

DESCRIPTION

Title of Invention

CRANE TYPE TRANSPORT DEVICE AND TRANSPORT METHOD

5 Technical Field

[0001] The present disclosure relates to a crane type transport device and a transport method.

Background Art

10 [0002] Patent Document 1 discloses, in a crane or the like, a method of preventing sway of a load suspended with a rope by negatively feeding back a signal obtained by performing phase lead/lag compensation on a deviation between a sway angle detection estimation value and a sway angle setting value of the rope to a speed command of a driving device.

Citation List

15 Patent Literature

[0003] [Patent Document 1] Japanese Unexamined Patent Publication No. H08-295486

Summary of Invention

Technical Problem

20 [0004] The present disclosure provides a crane type transport device effective in improving transport efficiency.

Solution to Problem

25 [0005] A crane type transport device according to an aspect of the present disclosure includes: a hoist medium that lifts transport object with a rope; a command generation unit configured to generate a speed command pattern for moving the transport object from a first position to

a second position; a displacement driver configured to displace the hoist medium in a displacement direction intersecting a vertical direction based on the speed command pattern; a sensor configured to detect a moving distance of the transport object; an error estimation unit configured to estimate, based on the speed command pattern and the moving distance of the transport object detected by the sensor during movement of the hoist medium based on the speed command pattern, a stop position error between the second position and a position of the transport object at a time when the movement of the hoist medium based on the speed command pattern is completed; and a pattern correction unit configured to correct the speed command pattern so as to reduce the stop position error during the movement of the hoist medium based on the speed command pattern.

[0006] A transport method according to another aspect of the present disclosure includes: generating a speed command pattern for moving a transport object from a first position to a second position by displacing a hoist medium that lifts up the transport object with a rope in a displacement direction intersecting a vertical direction with a displacement driver; estimating, during movement of the hoist medium based on the speed command pattern, a stop position error between the second position and a position of the transport object at a time when the movement of the hoist medium based on the speed command pattern is completed based on the speed command pattern and a moving distance of the transport object detected with a sensor; and correcting the speed command pattern so as to reduce the stop position error during the movement of the hoist medium based on the speed command pattern.

Advantageous Effects of Invention

[0007] According to the present disclosure, it is possible to provide a crane type transport device effective for improvement of transport efficiency.

Brief Description of Drawings

[0008] FIG. 1 is a schematic diagram illustrating an example configuration of a crane type transport device.

FIG. 2 is a schematic diagram illustrating an example configuration of a controller.

FIG. 3 is a block diagram illustrating an example configuration of a control circuit.

FIG. 4 is a graph illustrating a speed command pattern.

FIG. 5 is a block diagram illustrating an example hardware configuration of the control circuit.

FIG. 6 is a schematic diagram illustrating an example modification of the crane type transport device.

FIG. 7 is a flow chart illustrating a lifting procedure.

FIG. 8 is a flow chart illustrating a moving procedure.

FIG. 9 is a flow chart illustrating a lowering procedure.

Description of Embodiments

[0009] Hereinafter, an embodiment will be described in detail with reference to the drawings. In the description, the same elements or elements having the same functions are denoted by the same reference numerals, and redundant description will be omitted.

[0010] Crane Type Transport Device

A crane type transport device 1 illustrated in FIG. 1 is a device that lifts

and conveys a transport object with a rope. Specific examples of the crane type transport device 1 include a so-called overhead crane. As illustrated in FIG. 1, the crane type transport device 1 includes a support 2, a hoist medium 3, a hoisting device 10, a displacement driver 20, and a sensor 30. The support 2 supports a transport object 9 from below. The hoist medium 3 lifts up the transport object 9 with the suspended a rope 4. For example, the hoist medium 3 lifts the support 2 supporting the transport object 9 with the rope 4.

[0011] The hoisting device 10 is provided in the hoist medium 3, and changes a hanging length of the rope 4 from the hoist medium 3. For example, the hoisting device 10 includes a reel 11, a motor 12, a brake 13, and a winding controller 100. The reel 11 winds up the rope 4. The motor 12 rotates the reel 11 by receiving power supply, and changes a wound length of the rope 4 with the reel 11.

[0012] For example, the motor 12 rotates the reel 11 in a winding direction or a feeding direction. When the motor 12 rotates the reel 11 in the winding direction, the wound length of the rope 4 on the reel 11 becomes longer. Thus, the hanging length of the rope 4 from the hoist medium 3 is shortened, and the support 2 and the transport object 9 are lifted. When the motor 12 rotates the reel 11 in the feeding direction, the wound length of the rope 4 on the reel 11 is shortened. As a result, the hanging length of the rope 4 from the hoist medium 3 is increased, and the support 2 and the transport object 9 are lowered.

[0013] The motor 12 may be a synchronous motor or may be an induction motor. Specific examples of the synchronous motor include a permanent magnet type synchronous motor and a synchronous

reluctance motor. Specific examples of the permanent magnet type synchronous motor include a surface permanent magnet (SPM) motor, an interior permanent magnet (IPM) motor, and the like.

[0014] The brake 13 is supplied with power and applies a braking force to the reel 11 to forcibly stop the rotation of the reel 11. The winding controller 100 operates the motor 12 and the brake 13 based on a command from a host controller 300.

[0015] The displacement driver 20 displaces the hoist medium 3 along a displacement direction 29 intersecting a vertical direction. As an example, the displacement driver 20 displaces the hoist medium 3 along a horizontal displacement direction 29 orthogonal to the vertical direction.

[0016] The displacement driver 20 includes a motor 21 and a displacement controller 200. The motor 21 is supplied with power to displace the hoist medium 3 along the displacement direction. The motor 21 may be a synchronous motor or may be an induction motor. Specific examples of the synchronous motor include a permanent magnet type synchronous motor and a synchronous reluctance motor. Specific examples of the permanent-magnet synchronous motor include an SPM motor and an IPM motor. The displacement controller 200 operates the motor 21 based on a command from the host controller 300.

[0017] The sensor 30 is configured to detect a moving distance of the transport object 9 based on the displacement driver 20. For example, the sensor 30 includes a mover 31 and a detector 32. The mover 31 is fixed to the lower surface of the support 2 and moves together with the

support 2. The detector 32 is fixed to a floor surface or the like, and detects a moving distance of the support 2 along the displacement direction 29. Specific examples of the sensor 30 include a magnetic or optical non-contact displacement sensor. For example, the sensor 30
5 may be the optical sensor including the mover 31 which is a reflector and the detector 32 which is configured to irradiate the mover 31 with laser and to measure the moving distance based on the laser returned from the mover 31.

[0018] As described above, with the sensor that detects the displacement of the portion suspended with the rope 4, the displacement of the transport object 9 due to a sway of the rope 4 can also be detected. The sensor 30 may be configured to detect a moving distance of the hoist medium 3 as the moving distance of the transport object 9. With the sensor that detects the moving distance of the hoist medium 3,
10 a stable detection result that does not include the sway of the rope 4 can be obtained.

[0019] FIG. 2 is a schematic diagram illustrating configurations of the winding controller 100 and the displacement controller 200. The winding controller 100 includes a power conversion circuit 110 and a control circuit 120. The power conversion circuit 110 performs power conversion between a primary side connected to a power supply 90 and a secondary side connected to the motor 12. The power of the primary side may be alternate-current (AC) power or direct-current (DC) power. If the motor 12 is an AC motor, the power of the secondary side is AC power. As an example, the power of the primary side and the power of the secondary side are both three-phase AC power.
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[0020] For example, the power conversion circuit 110 includes a rectifier circuit 111, a DC bus 112, a smoothing capacitor 113, an inverter circuit 114, and a current sensor 115. The rectifier circuit 111 converts the power of the primary side into DC power and outputs the DC power to the DC bus 112. Specific examples of the rectifier circuit 111 include a diode bridge circuit including a plurality of diodes 116. The rectifier circuit 111 may be a pulse width modulation (PWM) converter circuit. The smoothing capacitor 113 smoothes the DC voltage in the DC bus 112.

[0021] The inverter circuit 114 converts the DC power of the DC bus 112 into power of the secondary side. The inverter circuit 114 includes a plurality of switching elements 117. Each of the switching elements 117 is, for example, a power metal-oxide-semiconductor field effect transistor (MOSFET), an insulated gate bipolar transistor (IGBT), or the like, and is switched on/off in accordance with a gate driving signal. The inverter circuit 114 converts the DC power into the power of the secondary side by switching on/off the switching elements 117 in response to the supply of the gate driving signal.

[0022] The current sensor 115 detects a current flowing between the inverter circuit 114 and the motor 12. For example, the current sensor 115 may be configured to detect currents of all phases (U phase, V phase, and W phase) of the three-phase alternating current, or may be configured to detect currents of any two phases of the three-phase alternating current. Since the sum of the currents of the U phase, the V phase, and the W phase is zero as long as no zero-phase current flows, the information on the currents of all the phases is obtained even when

the currents of two phases are detected.

[0023] The configuration of the power conversion circuit 110 described above is merely an example, and may be modified in any manner as long as power suitable for driving the motor 12 can be generated on the secondary side. If the power of the primary side is DC power, the power conversion circuit 110 need not include the rectifier circuit 111. The power conversion circuit 110 may be a matrix converter circuit that performs bi-directional power conversion between the primary side and the secondary side without an intermediate DC conversion.

[0024] The control circuit 120 controls the power conversion circuit 110 to generate power necessary for driving the motor 12 on the secondary side. For example, the control circuit 120 controls the power conversion circuit 110 to apply a secondary side voltage corresponding to a voltage command to the motor 12. The control circuit 120 may control the power conversion circuit 110 to supply a secondary side current corresponding to a current command to the motor 12.

[0025] The control circuit 120 controls not only the power conversion circuit 110 but also the brake 13. For example, the control circuit 120 supplies the brake 13 with the braking power necessary for generating the braking force. For example, the control circuit 120 supplies braking power to the brake 13 in conjunction with the power conversion circuit 110 stopping the power supply to the motor 12.

[0026] The displacement controller 200 includes a power conversion circuit 210 and a control circuit 220. The power conversion circuit 210 performs power conversion between a primary side connected to the power supply 90 and a secondary side connected to the motor 21. The

power of the primary side may be AC power or DC power. If the motor 21 is an AC motor, the power of the secondary side is AC power. As an example, the power of the primary side and the power of the secondary side are both three-phase AC power.

5 [0027] For example, the power conversion circuit 210 includes a rectifier circuit 211, a DC bus 212, a smoothing capacitor 213, an inverter circuit 214, and a current sensor 215. The rectifier circuit 211 converts the power of the primary side into DC power and outputs the DC power to the DC bus 212. Specific examples of the rectifier circuit
10 211 include a diode bridge circuit including a plurality of diodes 216. The rectifier circuit 211 may be a PWM converter circuit. The smoothing capacitor 213 smoothes the DC voltage in the DC bus 212.

[0028] The inverter circuit 214 converts the DC power of the DC bus
15 212 into power of the secondary side. The inverter circuit 214 includes a plurality of switching elements 217. Each of the switching elements 217 is, for example, a power MOSFET, an IGBT, or the like, and is switched on/off in accordance with a gate driving signal. The inverter circuit 214 converts the DC power into the power of the secondary side by
20 switching on/off the switching elements 217 in response to the supply of the gate driving signal.

[0029] The current sensor 215 detects a current flowing between the inverter circuit 214 and the motor 21. For example, the current sensor 215 may be configured to detect currents of all phases (U phase, V phase, and W phase) of the three-phase alternating current, or may be
25 configured to detect currents of any two phases of the three-phase alternating current.

[0030] Similarly to the configuration of the power conversion circuit 110, the configuration of the power conversion circuit 210 may be modified as appropriate. For example, if the power of the primary side is DC power, the power conversion circuit 210 may not include the rectifier circuit 211. The power conversion circuit 210 may be a matrix converter circuit.

[0031] The control circuit 220 controls the power conversion circuit 210 to generate power necessary for driving the motor 21 on the secondary side. For example, the control circuit 220 controls the power conversion circuit 210 to apply a secondary side voltage corresponding to a voltage command to the motor 21. The control circuit 220 may control the power conversion circuit 210 to supply a secondary side current corresponding to a current command to the motor 21.

[0032] The control circuit 120 and the control circuit 220 may be configured to perform transport control for transporting the transport object 9 from a transport start position to a transport target position in accordance with a command from the host controller 300. For example, the host controller 300 outputs a lifting command to the control circuit 120, outputs a transport command to the control circuit 220, and outputs a lowering command to the control circuit 120. The lifting command is a command to lift the transport object 9 at the transport start position. The transport command is a command to transport the lifted transport object 9 from the transport start position to the transport target position. The lowering command is a command to lower the transport object 9 at the transport target position.

[0033] The control circuit 120 controls the power conversion circuit

110 and the sensor 30 to lift the transport object in accordance with the lifting command, and controls the power conversion circuit 110 and the brake 13 to lower the transport object in accordance with the lowering command. The control circuit 220 controls the power conversion circuit 210 to transport the transport object in accordance with the transport command. For example, the control circuit 220 generates a speed command pattern for moving the transport object 9 from a transport start position (a first position) to a transport target position (a second position), and moves the hoist medium 3 with the displacement driver 20 based on the speed command pattern.

[0034] The speed command pattern is a pattern for determining transition (temporal change) of the displacement speed command value. The control circuit 220 controls the power conversion circuit 210 so that the displacement speed of the hoist medium 3 at each time during movement follows the displacement speed command value of the speed command pattern by rotating the motor 21.

[0035] If the hoist medium 3 can be displaced at a displacement speed that perfectly matches the speed command pattern, the transport completion position of the transport object 9 matches the transport target position. However, in practice, it is difficult to completely match the displacement speed of the hoist medium 3 with the speed command pattern. For this reason, a deviation between the displacement speed command value in the speed command pattern and the displacement speed of the hoist medium 3 is accumulated, and the deviation may occur between the transport completion position and the transport target position of the transport object 9. In a case where the deviation is large,

it is necessary to adjust the position of the hoist medium 3 by re-movement or the like before the transport object 9 is lowered, and the transport efficiency of the transport object 9 deteriorates.

[0036] On the other hand, the control circuit 220 is configured to, during movement of the hoist medium 3 based on the speed command pattern, perform: estimating a stop position error between the predicted stop position of the transport object 9 and the transport target position based on the speed command pattern and the moving distance of the transport object 9 detected by the sensor 30; and correcting the speed command pattern to reduce the stop position error during movement of the hoist medium 3 based on the speed command pattern. The predicted stop position is a predicted position of the hoist medium 3 at the time when the movement of the transport object 9 based on the speed command pattern is completed. For example, the control circuit 220 calculates a moving distance error between the estimated moving distance of the transport object 9 based on the speed command pattern and the moving distance of the transport object 9 detected by the sensor 30, and estimates the stop position error based on the moving distance error.

[0037] As described above, with the configuration in which the speed command pattern is corrected so as to reduce the stop position error, the stop position error is estimated based on the moving distance error actually generated during the movement based on the speed command pattern, and the speed command pattern is corrected so as to reduce the stop position error. Therefore, the stop position error can also be reduced by open loop control based on the speed command pattern. By

reducing the stop position error, it is possible to reduce position adjustment by re-movement of the hoist medium 3 or the like. The open-loop control herein represents control that does not include a feedback loop of position. The feedback loop of position is a control loop that sequentially changes the speed command based on the deviation between position feedback information and the position command.

[0038] Hereinafter, example configurations of the control circuit 120 and the control circuit 220 will be described in more detail. FIG. 3 is a block diagram illustrating the configuration of the control circuit. As illustrated in FIG. 3, the control circuit 120 includes a command generation unit 121, an auto control unit 122, and a length information transmission unit 123 as functional blocks.

[0039] The command generation unit 121 is configured to generate a lifting speed command pattern for lifting the transport object 9 based on the lifting command from the host controller 300. The lifting speed command pattern is a pattern for determining transition of the lifting speed command value of the transport object 9. The lifting command includes a lifting target height. For example, the command generation unit 121 generates a lifting speed command pattern so as to start lifting the transport object 9 and stop lifting the transport object 9 at the lifting target height.

[0040] The command generation unit 121 is further configured to generate a lowering speed command pattern for lowering the transport object 9 based on the lowering command from the host controller 300. The lowering speed command pattern is a pattern for determining

transition of the lowering speed command value of the transport object 9. The lowering command includes a lowering target height. For example, the command generation unit 121 generates the lowering speed command pattern so as to start lowering of the transport object 9 and stop lowering of the transport object 9 at the lowering target height.

[0041] The auto control unit 122 is configured to control the power conversion circuit 110 to rotate the reel 11 with the motor 12 based on the lifting speed command pattern. For example, the auto control unit 122 controls the power conversion circuit 110 so that the lifting speed of the transport object 9 at each time during the lifting of the transport object 9 follows the lifting speed command value of the lifting speed command pattern by rotating the reel 11. The auto control unit 122 is further configured to control the power conversion circuit 110 to rotate the reel 11 with the motor 12 based on the lowering speed command pattern. For example, the auto control unit 122 controls the power conversion circuit 110 so that the lowering speed of the transport object 9 at each time during the lowering of the transport object 9 follows the lowering speed command value of the lowering speed command pattern by rotating the reel 11.

[0042] The auto control unit 122 is further configured to release braking of the reel 11 with the brake 13 before starting the rotation of the reel 11 based on the lifting speed command pattern or the lowering speed command pattern, and to resume the braking of the reel 11 with the brake 13 after completing the rotation of the reel 11 based on the lifting speed command pattern or the lowering speed command pattern.

[0043] The auto control unit 122 is further configured to transmit a

lifting completion notification to the host controller 300 after completing rotation of the reel 11 based on the lifting speed command pattern and resuming braking of the reel 11 with the brake 13. After receiving the lifting completion notification from the auto control unit 122, the host controller 300 transmits the transport command to the control circuit 220.

[0044] The length information transmission unit 123 is configured to acquire information on a rotation angle of the reel 11 from the auto control unit 122 and the like, and to calculate the hanging length of the rope 4 from the hoist medium 3 (for example, from the reel 11). Hereinafter, the calculation result of the hanging length is referred to as “rope length information”. The length information transmission unit 123 transmits the rope length information to the control circuit 220. The length information transmission unit 123 may transmit the rope length information to the control circuit 220 via the host controller 300.

[0045] The control circuit 220 includes a command generation unit 221, a command storage unit 222, an auto control unit 227, an error estimation unit 223, and a pattern correction unit 224 as functional blocks. The command generation unit 221 is configured to generate the speed command pattern based on the transport command. The transport command includes a transport target position. The command generation unit 221 generates a speed command pattern to start the movement of the hoist medium 3 at a current position (a transport start position) and to stop the movement of the hoist medium 3 at a transport target position.

[0046] The command generation unit 221 may generate a speed

command pattern including an acceleration period, a constant speed period following the acceleration period, and a deceleration period following the constant speed period. The command generation unit 221 may generate a speed command pattern in which a transition of an acceleration in an acceleration period and a transition of an absolute value of an acceleration in a deceleration period are equal to each other. For example, the command generation unit 221 may generate a speed command pattern in which the acceleration in the acceleration period and the absolute values of the acceleration in the deceleration period are the same constant values (see FIG. 4). The command generation unit 221 stores the generated speed command pattern in the command storage unit 222.

[0047] The auto control unit 227 is configured to move the hoist medium 3 with the displacement driver 20 based on the speed command pattern stored in the command storage unit 222. For example, the auto control unit 227 controls the power conversion circuit 210 so that the displacement speed of the hoist medium 3 at each time during movement follows the displacement speed command value of the speed command pattern by rotating the motor 21.

[0048] The error estimation unit 223 is configured to calculate a moving distance error between an estimated moving distance of the transport object 9 based on the speed command pattern and a moving distance of the transport object 9 detected by the sensor 30 during movement of the hoist medium 3 based on the speed command pattern stored in the command storage unit 222, and to estimate a stop position error between the predicted stop position and the transport target

position based on the moving distance error. The error estimation unit 223 may calculate the moving distance error before completion of the constant speed period, or may calculate the moving distance error in the acceleration period. If calculating the moving distance error in the acceleration period, the error estimation unit 223 calculates the moving distance error after the acceleration period is completed and before the constant speed period is completed. The error estimation unit 223 may estimate the moving distance error in the deceleration period based on the moving distance error in the acceleration period, and may estimate the stop position error based on the moving distance error in the acceleration period and the moving distance error in the deceleration period. Hereinafter, the moving distance error in the acceleration period is referred to as an “error during acceleration”, and the moving distance error in the deceleration period is referred to as an “error during deceleration”.

[0049] For example, the error estimation unit 223 detects completion of the acceleration period based on the displacement speed command value of the hoist medium 3 reaching the displacement speed command value in the constant speed period. The error estimation unit 223 may detect completion of the acceleration period based on the detected or estimated value of the displacement speed of the hoist medium 3 reaching the displacement speed command value in the constant speed period. Hereinafter, a time point at which completion of the acceleration period is detected is referred to as an “acceleration completion time”. The error estimation unit 223 calculates the estimated moving distance by integrating the displacement speed command value up to the

acceleration completion time. The error estimation unit 223 is further configured to acquire a moving distance of the transport object 9 detected by the sensor 30 in the acceleration completion time. Hereinafter, the moving distance of the transport object 9 detected by the sensor 30 is referred to as a “detected moving distance”. The error estimation unit 223 is configured to calculate the error during acceleration based on the estimated moving distance and the detected moving distance. For example, the error estimation unit 223 calculates the error during acceleration by subtracting the detected moving distance from the estimated moving distance.

[0050] The error estimation unit 223 calculates the error during deceleration based on the error during acceleration. As described above, if the transition of the acceleration in the acceleration period and the transition of the absolute value of the acceleration in the deceleration period are equal to each other, the error during deceleration tends to be a value approximate to the error during acceleration. Accordingly, if the transition of the acceleration in the acceleration period and the transition of the absolute value of the acceleration in the deceleration period are equal to each other, the error during deceleration is calculated based on the following expression.

$$\text{error during deceleration} = \text{error during acceleration} \quad (1)$$

If the transition of the acceleration in the acceleration period and the transition of the absolute value of the acceleration in the deceleration period are not equal to each other, the error estimation unit 223 may calculate the error during deceleration by performing a correction operation on the error during acceleration based on a difference between

an acceleration pattern and a deceleration pattern. The acceleration pattern herein represents a portion corresponding to the acceleration period in the speed command pattern, and the deceleration pattern herein represents a portion corresponding to the deceleration period in the speed command pattern.

[0051] The error estimation unit 223 estimates the stop position error based on the error during acceleration and the error during deceleration. For example, the error estimation unit 223 estimates the stop position error by summing the error during acceleration and the error during deceleration. If the transition of the acceleration in the acceleration period and the transition of the absolute value of the acceleration in the deceleration period are equal to each other, the error estimation unit 223 may estimate the stop position error by doubling the error during acceleration. As described above, if the error during acceleration is calculated by subtracting the detected moving distance from the estimated moving distance, the stop position error being a positive value means that the moving distance of the transport object 9 is insufficient with respect to the transport target position. On the other hand, the stop position error being a negative value means that the moving distance of the transport object 9 is excessive with respect to the transport target position.

[0052] The pattern correction unit 224 is configured to correct the speed command pattern stored in the command storage unit 222 so as to reduce the stop position error during movement of the hoist medium 3 based on the speed command pattern. For example, the pattern correction unit 224 changes a start timing of the deceleration period so

as to reduce the stop position error before the completion of the constant speed period. For example, the pattern correction unit 224 extends or shortens the constant speed period by changing the start timing of the deceleration period based on the speed command value in the constant speed period and the stop position error. As an example, the pattern correction unit 224 adds a time correction value obtained by dividing the stop position error by the speed command value to the start timing of the deceleration period. If the time correction value is a positive value, the constant speed period is extended by a length corresponding to the time correction value. If the time correction value is a negative value, the constant speed period is shortened by a length corresponding to the time correction value.

[0053] After the speed command pattern stored in the command storage unit 222 is corrected, the auto control unit 227 controls the displacement driver 20 to continue to move the hoist medium 3 based on the speed command pattern after correction. Hereinafter, the speed command pattern after correction is referred to as a “corrected speed command pattern”. Based on the corrected speed command pattern, the excess or the insufficiency of the moving distance of the transport object 9 is reduced as compared with the case based on the speed command pattern before correction. For example, if the constant speed period is extended by a length corresponding to the time correction value, the insufficiency of the moving distance of the transport object 9 is reduced. If the constant speed period is shortened by an amount corresponding to the time correction value, the excess of the moving distance of the transport object 9 is reduced.

[0054] The displacement controller 200 may further include a frequency calculation unit 225 and a notch filter 226. The frequency calculation unit 225 is configured to calculate a native frequency of the rope 4 and the transport object 9 based on the hanging length of the rope 4 from the hoist medium 3 (for example, from the reel 11) to the transport object 9.

[0055] The frequency calculation unit 225 may acquire information on the hanging length of the rope 4 from the hoisting device 10, and calculate the native frequency based on the acquired hanging length. For example, the frequency calculation unit 225 receives the rope length information transmitted by the length information transmission unit 123, and calculates the native frequency based on the rope length information. For example, the frequency calculation unit 225 calculates the native frequency with the following expression.

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{L}} \quad (2)$$

f: native frequency

g: gravitational acceleration

L: rope length

The notch filter 226 is configured to remove components corresponding to the native frequency from the speed command pattern stored in the command storage unit 222. For example, the notch filter 226 removes a frequency component corresponding to the native frequency from the speed command pattern by band-pass filter processing. Hereinafter, the speed command pattern from which the frequency component corresponding to the native frequencies is removed (the speed command

pattern after passing through the notch filter 226) will be referred to as a “filtered speed command pattern”. The notch filter 226 stores the filtered speed command pattern in the command storage unit 222.

[0056] FIG. 4 is a graph illustrating the speed command pattern, in which the horizontal axis represents an elapsed time and the vertical axis represents the speed command value. The solid line plot is an example of the speed command pattern before passing through the notch filter 226, and includes an acceleration period T11 that represents an acceleration at a constant rate of acceleration, a constant speed period T12, and a deceleration period T13 that represents a deceleration at a constant rate of acceleration.

[0057] The broken line plot is an example of a filtered speed command pattern that has passed through the notch filter 226, and includes an acceleration period T21, a constant speed period T22, and a deceleration period T23. By passing through the notch filter 226, the acceleration in the acceleration period is no longer a constant value, and the acceleration in the deceleration period is also no longer a constant value. Even after passing through the notch filter 226, the transition of the acceleration in the acceleration period and the transition of the absolute value of the acceleration in the deceleration period are equal to each other.

[0058] The frequency calculation unit 225 is configured to calculate the native frequency before the auto control unit 227 starts the movement of the hoist medium 3 based on the speed command pattern. Before the auto control unit 227 starts the movement of the hoist medium 3 based on the speed command pattern, the notch filter 226 performs the

above-described filter processing on the speed command pattern stored in the command storage unit 222. The auto control unit 227 is configured to move the hoist medium 3 with the displacement driver 20 based on the filtered speed command pattern. The error estimation unit 223 calculates the moving distance error based on the filtered speed command pattern during movement of the hoist medium 3 based on the filtered speed command pattern, and estimates the stop position error based on the calculated moving distance error. The pattern correction unit 224 corrects the filtered speed command pattern so as to reduce the stop position error.

[0059] Returning to the FIG. 3, the displacement controller 200 may further include a notification unit 228. The notification unit 228 is configured to notify an operator of the start timing of the deceleration period changed by the pattern correction unit 224. For example, the notification unit 228 notifies the start timing of the deceleration period changed by the pattern correction unit 224 by displaying on a user interface 296 (described later), audio output, or the like.

[0060] After completing the movement of the hoist medium 3 based on the speed command pattern, the auto control unit 227 transmits a movement completion notification to the host controller 300. After receiving the movement completion notification from the auto control unit 227, the host controller 300 transmits the lowering command to the control circuit 120. In response to this, the control circuit 120 lowers the transport object 9.

[0061] The auto control unit 227 may be configured to further move the hoist medium 3 with the displacement driver 20 so as to reduce an

actual error between a moving distance of the transport object 9 detected by the sensor 30 in a state where the movement of the hoist medium 3 based on the speed command pattern is completed and a target moving distance from the transport start position to the transport target position. If the actual error is equal to or less than a predetermined upper limit value, the auto control unit 227 transmits a movement completion notification to the host controller 300. The auto control unit 227 further moves the hoist medium 3 with the displacement driver 20 so as to reduce the actual error when the actual error exceeds the upper limit value.

[0062] FIG. 5 is a block diagram illustrating an example hardware configuration of the control circuit. As illustrated in FIG. 5, the control circuit 120 includes one or more processors 191, a memory 192, storage 193, a communication port 194, a switching control circuit 195, a brake control circuit 196, and a user interface 197. The storage 193 stores a program for configuring each functional block described above in the control circuit 120.

[0063] The storage 193 may include a built-in storage medium such as a hard disk or a nonvolatile memory, or may include a portable storage medium such as a universal serial bus (USB) flash drive or an optical disk.

[0064] The memory 192 temporarily stores the program loaded from the storage 193. Specific examples of the memory 192 include a random-access memory. The processor(s) 191 causes the control circuit 120 to configure each functional block described above by executing a program loaded in the memory 192. The processor(s) 191 stores the

calculation results in the memory 192 as appropriate.

[0065] The communication port 194 performs wired or wireless communication with the host controller 300 based on a request from the processor(s) 191. The switching control circuit 195 outputs a gate driving signal to the switching elements 117 based on a request from the processor(s) 191. The brake control circuit 196 supplies braking power to the brake 13 based on a request from the processor(s) 191.

[0066] The user interface 197 inputs and outputs information to and from the operator through a display device, an input device, and the like. Specific examples of the display device include a liquid crystal monitor and an organic electro-luminescence (EL) monitor. Specific examples of the input device include a keyboard, a mouse, and a keypad. The input device may be integrated with the display device as a so-called touch panel.

[0067] The control circuit 220 includes one or more processors 291, a memory 292, storage 293, a communication port 294, a switching control circuit 295, and the user interface 296. The storage 293 stores a program for causing the control circuit 220 to perform: generating the speed command pattern; calculating the moving distance error during movement of the hoist medium 3 based on the speed command pattern and estimating the stop position error based on the moving distance error; and correcting the speed command pattern so as to reduce the stop position error during movement of the hoist medium 3 based on the speed command pattern. For example, the storage 293 stores a program for configuring the above-described functional blocks in the control circuit 220.

[0068] The storage 293 may include a built-in storage medium such as a hard disk or a nonvolatile memory, or may include a portable storage medium such as a USB flash drive or an optical disk.

[0069] The memory 292 temporarily stores the program loaded from the storage 293. Specific examples of the memory 292 include a random-access memory. The processor(s) 291 causes the control circuit 220 to configure each functional block described above by executing a program loaded in the memory 292. The processor(s) 291 stores the calculation results in the memory 292 as appropriate.

[0070] The communication port 294 performs wired or wireless communication with the host controller 300 based on a request from the processor(s) 291. The switching control circuit 295 outputs a gate driving signal to the switching elements 217 based on a request from one or more the processor 291.

[0071] The user interface 296 inputs and outputs information to and from the operator through a display device, an input device, and the like. Specific examples of the display device include a liquid crystal monitor and an EL monitor. Specific examples of the input device include a keyboard, a mouse, and a keypad. The input device may be integrated with the display device as a so-called touch panel.

[0072] Although the crane type transport device 1 including one displacement driver 20 is illustrated in FIG. 1, the crane type transport device 1 may include two or more displacement drivers 20 as illustrated in FIG. 6. The crane type transport device 1 illustrated in FIG. 6 includes a displacement driver 20A and a displacement driver 20B. The displacement driver 20A (a travelling driver) displaces the hoist medium

3 along a displacement direction 29A intersecting (for example, orthogonal to) the vertical direction. The displacement driver 20B (a displacement driver) displaces the hoist medium 3 along a displacement direction 29B that intersects (for example, is orthogonal to) the vertical direction and the displacement direction 29A. In such a configuration, each of the displacement driver 20A and the displacement driver 20B may be configured similarly to the above-described the displacement driver 20. In this case, the sensor 30 may be provided for each of the displacement driver 20A and the displacement driver 20B.

[0073] Transport Procedure

As an example of the transport method, an example transport procedure performed by the crane type transport device 1 will be described below. The procedure includes: generating the speed command pattern; calculating the moving distance error during movement of the hoist medium 3 based on the speed command pattern and estimating the stop position error based on the moving distance error; and correcting the speed command pattern so as to reduce the stop position error during movement of the hoist medium 3 based on the speed command pattern. The procedure may further include moving the hoist medium 3 with the displacement driver 20 based on the speed command pattern.

[0074] The transport procedure includes a “lifting procedure”, a “moving procedure”, and a “lowering procedure”. Hereinafter, each procedure will be described in detail.

[0075] Lifting Procedure

As illustrated in FIG. 7, the control circuit 120 performs steps S01, S02, S03, S04, S05, S06, and S07. In the step S01, the command generation

unit 121 waits for a lifting command from the host controller 300. In the step S02, the command generation unit 121 generates the lifting speed command pattern based on the lifting command. In the step S03, the auto control unit 122 releases the braking of the reel 11 with the brake 13. In the step S04, the auto control unit 122 rotates the reel 11 with the motor 12 based on the lifting speed command pattern. In the step S05, the auto control unit 122 resumes the braking of the reel 11 with the brake 13. In the step S06, the length information transmission unit 123 transmits the rope length information. In the step S07, the auto control unit 122 transmits the rise completion notification to the host controller 300. In response, the host controller 300 transmits the transport command to the control circuit 220.

[0076] Moving Procedure

As illustrated in FIG. 8, the control circuit 220 first performs steps S11, S12, and S13. In the step S11, the control circuit 220 waits for a transport command from the host controller 300. In the step S12, the command generation unit 221 generates the speed command pattern based on the transport command.

[0077] In the step S13, the frequency calculation unit 225 calculates the native frequency of the rope 4 and the transport object 9 based on the hanging length of the rope 4 from the hoist medium 3 to the transport object 9, and the notch filter 226 generates the filtered speed command pattern based on the native frequency. For example, the frequency calculation unit 225 receives the rope length information transmitted from the length information transmission unit 123, and calculates the native frequency based on the rope length information. The notch filter

226 generates the filtered speed command pattern by removing a frequency component corresponding to the native frequency from the speed command pattern stored in the command storage unit 222 by band-pass filter processing. The notch filter 226 stores the filtered speed command pattern in the command storage unit 222.

[0078] The control circuit 220 then performs steps S14, S15, and S16. In the step S14, the auto control unit 227 causes the displacement driver 20 to start acceleration of the hoist medium 3 in accordance with the acceleration period of the filtered speed command pattern. In the step S15, the auto control unit 227 waits for the displacement speed command value of the hoist medium 3 to reach the displacement speed command value of the constant speed period. In the step S16, the auto control unit 227 causes the displacement driver 20 to start moving the hoist medium 3 in accordance with the constant speed period of the filtered speed command pattern.

[0079] The control circuit 220 then performs steps S17 and S18. In the step S17, the error estimation unit 223 calculates the error during acceleration based on the estimated moving distance and the detected moving distance, and estimates the stop position error based on the calculated error during acceleration.

[0080] In the step S18, the pattern correction unit 224 corrects the filtered speed command pattern stored in the command storage unit 222 so as to reduce the stop position error. The filtered speed command pattern corrected by the pattern correction unit 224 corresponds to the above-described corrected speed command pattern. The auto control unit 227 continues the movement of the hoist medium 3 with the

displacement driver 20 based on the corrected speed command pattern.

[0081] The control circuit 220 then performs steps S21, S22, and S23.

In the step S21, the auto control unit 227 waits for the start timing of the deceleration period in the corrected speed command pattern. In the step

5 S22, the auto control unit 227 causes the displacement driver 20 to start acceleration of the hoist medium 3 in accordance with the deceleration period of the corrected speed command pattern. In the step S23, the auto control unit 227 waits for the decelerated the displacement driver 20 to stop.

10 [0082] Next, the control circuit 220 performs a step S24. In the step S24, the auto control unit 227 calculates the actual error, and checks whether the actual error is equal to or less than the upper limit value.

[0083] If it is determined that the actual error exceeds the upper limit value in the step S24, the control circuit 220 performs a step S25. In the

15 step S25, the auto control unit 227 further moves the hoist medium 3 with the displacement driver 20 so as to reduce the actual error. Thereafter, the control circuit 120 performs the step S24 again.

[0084] If it is determined that the actual error is equal to or less than the upper limit value in the step S24, the control circuit 220 performs a step

20 S26. In the step S26, the auto control unit 227 transmits the movement completion notification to the host controller 300. In response, the host controller 300 transmits the lowering command to the control circuit 120.

[0085] Lowering Procedure

25 As illustrated in FIG. 9, the control circuit 120 performs steps S31, S32, S33, S34, S35, and S36. In the step S31, the command generation unit

121 waits for a lowering command from the host controller 300. In the step S32, the command generation unit 121 generates a lowering speed command pattern based on the lowering command. In the step S33, the auto control unit 122 releases the braking of the reel 11 with the brake 13. In the step S34, the auto control unit 122 rotates the reel 11 with the motor 12 based on the lowering speed command pattern. In the step S35, the auto control unit 122 resumes the braking of the reel 11 with the brake 13. In the step S36, the auto control unit 122 transmits a lowering completion notification to the host controller 300.

[0086] As described above, the crane type transport device 1 includes: the hoist medium 3 configured to lift the transport object 9 with the rope 4; the command generation unit 221 configured to generate the speed command pattern for moving the transport object 9 from the first position to the second position; the sensor 30 configured to detect the moving distance of the transport object 9; the displacement driver 20 configured to displace the hoist medium 3 in the displacement direction intersecting the vertical direction based on the speed command pattern; the error estimation unit 223 configured to estimate, based on the speed command pattern and the moving distance of the transport object 9 detected by the sensor 30 during movement of the hoist medium 3 based on the speed command pattern, the stop position error between the second position and the position of the transport object 9 at a time when the movement of the hoist medium 3 based on the speed command pattern is completed; and the pattern correction unit 224 configured to correct the speed command pattern so as to reduce the stop position error during the movement of the hoist medium 3 based on the speed

command pattern.

[0087] With this crane type transport device 1, during movement based on the speed command pattern, the stop position error is estimated based on the speed command pattern and the actual moving distance of the transport object, and the speed command pattern is corrected so as to reduce the stop position error. Accordingly, the stop position error can also be reduced by the open loop control based on the speed command pattern. By reducing the stop position error, it is possible to reduce position adjustment by re-movement of the hoist medium 3 or the like. Therefore, it is effective in improving the conveying work efficiency of the transport object 9.

[0088] The error estimation unit 223 may be configured to, during movement of the hoist medium based on the speed command pattern, calculate the estimated moving distance of the transport object 9 based on the speed command pattern, calculate the moving distance error between the estimated moving distance and the moving distance of the transport object 9 detected by the sensor 30, and estimate the stop position error based on the moving distance error. In this case, the stop position error can be estimated more easily.

[0089] The crane type transport device 1 may further include: the frequency calculation unit 225 configured to calculate the native frequency of the rope 4 and the transport object 9 based on the hanging length of the rope 4 from the hoist medium 3 to the transport object 9; and the notch filter 226 configured to remove a component corresponding to the native frequency from the speed command pattern. The error estimation unit 223 may be further configured to calculate,

during movement of the hoist medium 3 based on the filtered speed command pattern output from the notch filter 226, the moving distance error based on the filtered speed command pattern. With the filtered speed command pattern, sway of the transport object 9 during movement is prevented. Therefore, it is possible to further reduce the stop position error by calculating the moving distance error based on the filtered speed command pattern during the movement of the hoist medium 3 based on the filtered speed command pattern. Therefore, it is more effective in improving the conveying work efficiency of the transport object 9.

[0090] The crane type transport device 1 may further include the hoisting device 10 configured to change the hanging length of the rope 4 from the hoist medium 3, and the frequency calculation unit 225 may be further configured to acquire information on the hanging length of the rope 4 from the hoisting device 10 and calculate the native frequency based on the acquired hanging length. The native frequency can be calculated with higher accuracy, and sway of the transport object 9 during movement can be further prevented.

[0091] The speed command pattern may include the acceleration period, the constant speed period following the acceleration period, and the deceleration period following the constant speed period. The error estimation unit 223 may be further configured to calculate the moving distance error before completion of the constant speed period, and to estimate the stop position error based on the moving distance error. The pattern correction unit 224 may be further configured to change the start timing of the deceleration period before completion of the constant

speed period so as to reduce the stop position error. Most of the moving distance error tends to occur in the acceleration period and the deceleration period. Accordingly, by estimating the stop position error before the completion of the constant speed period, the stop position error can be estimated with high accuracy at an earlier timing, and the speed command pattern can be corrected timely.

[0092] The error estimation unit 223 may be further configured to calculate the moving distance error in the acceleration period and to estimate the stop position error based on the calculated moving distance error. The pattern correction unit 224 may be further configured to change the start timing of the deceleration period before completion of the constant speed period so as to reduce the stop position error. The stop position error can be estimated with high accuracy at a further earlier timing, and the speed command pattern can be corrected timely.

[0093] The error estimation unit 223 may be further configured to estimate the moving distance error in the deceleration period based on the moving distance error in the acceleration period, and estimate the stop position error based on the moving distance error in the acceleration period and the moving distance error in the deceleration period. The stop position error can be estimated with high accuracy by simple calculation.

[0094] The pattern correction unit 224 may be further configured to change the start timing of the deceleration period by extending or shortening the constant speed period based on the speed command value in the constant speed period and the stop position error. The start timing of the deceleration period can be changed more appropriately.

[0095] The apparatus may further include the auto control unit 227 configured to move the hoist medium 3 with the displacement driver 20 based on the speed command pattern. The stop position error can be more reliably reduced.

5 [0096] The auto control unit 227 may be further configured to further move the hoist medium 3 with the displacement driver 20 so as to reduce the actual error between the moving distance of the transport object 9 detected by the sensor 30 in a state in which the movement of the hoist medium 3 based on the speed command pattern is completed
10 and the distance from the first position to the second position. In the configuration in which the auto control unit 227 further moves the hoist medium 3 in order to reduce the actual error, it is more beneficial to reduce the stop position error by correcting the speed command pattern.

15 [0097] Although the embodiments have been described above, the present disclosure is not necessarily limited to the above-described embodiments, and various modifications can be made without departing from the scope of the present disclosure.

Reference Signs List

20 [0098] 1: crane type transport device; 3: hoist medium; 9: Transport object; 4: rope; 10: hoisting device; 20: displacement driver; 30: sensor; 221: command generation unit; 227: auto control unit; 223: error estimation unit; 224: pattern correction unit; 225: frequency calculation unit; 226: notch filter; 228: notification unit.

CLAIMS

[Claim 1]

A crane type transport device comprising:

a hoist medium configured to lift transport object with a rope;

5 a command generation unit configured to generate a speed command pattern for moving the transport object from a first position to a second position;

10 a displacement driver configured to displace the hoist medium in a displacement direction intersecting a vertical direction based on the speed command pattern;

 a sensor configured to detect a moving distance of the transport object;

15 an error estimation unit configured to estimate, based on the speed command pattern and the moving distance of the transport object detected by the sensor during movement of the hoist medium based on the speed command pattern, a stop position error between the second position and a position of the transport object at a time when the movement of the hoist medium based on the speed command pattern is completed; and

20 a pattern correction unit configured to correct the speed command pattern so as to reduce the stop position error during the movement of the hoist medium based on the speed command pattern.

[Claim 2]

25 The crane type transport device according to claim 1, wherein the error estimation unit is further configured to, during movement of the hoist medium based on the speed command pattern, perform:

calculating an estimated moving distance of the transport object based on the speed command pattern;

calculating a moving distance error between the estimated moving distance and the moving distance of the transport object detected by the sensor; and

estimating the stop position error based on the moving distance error.

[Claim 3]

The crane type transport device according to claim 2, further comprising:

a frequency calculation unit configured to calculate a native frequency of the rope and the transport object based on a hanging length of the rope from the hoist medium to the transport object; and

a notch filter configured to remove a component corresponding to the native frequency from the speed command pattern;

wherein the error estimation unit is further configured to calculate, during movement of the hoist medium based on a filtered speed command pattern output from the notch filter, the moving distance error based on the filtered speed command pattern.

[Claim 4]

The crane type transport device according to claim 3, further comprising a hoisting device configured to change a hanging length of the rope from the hoist medium;

wherein the frequency calculation unit is further configured to acquire information on the hanging length of the rope from the hoisting device and to calculate the native frequency based on the acquired

hanging length.

[Claim 5]

The crane type transport device according to any one of claims 2 to 4, wherein the speed command pattern includes an acceleration period, a constant speed period following the acceleration period, and a deceleration period following the constant speed period;

wherein the error estimation unit is further configured to calculate the moving distance error before completion of the constant speed period, and to estimate the stop position error based on the moving distance error; and

wherein the pattern correction unit is further configured to change a start timing of the deceleration period before completion of the constant speed period so as to reduce the stop position error.

[Claim 6]

The crane type transport device according to claim 5, wherein the error estimation unit is further configured to calculate the moving distance error in the acceleration period and to estimate the stop position error based on the calculated moving distance error; and

wherein the pattern correction unit is further configured to change a start timing of the deceleration period before completion of the constant speed period so as to reduce the stop position error.

[Claim 7]

The crane type transport device according to claim 6, wherein the error estimation unit is further configured to estimate the moving distance error in the deceleration period based on the moving distance error in the acceleration period, and to estimate the stop position error

based on the moving distance error in the acceleration period and the moving distance error in the deceleration period.

[Claim 8]

The crane type transport device according to any one of claims 5 to 7, wherein the pattern correction unit is further configured to change the start timing of the deceleration period by extending or shortening the constant speed period based on a speed command value in the constant speed period and the stop position error.

[Claim 9]

The crane type transport device according to any one of claims 1 to 8, further comprising an auto control unit configured to move the hoist medium with the displacement driver based on the speed command pattern.

[Claim 10]

The crane type transport device according to claim 9, wherein the auto control unit is further configured to further move the hoist medium with the displacement driver so as to reduce an actual error between the moving distance of the transport object detected by the sensor in a state in which the movement of the hoist medium based on the speed command pattern is completed and a distance from the first position to the second position.

[Claim 11]

A transport method comprising:

generating a speed command pattern for moving a transport object from a first position to a second position by displacing a hoist medium that lifts up the transport object with a rope in a displacement

direction intersecting a vertical direction with a displacement driver;

estimating, during movement of the hoist medium based on the speed command pattern, a stop position error between the second position and a position of the transport object at a time when the movement of the hoist medium based on the speed command pattern is completed based on the speed command pattern and a moving distance of the transport object detected by a sensor; and

correcting the speed command pattern so as to reduce the stop position error during the movement of the hoist medium based on the speed command pattern.

[Claim 12]

The transport method according to claim 11, wherein estimating the stop position error includes calculating an estimated moving distance of the transport object based on the speed command pattern, calculating a moving distance error between the estimated moving distance and the moving distance of the transport object detected by the sensor, and estimating the stop position error based on the moving distance error during movement of the hoist medium based on the speed command pattern.

[Claim 13]

The transport method according to claim 11 or 12, further comprising moving the hoist medium with the displacement driver based on the speed command pattern.