tank |
| | 3 | water receiving tank |
| | 4 | motor (electric motor) |
| 25 | 4a | winding |
| | 4b | winding |
| | 4c | winding |
| | 4d | permanent magnet (rotor) |
| | 5 | belt (transmission mechanism) |
| 30 | 6 | speed reduction mechanism and clutch (transmission mechanism) |
| | 7 | geared motor |
| | 8 | brake belt |
| | 9 | washing machine outer frame |

	10	panel
	11	lid
	12	display
	13	control device
5	14	water supply valve
	15	drain valve
	16	rectifier circuit
	17	inverter circuit (power supply circuit)
	18	current detector
10	19	PWM controller
	20	controller
	21	velocity phase estimator
	22	three-phase two-phase converter
	23	$I\delta$ error amplifier
15	24	$I\gamma$ error amplifier
	25	two-phase three-phase converter
	26	velocity error amplifier
	27	field weakening setter
	28	γ -axis induced voltage calculator
20	29	γ -axis induced voltage error amplifier
	30	phase computing unit
	31	motor pulley (transmission mechanism)
	32	impeller pulley (transmission mechanism)

CLAIMS

1. A washing machine comprising:
a rotating object that comes into contact with laundry;
5 an electric motor having a permanent magnet and windings;
a power supply circuit that supplies current to the electric motor;
a transmission mechanism that transmits torque of the electric motor to the
rotating object; and
a controller that executes a washing control operation,
10 wherein the controller is configured to execute:
a first control process of energizing the windings regardless of a position
of the permanent magnet,
a second control process of energizing the windings in accordance with
the position of the permanent magnet; and
15 a lock detection process of detecting that motor lock has occurred when
the permanent magnet is not rotated at a predetermined rotation speed after transition from
the first control process to the second control process, and
the controller performs phase fixed control in different phases a plurality of times
at a start of driving by the first control process upon detecting motor lock in the lock
20 detection process.
2. The washing machine according to Claim 1, wherein the controller changes a
phase of phase fixed control by the first control process upon detecting that the motor lock
has occurred in the lock detection process.
25
3. The washing machine according to any one of Claims 1 and 2, wherein the
controller inverses a drive rotation direction by the first control process upon detecting that
the motor lock has occurred in the lock detection process in a stirring or rinsing sequence.
4. A washing machine comprising:
30 a rotating object that comes into contact with laundry;
an electric motor having a permanent magnet and windings;
a power supply circuit that supplies current to the electric motor;

a transmission mechanism that transmits torque of the electric motor to the rotating object; and

a controller that executes a washing control operation,

wherein the controller is configured to execute:

5 a first control process of energizing the windings regardless of a position of the permanent magnet,

 a second control process for energizing the windings in accordance with the position of the permanent magnet; and

 a lock detection process of detecting that motor lock has occurred when
10 the permanent magnet is not rotated at a predetermined rotation speed after transition from the first control process to the second control process, and

 the controller reduces a drive rotation speed acceleration by the first control process upon detecting that the motor lock has occurred in the lock detection process.

15 5. The washing machine according to Claim 4, wherein the controller increases current or voltage controlled by the first control process upon detecting that motor lock has occurred in the lock detection process.

 6. The washing machine according to any one of Claims 4 and 5, wherein the
20 controller inverses a drive rotation direction by the first control process upon detecting that the motor lock has occurred in the lock detection process in a stirring or rinsing sequence.