

DESCRIPTION

Title of the Invention: Robot and Robot Controlling Method

Technical Field

[0001]

5 The present disclosure relates to a robot and a robot controlling method.

Background Art

[0002]

10 Conventionally, a robot including a robot arm is known. For example, Japanese Patent No. 6398204 discloses a robot including a robot arm including a plurality of links. In this robot, a motor and a gear reducer generate heat when the robot arm operates. The robot described in Japanese Patent No. 6398204 compensates for changes in the
15 lengths of the links caused by the heat generated by the motor and the gear reducer.

Prior Art

Patent Document

[0003]

20 Patent Document 1: Japanese Patent No. 6398204

Summary of the Invention

[0004]

25 Although not described in Japanese Patent No. 6398204, when an inclined gear such as a helical gear including teeth extending in a direction inclined with

respect to a rotation axis direction of rotation as viewed
in a radial direction of the rotation is arranged in a
drive mechanism configured to drive a robot arm, the
rotational position of the inclined gear changes due to
5 the teeth inclined with respect to the rotation axis
direction as viewed in the radial direction when a
deviation occurs in the rotation axis direction of the
inclined gear due to thermal expansion. However, the
robot described in Japanese Patent No. 6398204 compensates
10 only for the changes in the lengths due to thermal
expansion of the links of the robot arm caused by a
temperature change. Therefore, the robot does not
compensate for the change in the rotational position of
the inclined gear, and thus the robot does not
15 sufficiently compensate for the influence of thermal
expansion. Therefore, when the inclined gear including
the teeth extending in the direction inclined with respect
to the rotation axis direction of rotation as viewed in
the radial direction of the rotation is arranged in the
20 drive mechanism configured to drive the robot arm, the
positioning accuracy is decreased.

[0005]

The present disclosure is intended to solve the above
problems. The present disclosure aims to provide a robot
25 and a robot controlling method each capable of reducing or

preventing a decrease in positioning accuracy even when an inclined gear including teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation is arranged in a drive mechanism configured to drive a robot arm.

[0006]

A robot according to a first aspect of the present disclosure includes a robot arm, a drive mechanism including an inclined gear including teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation to drive the robot arm, and a controller configured or programmed to compensate for an influence of an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion of at least one of the robot arm or the drive mechanism.

[0007]

As described above, the robot according to the first aspect of the present disclosure includes the controller configured or programmed to compensate for the influence of the axial deviation of the inclined gear in the rotation axis direction due to the thermal expansion of at least one of the robot arm or the drive mechanism. Accordingly, it is possible to compensate for the

influence of the axial deviation of the inclined gear in the rotation axis direction due to the thermal expansion, and thus a decrease in positioning accuracy can be reduced or prevented even when the inclined gear including the teeth extending in the direction inclined with respect to the rotation axis direction of rotation as viewed in the radial direction of the rotation is arranged in the drive mechanism configured to drive the robot arm.

[0008]

A robot controlling method according to a second aspect of the present disclosure includes acquiring a measurement value representing a temperature of a robot arm driven by a drive mechanism including an inclined gear including teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation, and compensating for an influence of an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion of at least one of the robot arm or the drive mechanism based on an acquired measurement value.

[0009]

As described above, the robot controlling method according to the second aspect of the present disclosure includes compensating for the influence of the axial deviation of the inclined gear in the rotation axis

direction due to the thermal expansion of at least one of the robot arm or the drive mechanism based on the acquired measurement value. Accordingly, it is possible to compensate for the influence of the axial deviation of the inclined gear in the rotation axis direction due to the thermal expansion, and thus it is possible to provide the robot controlling method capable of reducing or preventing a decrease in positioning accuracy even when the inclined gear including the teeth extending in the direction inclined with respect to the rotation axis direction of rotation as viewed in the radial direction of the rotation is arranged in the drive mechanism configured to drive the robot arm.

[0010]

It is possible to reduce or prevent a decrease in positioning accuracy even when the inclined gear including the teeth extending in the direction inclined with respect to the rotation axis direction of rotation as viewed in the radial direction of the rotation is arranged in the drive mechanism configured to drive the robot arm.

Brief Description of the Drawings

[0011]

FIG. 1 is a diagram showing the configuration of a robot according to an embodiment.

FIG. 2 is a block diagram showing the configuration

of the robot according to the embodiment.

FIG. 3 is a diagram showing the configuration of a drive mechanism according to the embodiment.

FIG. 4 is a diagram for illustrating the influence of thermal expansion.

FIG. 5 is a diagram for illustrating a deviation in the rotation direction of a robot arm due to thermal expansion in the rotation axis direction of a gear.

FIG. 6 is a diagram for illustrating compensation for the positional deviation of a substrate.

FIG. 7 is a flowchart for illustrating a control method for compensating for the influence of thermal expansion of the robot according to the embodiment.

FIG. 8 is a diagram showing a comparison between the robot according to the embodiment and comparative examples.

Modes for Carrying Out the Invention

[0012]

An embodiment embodying the present disclosure is hereinafter described on the basis of the drawings.

[0013]

Configuration of Robot

The configuration of a robot 100 according to the embodiment is now described with reference to FIGS. 1 to 6. As shown in FIG. 1, the robot 100 is a substrate

transport robot. The robot 100 is disposed in a clean room 200. The robot 100 is also disposed in a vacuum environment. Specifically, the robot 100 is disposed in a vacuum chamber 201.

5 [0014]

The robot 100 includes a robot arm 10, a substrate holding hand 20 disposed at a distal end of the robot arm 10, and a controller 30. The substrate holding hand 20 holds a substrate W. Specifically, the substrate holding
10 hand 20 is a passive hand that holds the substrate W with a frictional force. The substrate W is a semiconductor wafer, for example. The semiconductor wafer is subjected to a predetermined process in a processing chamber 202.

[0015]

15 The robot arm 10 is a horizontal articulated robot arm. The robot arm 10 includes a first arm 11 and a second arm 12. A first end of the first arm 11 is connected to a base 13 via a first joint JT1. A first end of the second arm 12 is connected to a second end of the
20 first arm 11 via a second joint JT2. The substrate holding hand 20 is connected to a second end of the second arm 12 via a third joint JT3.

[0016]

The first joint JT1 rotates the first arm 11 around a
25 first rotation axis A1 extending in an upward-downward

direction with respect to the base 13. The second joint JT2 rotates the second arm 12 around a second rotation axis A2 extending in the upward-downward direction with respect to the first arm 11. The third joint JT3 rotates the substrate holding hand 20 around a third rotation axis A3 extending in the upward-downward direction with respect to the second arm 12.

[0017]

As shown in FIG. 2, a drive mechanism 40 configured to drive the robot arm 10 is disposed at each of the first joint JT1, the second joint JT2, and the third joint JT3. The drive mechanism 40 of the first joint JT1 is disposed on the first arm 11, the drive mechanism 40 of the second joint JT2 is disposed on the first arm 11, and the drive mechanism 40 of the third joint JT3 is disposed on the second arm 12. The arrangement of the drive mechanisms 40 is not limited to this.

[0018]

The drive mechanism 40 includes a motor 41, an encoder 42, and a power transmitter 43. The motor 41 is a drive source of a drive force in the drive mechanism 40. The motor 41 is a servomotor, for example. The encoder 42 detects rotation of the motor 41. Specifically, the encoder 42 detects the rotational position of an output shaft 41a of the motor 41. The power transmitter 43

transmits the drive force of the motor 41. The drive mechanism 40 rotates targets to be driven such as the first arm 11, the second arm 12, and the substrate holding hand 20 by transmitting the drive force of the motor 41.

5 [0019]

As shown in FIG. 3, the power transmitter 43 includes a gear 44a, a gear 44b, a gear 44c, a gear 44d, a rotation shaft 45, and a rotation shaft 46. The gears 44a and 44b rotate while meshing with each other, and the gears 44c and 44d rotate while meshing with each other. The gears 44a and 44b are bevel gears, the rotation axes of which are perpendicular to each other, for example. In this embodiment, each of the gears 44c and 44d includes teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation. The gears 44c and 44d are helical gears including helical tooth traces, for example. Helical gears are also called helical gears. The gear 44c is an example of an inclined gear or a first inclined gear. The gear 44d is an example of an inclined gear or a second inclined gear. The rotation shaft 45 is an example of a rotation shaft or a first rotation shaft. The rotation shaft 46 is an example of a rotation shaft or a second rotation shaft.

25 [0020]

The gear 44a is attached to the output shaft 41a of the motor 41. The gear 44b is attached to the rotation shaft 45. The gear 44c is attached to the rotation shaft 45. The gear 44d is attached to the rotation shaft 46.

5 The drive force of the motor 41 is transmitted to the rotation shaft 45 via the output shaft 41a, the gear 44a, and the gear 44b. The drive force of the motor 41 transmitted to the rotation shaft 45 is transmitted to the rotation shaft 46 via the gears 44c and 44d as the
10 rotation shaft 45 rotates. The output side of the rotation shaft 46 is connected to targets to be driven such as the second arm 12, the substrate holding hand 20, and the base 13. When a drive force is transmitted from the motor 41 to the rotation shaft 46, the targets to be
15 driven rotate. For example, in the drive mechanism 40 disposed at the first joint JT1, the rotation shaft 46 is connected to the base 13. When a drive force is transmitted from the motor 41 to the rotation shaft 46, the robot arm 10 rotates the first joint JT1 around the
20 first rotation axis A1. The power transmitter 43 is not limited to the configuration shown in FIG. 3. The power transmitter 43 also includes a bearing, for example.

[0021]

The robot arm 10 is made of a material having a
25 thermal expansion coefficient different from those of the

gears 44c and 44d, the rotation shaft 45, and the rotation shaft 46. The first arm 11 and the second arm 12 of the robot arm 10 are made of aluminum. The gears 44c and 44d, the rotation shaft 45, and the rotation shaft 46 are made of iron. The thermal expansion coefficient of aluminum is greater than that of iron.

[0022]

The controller 30 controls the operation of the robot arm 10 by executing a predetermined program. The controller 30 controls the operation of the robot arm 10 by controlling power to be supplied to the motor 41 arranged at each of the first joint JT1, the second joint JT2, and the third joint JT3. The controller 30 includes a computer including an arithmetic unit such as a central processing unit (CPU) and a storage device such as a flash memory, for example. The controller 30 controls the operation of the robot arm 10 to execute a control process of transport operation to transport the substrate W to a predetermined position set in advance based on a control amount taught in advance. The control amount taught in advance is stored in the storage device.

[0023]

As shown in FIG. 2, the robot 100 includes a temperature sensor 50 to measure the temperature of the robot arm 10 including the drive mechanism 40. The

temperature sensor 50 includes an ambient temperature sensor 51 and an encoder temperature sensor 52. The ambient temperature sensor 51 measures the outside air temperature of the robot arm 10. The ambient temperature sensor 51 is disposed on the outer surface of the robot 100. For example, the ambient temperature sensor 51 is disposed on the outer surface of the first arm 11 of the robot arm 10. The encoder temperature sensor 52 is disposed in the encoder 42 of the drive mechanism 40. The encoder temperature sensor 52 is disposed in the encoder 42 of the drive mechanism 40 at each of the first joint JT1, the second joint JT2, and the third joint JT3. The temperature sensor 50 is a thermocouple, for example. The temperature sensor 50 outputs a measurement result indicating the measured temperature to the controller 30. [0024]

Compensation for Influence of Thermal Expansion

As shown in FIG. 4, when the robot arm 10 operates, the influence of thermal expansion of at least one of the robot arm 10 or the drive mechanism 40 due to heat generation from the motor 41 or a change in outside air temperature, for example, occurs. As the influence of thermal expansion, a positional deviation from a target position occurs in the substrate W transport operation. FIG. 4 shows a positional deviation caused by a

temperature change of the robot arm 10 when the robot arm 10 is controlled to a target position, which is the same teaching position. In FIG. 4, the position of the robot arm 10 at a temperature of $T^{\circ}\text{C}$ is shown together with a solid line indicating a schematic position. In FIG. 4, the schematic position of the robot arm 10 at a temperature of $T + \Delta T^{\circ}\text{C}$ is shown by a dotted line. In this embodiment, the controller 30 executes a process to compensate for the influence of thermal expansion.

[0025]

As shown in FIG. 5, as the influence of thermal expansion, a rotational deviation occurs at each of the first joint JT1, the second joint JT2, and the third joint JT3, which is a deviation of the robot arm 10 in the rotation direction due to the thermal expansion. For example, between the driving side gear 44c on the motor 41 side and the driven side gear 44d on the output side, a deviation in the rotation axis direction occurs due to a difference in thermal expansion in the rotation axis direction between the rotation shaft 45 and the rotation shaft 46. The gears 44c and 44d include tooth traces that are inclined relative to each other, and thus a deviation in the rotation direction occurs due to the deviation in the rotation axis direction.

[0026]

Specifically, when there is a temperature change of $\Delta T^{\circ}\text{C}$ from the reference temperature, the shift amount δ_z is expressed as the deviation in the rotation axis direction, which is the difference in thermal expansion in the rotation axis direction between the rotation shaft 45 and the rotation shaft 46, by the following formula (1):

[Formula 1]

$$\delta_z = K_a \cdot L_a \cdot \Delta T - K_s \cdot L_s \cdot \Delta T \dots (1)$$

where L_a represents the length of the rotation shaft 45 to which the gear 44c is attached at the reference temperature, K_a represents the thermal expansion coefficient, L_s represents the length of the rotation shaft 46 to which the gear 44d is attached at the reference temperature, and K_s represents the thermal expansion coefficient.

When the inclination of the teeth of the gears 44c and 44d with respect to the rotation axis direction is defined as α , the shift amount δ_l representing the deviation in the rotation direction between the gears 44c and 44d caused by the shift amount δ_z in the rotation axis direction is expressed by the following formula (2).

[Formula 2]

$$\delta_l = \delta_z \cdot \tan \alpha \dots (2)$$

The shift amount δ_l in the rotation direction represents the magnitude of the deviation in the rotation

direction. Therefore, when the radius of the driven side gear 44d is r_s and the rotation angle of the deviation in the rotation direction between the gears 44c and 44d caused by the shift amount δ_z of the deviation in the rotation axis direction thermal expansion is δ_θ , $r_s \cdot \delta_\theta = \delta_l$ is true, and thus the following formula (3) is true.

[Formula 3]

$$\delta_\theta = \frac{(K_a \cdot L_a - K_s \cdot L_s) \cdot \tan \alpha}{r_s} \cdot \Delta T \quad \dots (3)$$

$$= K_T \cdot \Delta T$$

[0027]

K_T is a proportionality constant for calculating the rotation angle of the deviation in the rotation direction due to thermal expansion in the rotation axis direction. That is, a deviation occurs between the rotation angles of the gears 44c and 44d in proportion to the magnitude of the temperature change. δ_θ , which is the rotation angle of the deviation in the rotation direction between the gears 44c and 44d, is the rotation angle of the deviation of the robot arm 10 in the rotation direction due to thermal expansion. In other words, the deviation of the robot arm 10 in the rotation direction occurs as the influence of the deviation in the rotation axis direction between the gears 44c and 44d due to thermal expansion. Due to the rotation angle of the deviation of the robot arm 10 in the rotation direction represented by δ_θ , a positional

deviation from the target position occurs when the robot arm 10 is driven.

[0028]

As shown in FIG. 4, the influence of thermal expansion causes a change in the length of the robot arm 10 in addition to the deviation of the robot arm 10 in the rotation direction. The lengths of the robot arm 10 and the substrate holding hand 20 from one end to the other end change due to thermal expansion caused by a temperature change. For example, when the temperature is $T^{\circ}\text{C}$, the length of the first arm 11 from the first joint JT1 to the second joint JT2 is L_1 , the length of the second arm 12 from the second joint JT2 to the third joint JT3 is L_2 , and the length of the substrate holding hand 20 from the third joint JT3 to the center position of the substrate holding hand 20 is L_H . In such a case, when the temperature changes from $T^{\circ}\text{C}$ to $T + \Delta T^{\circ}\text{C}$, L_1 , L_2 , and L_H change to $L_1 + \delta_{L1}$, $L_2 + \delta_{L2}$, and $L_H + \delta_{LH}$, respectively, due to thermal expansion. That is, δ_{L1} , δ_{L2} , and δ_{LH} each represent the magnitude of the change in the length of the robot arm 10 due to thermal expansion caused by a temperature change of $\Delta T^{\circ}\text{C}$. δ_{L1} , δ_{L2} , and δ_{LH} represent a change in the length of the first arm 11, a change in the length of the second arm 12, and a change in the length of the substrate holding hand 20, respectively. The changes

in the lengths of the robot arm 10 and the substrate holding hand 20 cause a positional deviation, which is an error from the target position in the operation of the robot arm 10. The magnitudes of δ_{L1} , δ_{L2} , and δ_{LH} are
5 proportional to the temperature change ΔT , for example.
[0029]

In response to such an influence of thermal expansion, in this embodiment, the controller 30 compensates for the change in the length of the robot arm
10 10 due to thermal expansion and the deviation of the robot arm 10 in the rotation direction caused by the axial deviation due to thermal expansion, based on the temperature of the robot arm 10. That is, based on the temperature of the robot arm 10 including the drive
15 mechanism 40, the controller 30 compensates for the change in the length of the robot arm 10 due to thermal expansion and δ_{θ} , which is the rotation angle of the deviation of the robot arm 10 in the rotation direction, caused by the shift amount δ_z , which is the axial deviation between the
20 gears 44c and 44d caused by the difference in thermal expansion in the rotation axis direction between the rotation shafts 45 and 46.

[0030]

Specifically, as shown in FIG. 4, when the position
25 coordinates of the substrate W held by the substrate

caused by a temperature change ΔT is expressed by the following formula (6).

[Formula 6]

$$\begin{cases} \delta_X = X_{T+\Delta T} - X \\ \delta_Y = Y_{T+\Delta T} - Y \end{cases} \dots (6)$$

5 δ_X represents the magnitude of the positional deviation in the X direction, and δ_Y represents the magnitude of the positional deviation in a Y direction.

[0032]

10 In this embodiment, the controller 30 compensates for the influence of thermal expansion by compensating for the positional deviation of the substrate W from the target position in the transport operation represented by δ_X and δ_Y . Specifically, the controller 30 corrects the operation of the robot arm 10 by the drive mechanism 40 so as to

15 compensate for the rotational deviation of the robot arm 1 due to the change in the rotational positions of the gears 44c and 44d caused by the axial deviation, which is the deviation in the rotation axis direction between the rotation shafts 45 and 46. In other words, the controller

20 30 corrects the target position in the transport operation based on δ_X and δ_Y , which are the positional deviations due to thermal expansion. In order to compensate for the influence of thermal expansion, the controller 30 acquires a measurement value representing the temperature of the

25 robot arm 10 based on measurement by the temperature

sensor 50. Specifically, the controller 30 estimates a measurement value representing the temperature of the robot arm 10 based on each of the measurement result of the ambient temperature sensor 51 and the measurement
5 result of the encoder temperature sensor 52. The controller 30 stores parameters and programs for calculating the measurement value representing the temperature of the robot arm 10 in advance, for example. The controller 30 estimates the temperature distribution
10 in the robot arm 10 and the drive mechanism 40 based on the measurement results from the ambient temperature sensor 51 and the encoder temperature sensor 52. For example, the controller 30 acquires a measurement value representing the temperature of the robot arm 10 for
15 compensating for the influence of thermal expansion based on the temperature distribution of the robot arm 10 and the drive mechanism 40 estimated from the structure, specific heat, etc. of each of the robot arm 10 and each portion of the drive mechanism 40. The temperature of the
20 robot arm 10 referred to here includes the temperature of each portion of the drive mechanism 40. For example, the controller 30 acquires measurement values representing the temperatures of the rotation shaft 45 and the rotation shaft 46 in the drive mechanism 40 at each of the first
25 joint JT1, the second joint JT2, and the third joint JT3

as the temperature of the robot arm 10 for compensating for the influence of expansion.

[0033]

The controller 30 compensates for δ_{L1} , δ_{L2} , and δ_{LH} , which are changes in the length of the robot arm 10 due to thermal expansion, and $\delta_{\theta L1}$, $\delta_{\theta L2}$, and $\delta_{\theta LH}$, which are rotation angles of deviations of the robot arm 10 in the rotation direction due to thermal expansion, based on the acquired measured values representing the temperature of the robot arm 10. Based on the acquired measurement values representing the temperature of the robot arm 10, the controller 30 compensates for the change in the length of the robot arm 10 due to thermal expansion and the deviation of the robot arm 10 in the rotation direction caused by the axial deviation due to thermal expansion by correcting the control amount to correct θ_{L1} , θ_{L2} , and θ_{LH} such that no positional deviation occurs from the target position in the transport operation even when δ_x and δ_y , which are the magnitudes of the positional deviations calculated by the above formulas (4), (5), and (6), are included.

[0034]

The controller 30 stores in advance parameters such as proportionality constants for calculating δ_{L1} , δ_{L2} , and δ_{LH} , each of which is a change in the length of the robot

arm 10, and an arithmetic processing program. The controller 30 also stores in advance the proportionality constant K_T in the above formula (3) for each of the first joint JT1, the second joint JT2, and the third joint JT3.

5 The controller 30 corrects the operation of the robot arm 10 by the drive mechanism 40 by correcting the values of θ_{L1} , θ_{L2} , and θ_{LH} in the above formula (5) based on the measurement values representing the temperature of the robot arm 10 acquired by the temperature sensor 50, so as to compensate for the influence of thermal expansion.

That is, the controller 30 compensates for δx and δy , which are positional deviations from the target position due to thermal expansion, by correcting the values of θ_{L1} , θ_{L2} , and θ_{LH} indicating the rotation angles at the first joint JT1, the second joint JT2, and the third joint JT3, which are set in advance, based on the above formula (5).

Various parameters for the controller 30 to perform an arithmetic process for compensation are acquired through a plurality of trials, for example.

20 [0035]

Compensation for Substrate Positional Deviation

As shown in FIG. 6, the position of the substrate W on the substrate holding hand 20 may deviate from the center position of the substrate holding hand 20 during transport, for example. The positional deviation of the

25

substrate W during transport is likely to occur when the substrate holding hand 20 is a passive hand that holds the substrate W only with a frictional force. Therefore, a positional deviation detector 60 is disposed in the vicinity of the processing chamber 202.

[0036]

The positional deviation detector 60 includes a first sensor 61 and a second sensor 62. The first sensor 61 and the second sensor 62 are non-contact sensors. The first sensor 61 and the second sensor 62 are photoelectronic sensors such as a reflective sensor or a transmissive sensor, for example. The first sensor 61 and the second sensor 62 detect the passage of the outer edge of the substrate W while the substrate W is being transported to the processing chamber 202. The detection results of the first sensor 61 and the second sensor 62 are input to the controller 30. The controller 30 calculates the magnitude of the positional deviation of the substrate W on the substrate holding hand 20 based on the detection results from the first sensor 61 and the second sensor 62.

[0037]

For example, the controller 30 acquires the center position of the substrate holding hand 20 at the timing at which the first sensor 61 and the second sensor 62 detect the passage of the outer edge of the substrate W, using

the encoder 42 at each joint. The controller 30 calculates imaginary circles C1 and C2 having a diameter equal to the diameter of the substrate W, centered on the center position of the substrate holding hand 20. The controller 30 acquires a plane vector representing a deviation between the intersection of the imaginary circles C1 and C2 and the position of the first sensor 61. This plane vector is indicated by an open arrow in the right diagram of FIG. 6. The deviation represented by this plane vector is equal to a positional deviation between the center position of the substrate holding hand 20 and the center of the substrate W. Detection of the positional deviation of the substrate W by the second sensor 62 is similar to that by the first sensor 61, and thus detailed description thereof is omitted. The controller 30 acquires an average value of the plane vector obtained from the detection result of the first sensor 61 and the plane vector obtained from the detection result of the second sensor 62, and compensates for the positional deviation of the substrate W on the substrate holding hand 20, using the acquired average value as a compensation amount for the positional deviation of the substrate W on the substrate holding hand 20. By acquiring the average value, the positional deviation of the substrate W with respect to the substrate holding hand

20 can be accurately acquired.

[0038]

When compensation for the positional deviation of the substrate W on the substrate holding hand 20 is performed, 5 the influence of thermal expansion also occurs.

Therefore, the controller 30 compensates for not only the influence of thermal expansion at the target position, but also the influence of thermal expansion included in the compensation amount for the positional deviation of the 10 substrate W on the substrate holding hand 20.

[0039]

That is, the controller 30 performs the arithmetic process to compensate for the influence of thermal expansion when the robot arm 10 is in a posture state at 15 the time of detection when compensation for the positional deviation of the substrate W on the substrate holding hand 20 is performed and when the robot arm 10 is in a posture state at the target position that is a teaching position. In other words, the controller 30 compensates for the 20 influence of thermal expansion for each posture of the robot arm 10 when the robot arm 10 accesses a predetermined access destination. Therefore, the controller 30 can compensate for the influence of thermal expansion at the target position and the influence of 25 thermal expansion included in the compensation amount for

the positional deviation of the substrate W on the substrate holding hand 20. When it is not necessary to consider the positional deviation of the substrate W on the substrate holding hand 20, such as when the substrate holding hand 20 is a hand other than a passive hand, the controller 30 compensates only for the influence of thermal expansion at the target position.

[0040]

Robot Controlling Method

A control method for the robot 100 that performs a process to compensate for the influence of thermal expansion according to this embodiment is now described with reference to a flowchart in FIG. 7. The control process operations from step S101 to step S103 are executed by the controller 30.

[0041]

In step S101, the measurement value representing the temperature of the robot arm 10 including the drive mechanism 40 is acquired. Specifically, the measurement value representing the temperature of the robot arm 10 is estimated based on the measurement result of the ambient temperature sensor 51 and the measurement result of the encoder temperature sensor 52. Then, in step S102, the compensation amount for the influence of thermal expansion is acquired based on the measurement value representing

the temperature of the robot arm 10. Then, in step S103,
the operation of the robot arm 10 by the drive mechanism
40 is corrected so as to compensate for the rotational
deviation, which is the deviation of the robot arm 10 in
5 the rotation direction due to the changes in the
rotational positions of the gears 44c and 44d.

Specifically, compensation for the influence of the axial
deviation, which is the deviation in the rotation axis
direction between the gears 44c and 44d in the drive
10 mechanism 40 due to thermal expansion, is performed based
on the compensation amount for the influence of thermal
expansion.

[0042]

Comparative Examples

15 Referring to FIG. 8, a comparison is now given
between a case in which compensation for the influence of
thermal expansion is not performed, a case in which
compensation only for a change in the length of the robot
arm 10 is performed without correcting the rotation angle
20 of the robot arm 10, and a case in which the rotation
angle of the robot arm 10 is corrected and compensation
for a change in the length of the robot arm 10 is
performed.

[0043]

25 In FIG. 8, a graph is shown in which the values of

the magnitudes of positional deviations detected in two mutually perpendicular directions, an X direction and a Y direction when a control is repeatedly performed to move a substrate holding hand 20 to a predetermined teaching position are plotted. In an upper portion of FIG. 8, a graph is shown in which the horizontal axis represents the magnitude of the positional deviation in the X direction and the vertical axis represents the magnitude of the positional deviation in the Y direction. In a lower portion of FIG. 8, a graph is shown in which the horizontal axis represents the number of measurements and the vertical axis represents the magnitudes of the positional deviations. In an example shown in FIG. 8, values are acquired when the movement to the predetermined teaching position is repeatedly performed, and thus the horizontal axis of the graph shown in the lower portion of FIG. 8 can be considered as the passage of time.

[0044]

When no correction or compensation is performed, the positional deviations in the X direction and Y direction are relatively large due to thermal expansion. When compensation only for a change in the length of a robot arm 10 is performed without correcting the rotation angle of the robot arm 10, the positional deviations are smaller than when no correction or compensation is performed, but

the values of the positional deviations are relatively large. In particular, when no correction or compensation is performed and when compensation only for the change in the length is performed without correcting the rotation angle, the values of the positional deviations change relatively greatly in the range of a small number of measurements. This is conceivably because a motor 41 generates heat as it is repeatedly driven after a robot starts to operate, causing the temperature to gradually rise.

[0045]

When the rotation angle of the robot arm 10 is corrected and compensation for the change in the length of the robot arm 10 is performed as in the robot 100 according to this embodiment, the positional deviations in both the X direction and the Y direction are relatively small.

[0046]

Advantages of This Embodiment

According to this embodiment, as described above, the robot 100 includes the controller 30 configured or programmed to compensate for the influence of the axial deviation in the rotation axis direction between the gears 44c and 44d serving as the inclined gears due to thermal expansion of at least one of the robot arm 10 or the drive

mechanism 40. Accordingly, it is possible to compensate for the influence of the axial deviation in the rotation axis direction between the gears 44c and 44d due to thermal expansion, and thus a decrease in positioning accuracy can be reduced or prevented even when the gears 44c and 44d including teeth extending in the direction inclined with respect to the rotation axis direction of rotation as viewed in the radial direction of the rotation are arranged in the drive mechanism 40 configured to drive the robot arm 10.

[0047]

According to this embodiment, as described above, the drive mechanism 40 includes the rotation shaft 45 and the rotation shaft 46 to which the gears 44c and 44d serving as the inclined gears are attached. The controller 30 is configured or programmed to compensate for the rotational deviation of the robot arm 10 in the rotation direction caused by the axial deviation due to thermal expansion between the rotation shafts 45 and 46 as the influence of the axial deviation. Accordingly, even when the deviation of the robot arm 10 in the rotation direction occurs due to thermal expansion of the rotation shaft 45 and the rotation shaft 46 in the rotation axis direction, it is possible to compensate for the deviation of the robot arm 10 in the rotation direction, and thus a decrease in

positioning accuracy due to a temperature change can be easily reduced or prevented.

[0048]

According to this embodiment, as described above, the
5 drive mechanism 40 of the robot 100 includes the gear 44c
serving as the first inclined gear and the gear 44d
serving as the second inclined gear, both of which are
configured to mesh with each other. Furthermore, the
drive mechanism 40 includes the rotation shaft 45 serving
10 as the first rotation shaft to which the gear 44c is
attached, and the rotation shaft 46 serving as the second
rotation shaft to which the gear 44d is attached. The
controller 30 is configured or programmed to compensate
for the rotational deviation of the robot arm 10 caused by
15 the axial deviation between the gears 44c and 44d due to
the difference in thermal expansion in the rotation axis
direction between the rotation shaft 45 and the rotation
shaft 46. Accordingly, even when the rotational positions
of the gears 44c and 44d change due to a difference in the
20 degree of thermal expansion between the rotation shafts 45
and 46 caused by a difference in thermal expansion
coefficient between members of the rotation shaft 45 and
members of the rotation shaft 46, or a difference in
temperature distribution between the rotation shaft 45 and
25 the rotation shaft 46, for example, it is possible to

easily compensate for the amount of rotational deviation of the robot arm 10 by compensating for the rotational deviation of the robot arm 10 caused by the axial deviation between the gears 44c and 44d.

5 [0049]

According to this embodiment, as described above, the controller 30 is configured or programmed to correct the operation of the robot arm 10 by the drive mechanism 40 so as to compensate for the rotational deviation of the robot arm 10 due to the changes in the rotational positions of the gears 44c and 44d serving as the inclined gears caused by the axial deviation. Accordingly, to compensate for the influence of the axial deviation, the operation of the robot arm 10 by the drive mechanism 40 can be corrected.

15 Therefore, positioning by driving the robot arm 10 can be easily corrected by correcting the operation of the robot arm 10, and thus a decrease in positioning accuracy can be easily reduced or prevented.

[0050]

20 According to this embodiment, as described above, the controller 30 is configured or programmed to acquire the measurement value representing the temperature of the robot arm 10 including the drive mechanism 40, and compensate for the influence of the axial deviation due to thermal expansion based on the acquired measurement value.

25

Accordingly, a change in the temperature of the robot arm
10 including the drive mechanism 40 can be easily acquired
by acquiring the measurement value representing the
temperature. Therefore, there is a correlation between
5 temperature change and thermal expansion, and thus it is
possible to accurately compensate for the influence of the
axial deviation due to expansion based on the measurement
value representing the temperature. Consequently, a
decrease in positioning accuracy can be accurately reduced
10 or prevented by acquiring the measurement value
representing the temperature.

[0051]

According to this embodiment, as described above, the
robot 100 includes the temperature sensor 50 to measure
15 the temperature of the robot arm 10 including the drive
mechanism 40. The controller 30 is configured or
programmed to acquire the measurement value based on
measurement by the temperature sensor 50, and compensate
for the influence of the axial deviation due to thermal
20 expansion based on the acquired measurement value.

Accordingly, the measurement value representing the
temperature of the robot arm 10 can be easily acquired
based on measurement by the temperature sensor 50.

Consequently, a decrease in the positioning accuracy of
25 the robot arm 10 can be easily reduced or prevented based

on the acquired measurement value representing the temperature of the robot arm 10.

[0052]

According to this embodiment, as described above, the drive mechanism 40 includes the motor 41 configured to serve as a drive source of a drive force for the drive mechanism 40, and the encoder 42 to detect rotation of the motor 41. The temperature sensor 50 includes the encoder temperature sensor 52 in the encoder 42. The controller 30 is configured or programmed to compensate for the influence of the axial deviation due to thermal expansion based on the measurement value estimated from the measurement result of the encoder temperature sensor 52. Accordingly, the measurement value representing the temperature of the robot arm 10 can be estimated based on the measurement result of the encoder temperature sensor 52 arranged in the encoder 42 that detects rotation of the motor 41, and thus the measurement value for compensating for the influence of thermal expansion can be acquired without arranging a sensor configured to measure temperature inside the robot arm 10. Therefore, the complexity of the internal structure of the robot arm 10 can be reduced or prevented as compared with a case in which a sensor is provided inside the robot arm 10 to measure temperature.

[0053]

According to this embodiment, as described above, the temperature sensor 50 includes the encoder temperature sensor 52 and the ambient temperature sensor 51 to measure
5 the outside air temperature of the robot arm 10. The controller 30 is configured or programmed to compensate for the influence of the axial deviation due to thermal expansion based on the measurement value estimated from each of the measurement result of the encoder temperature
10 sensor 52 and the measurement result of the ambient temperature sensor 51. Accordingly, the measurement value representing the temperature of the robot arm 10 can be more accurately estimated by acquiring the measurement result of the ambient temperature sensor 51 in addition to
15 the measurement result of the encoder temperature sensor 52. Therefore, it is possible to more accurately compensate for the influence of the axial deviation due to thermal expansion based on the measurement value without providing a sensor inside the robot arm 10 to measure
20 temperature and reduce or prevent the complexity of the internal structure of the robot arm 10.

[0054]

According to this embodiment, as described above, the controller 30 is configured or programmed to compensate
25 for the change in the length of the robot arm 10 due to

thermal expansion and the deviation of the robot arm 10 in the rotation direction caused by the deviation in the rotation axis direction, which is the axial deviation due to thermal expansion. Accordingly, it is possible to
5 compensate for the influence of the change in the length of the robot arm 10 due to thermal expansion in addition to the influence of thermal expansion in the rotation axis direction of the gears 44c and 44d serving as the inclined gears. Consequently, a decrease in the positioning
10 accuracy of the robot arm 10 can be further reduced or prevented.

[0055]

According to this embodiment, as described above, the robot 100 includes the substrate holding hand 20 at the
15 distal end of the robot arm 10. Accordingly, in the robot 100 that transports the substrate W using the substrate holding hand 20, which requires a relatively high positioning accuracy, a decrease in the positioning accuracy of the robot arm 10 can be effectively reduced or
20 prevented.

[0056]

According to this embodiment, as described above, the robot 100 is disposed in the clean room 200. Accordingly, in the robot 100 disposed in the clean room 200, which may
25 perform many repetitive movements, a decrease in

positioning accuracy due to a temperature change can be effectively reduced or prevented. In other words, it is possible to ensure stable repeatability even when the temperature changes.

5 [0057]

According to this embodiment, as described above, the robot 100 is disposed in a vacuum environment.

Accordingly, it is possible to compensate for the influence of thermal expansion in the robot 100 that is
10 used in a vacuum environment in which heat is unlikely to dissipate such that the temperature is likely to rise, and thus a decrease in the positioning accuracy of the robot arm 10 can be effectively reduced or prevented.

[0058]

15 Modified Examples

The embodiment disclosed this time must be considered as illustrative in all points and not restrictive. The scope of the present disclosure is not shown by the above description of the embodiment but by the scope of claims
20 for patent, and all modifications (modified examples) within the meaning and scope equivalent to the scope of claims for patent are further included.

[0059]

For example, while the example in which the substrate
25 holding hand 20 is a passive hand has been shown in the

aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the substrate holding hand may be a hand other than a passive hand. For example, the substrate holding hand may be a vacuum hand
5 that adsorbs the substrate, or an edge grip hand that fixes the substrate. When the substrate holding hand is a passive hand or a vacuum hand, it is not necessary to take into account a change in the length of the substrate holding hand and a deviation of the substrate holding hand
10 in the rotation direction among the influences of thermal expansion. That is, the arithmetic process for compensation may be performed in a state in which δ_{LH} and $\delta_{\theta LH}$ in the formula (5) according to the above embodiment are removed. When the substrate holding hand is a passive
15 hand or a vacuum hand, a temperature change from the time at which holding the substrate is started to the time at which holding the substrate is ended is very small even when the influences of a change in the length and/or a deviation in the rotation direction due to thermal
20 expansion occur in the substrate holding hand. Therefore, even when there is a positional deviation caused by a change in the length and/or a deviation in the rotation direction due to thermal expansion of the substrate holding hand, holding is started with the positional
25 deviation present and is ended with the positional

deviation present such that the influence on transport can be ignored. On the other hand, in an edge grip hand that fixes the position of the substrate on the substrate holding hand, it is preferable to perform the arithmetic
5 process for compensation in a state in which δ_{LH} and $\delta_{\theta LH}$ are included in the formula (5) according to the above embodiment.

[0060]

While the example in which the controller 30
10 compensates for the deviation of the robot arm 10 in the rotation direction caused by the deviation in the rotation axis direction due to thermal expansion between the rotation shaft 45 and the rotation shaft 46 has been shown in the aforementioned embodiment, the present disclosure
15 is not limited to this. In the present disclosure, compensation for a deviation of the robot arm in the rotation direction due to thermal expansion of at least one of the robot arm or the drive mechanism may be performed. That is, compensation for the influence of
20 thermal expansion of members in the drive mechanism other than the rotation shafts may be performed, or compensation for the influence of thermal expansion of the robot arm may be performed.

[0061]

25 While the example in which compensation for a change

in the length of the robot arm 10 due to thermal expansion
and a deviation of the robot arm 10 in the rotation
direction due to thermal expansion is performed has been
shown in the aforementioned embodiment, the present
5 disclosure is not limited to this. In the present
disclosure, compensation for a deviation of the robot arm
in the rotation direction due to thermal expansion may be
performed without performing compensation for a change in
the length of the robot arm due to thermal expansion. In
10 other words, compensation only for a deviation of the
robot arm in the rotation direction may be performed
without taking into account a change in the length of the
robot arm due to thermal expansion.

[0062]

15 While the example in which the robot 100 is disposed
in a vacuum environment in the clean room 200 has been
shown in the aforementioned embodiment, the present
disclosure is not limited to this. In the present
disclosure, the robot may be disposed outside the clean
20 room, or may be an atmospheric robot disposed in an
atmospheric environment.

[0063]

While the example in which the arithmetic process is
performed to compensate for a deviation of the robot arm
25 10 in the rotation direction due to thermal expansion

based on the proportionality constant K_T stored in advance has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, parameters such as the length of the structure, the thermal expansion coefficient, and the inclination of the tooth trace of the inclined gear, which are factors for an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion, may be stored in advance, and the parameter such as the thermal expansion coefficient stored in advance may be used to calculate a deviation of the robot arm in the rotation direction due to thermal expansion and compensate for the influence of thermal expansion.

[0064]

While the example in which the controller 30 compensates for the influence of thermal expansion based on the measurement results of the ambient temperature sensor 51 disposed on the robot arm 10 and the encoder temperature sensor 52 disposed on the encoder 42 has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the ambient temperature sensor may be disposed on the outer surface of the robot other than the robot arm, such as the base. Alternatively, the ambient temperature sensor may be disposed on a portion inside the

vacuum chamber other than the robot arm. The controller may acquire a measurement value representing the temperature of the robot arm including the drive mechanism by acquiring a measurement result obtained by measuring the temperature of the robot arm from outside the robot. Alternatively, the controller may compensate for the influence of thermal expansion based on a measurement result from a temperature sensor disposed inside the robot arm. The temperature sensor may be a contact type temperature sensor such as a thermistor or a resistance temperature detector other than a thermocouple, or a non-contact type temperature sensor such as a radiation temperature sensor or a color temperature sensor. Alternatively, the ambient temperature sensor may not be provided, and a measurement value representing the temperature may be estimated based on the measurement result of the encoder temperature sensor. Alternatively, the controller may indirectly acquire a measurement value of the temperature based on a measurement value representing a continuous operating time, a motor current value, or the operating speed of the robot arm, for example. In other words, the measurement value representing a continuous operating time, a motor current value, or the operating speed of the robot arm, for example, may be acquired as a measurement value

representing the temperature of the robot arm including the drive mechanism, and compensation for the influence of thermal expansion may be performed based on the measurement value representing a continuous operating
5 time, a motor current value, or the operating speed of the robot arm, for example, without calculating the temperature itself.

[0065]

While the example in which the power transmitter 43
10 in the drive mechanism 40 is a gear power transmitter including four gears: the gears 44a and 44b, and the gears 44c and 44d serving as the inclined gears has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the
15 power transmitter in the drive mechanism may be a belt pulley power transmitter including a pulley serving as an inclined gear and a toothed belt wound around the pulley. Even in such a case, when the pulley and the toothed belt include teeth arranged in a direction inclined with
20 respect to the rotation axis direction of the pulley, the influence of an axial deviation due to thermal expansion occurs, and thus a decrease in positioning accuracy can be reduced or prevented by compensating for the influence of thermal expansion. Furthermore, while the example in
25 which the inclined gears are helical gears has been shown

in the aforementioned embodiment, in the present disclosure, the inclined gears may be spiral bevel gears, which are bevel gears with helical teeth. Alternatively, the inclined gears may be internal helical gears. The number of gears in the drive mechanism may be other than four.

[0066]

While the example in which the robot arm 10 is made of a material having a thermal expansion coefficient different from those of the gears 44c and 44d serving as the inclined gears, the rotation shaft 45, and the rotation shaft 46 has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the robot arm, the inclined gears, and the rotation shafts may be made of materials having the same thermal expansion coefficient. Alternatively, the active side inclined gear and rotation shaft and the driven side inclined gear and rotation shaft may be made of materials having different thermal expansion coefficients.

[0067]

While the example in which the robot arm 10 is made of aluminum, and the gears 44c and 44d serving as the inclined gears, the rotation shaft 45, and the rotation shaft 46 are made of iron has been shown in the

aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the robot arm, the inclined gears, and the rotation shafts may be made of any material.

5 [0068]

While the example in which the robot 100 is a horizontal articulated robot arm in which one substrate holding hand 20 is disposed on one robot arm 10 has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, two or more substrate holding hands may be disposed at the distal end of the robot arm. Alternatively, a hand or an end effector other than the substrate holding hand may be disposed at the distal end of the robot arm. Alternatively, a plurality of robot arms may be provided. Alternatively, the robot arm may be a vertical articulated robot arm.

[0069]

While the example in which based on the detection result from the positional deviation detector 60 including the first sensor 61 and the second sensor 62, the controller 30 compensates for the positional deviation of the substrate W on the substrate holding hand 20, and compensates for the influence of thermal expansion included in the compensation amount in compensation for

the positional deviation of the substrate W on the substrate holding hand 20 has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the controller may not compensate for the influence of thermal expansion included in the compensation amount for the positional deviation of the substrate on the substrate holding hand. Alternatively, the controller may not compensate for the positional deviation of the substrate on the substrate holding hand. Alternatively, the positional deviation detector may detect the substrate on the substrate holding hand using only one of the first sensor and the second sensor.

[0070]

While the example in which the control processes to control driving of the robot arm 10, to acquire the measurement value representing the temperature of the robot arm 10, and to compensate for the influence of thermal expansion based on the measurement value representing the temperature of the robot arm 10 are executed by the common controller 30 has been shown in the aforementioned embodiment, the present disclosure is not limited to this. In the present disclosure, the control processes to control driving of the robot arm, to acquire the measurement value representing the temperature of the

robot arm, and to compensate for the influence of thermal expansion based on the measurement value representing the temperature of the robot arm may be executed by different control devices.

5 [0071]

The functionality of the elements disclosed herein may be implemented using circuitry or processing circuitry which includes general purpose processors, special purpose processors, integrated circuits, ASICs ("Application
10 Specific Integrated Circuits"), conventional circuitry and/or combinations thereof which are configured or programmed to perform the disclosed functionality. Processors are considered processing circuitry or circuitry as they include transistors and other circuitry
15 therein. The processor may be a programmed processor which executes a program stored in a memory. In the disclosure, the circuitry, units, or means are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed
20 herein or otherwise known which is programmed or configured to carry out the recited functionality. When the hardware is a processor which may be considered a type of circuitry, the circuitry, means, or units are a combination of hardware and software, the software being
25 used to configure the hardware and/or processor.

[0072]

Aspects

It will be appreciated by those skilled in the art that the exemplary embodiments described above are
5 specific examples of the following aspects.

[0073]

(Item 1)

A robot comprising:

a robot arm;

10 a drive mechanism including an inclined gear including teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation to drive the robot arm; and

15 a controller configured or programmed to compensate for an influence of an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion of at least one of the robot arm or the drive mechanism.

20 [0074]

(Item 2)

The robot according to item 1, wherein

the drive mechanism includes a rotation shaft to which the inclined gear is attached; and

25 the controller is configured or programmed to

compensate for a rotational deviation of the robot arm in a rotation direction caused by the axial deviation of the rotation shaft due to the thermal expansion as the influence of the axial deviation.

5 [0075]

(Item 3)

The robot according to item 2, wherein

the inclined gear includes a first inclined gear and a second inclined gear configured to mesh with each other;

10 the rotation shaft includes a first rotation shaft to which the first inclined gear is attached, and a second rotation shaft to which the second inclined gear is attached; and

the controller is configured or programmed to
15 compensate for the rotational deviation of the robot arm caused by the axial deviation between the first inclined gear and the second inclined gear due to a difference in the thermal expansion in the rotation axis direction between the first rotation shaft and the second rotation
20 shaft.

[0076]

(Item 4)

The robot according to item 2 or 3, wherein the controller is configured or programmed to correct
25 operation of the robot arm by the drive mechanism so as to

compensate for the rotational deviation of the robot arm due to a change in a rotational position of the inclined gear caused by the axial deviation.

[0077]

5 (Item 5)

The robot according to any one of items 1 to 3, wherein the controller is configured or programmed to acquire a measurement value representing a temperature of the robot arm including the drive mechanism, and

10 compensate for the influence of the axial deviation due to the thermal expansion based on an acquired measurement value.

[0078]

(Item 6)

15 The robot according to item 5, further comprising:
a temperature sensor to measure the temperature of the robot arm including the drive mechanism; wherein

the controller is configured or programmed to:

acquire the measurement value based on

20 measurement by the temperature sensor; and

compensate for the influence of the axial deviation due to the thermal expansion based on the acquired measurement value.

[0079]

25 (Item 7)

The robot according to item 6, wherein
the drive mechanism includes a motor configured to
serve as a drive source of a drive force for the drive
mechanism, and an encoder to detect rotation of the motor;

5 the temperature sensor includes an encoder
temperature sensor in the encoder; and

the controller is configured or programmed to
compensate for the influence of the axial deviation due to
the thermal expansion based on the measurement value
10 estimated from a measurement result of the encoder
temperature sensor.

[0080]

(Item 8)

The robot according to item 7, wherein
15 the temperature sensor includes the encoder
temperature sensor and an ambient temperature sensor to
measure an outside air temperature of the robot arm; and

the controller is configured or programmed to
compensate for the influence of the axial deviation due to
20 the thermal expansion based on the measurement value
estimated from each of the measurement result of the
encoder temperature sensor and a measurement result of the
ambient temperature sensor.

[0081]

25 (Item 9)

5 The robot according to any one of items 2 to 4,
wherein the controller is configured or programmed to
compensate for a change in a length of the robot arm due
to the thermal expansion and the rotational deviation of
the robot arm caused by the axial deviation due to the
thermal expansion.

[0082]

(Item 10)

10 The robot according to any one of items 1 to 9,
further comprising:
a substrate holding hand at a distal end of the robot
arm.

[0083]

(Item 11)

15 The robot according to any one of items 1 to 10,
wherein the robot is disposed in a clean room.

[0084]

(Item 12)

20 The robot according to any one of items 1 to 11,
wherein the robot is disposed in a vacuum environment.

[0085]

(Item 13)

A robot controlling method comprising:
acquiring a measurement value representing a
25 temperature of a robot arm driven by a drive mechanism

including an inclined gear including teeth extending in a direction inclined with respect to a rotation axis direction of rotation as viewed in a radial direction of the rotation; and

- 5 compensating for an influence of an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion of at least one of the robot arm or the drive mechanism based on an acquired measurement value.

10

CLAIMS

[Claim 1] A robot comprising:

a robot arm;

5 a drive mechanism including an inclined gear
including teeth extending in a direction inclined with
respect to a rotation axis direction of rotation as viewed
in a radial direction of the rotation to drive the robot
arm; and

10 a controller configured or programmed to compensate
for an influence of an axial deviation of the inclined
gear in the rotation axis direction due to thermal
expansion of at least one of the robot arm or the drive
mechanism.

15

[Claim 2] The robot according to claim 1, wherein
the drive mechanism includes a rotation shaft to
which the inclined gear is attached; and

the controller is configured or programmed to
20 compensate for a rotational deviation of the robot arm in
a rotation direction caused by the axial deviation of the
rotation shaft due to the thermal expansion as the
influence of the axial deviation.

25 [Claim 3] The robot according to claim 2, wherein

the inclined gear includes a first inclined gear and a second inclined gear configured to mesh with each other;

the rotation shaft includes a first rotation shaft to which the first inclined gear is attached, and a second
5 rotation shaft to which the second inclined gear is attached; and

the controller is configured or programmed to compensate for the rotational deviation of the robot arm caused by the axial deviation between the first inclined
10 gear and the second inclined gear due to a difference in the thermal expansion in the rotation axis direction between the first rotation shaft and the second rotation shaft.

15 [Claim 4] The robot according to claim 2, wherein the controller is configured or programmed to correct operation of the robot arm by the drive mechanism so as to compensate for the rotational deviation of the robot arm due to a change in a rotational position of the inclined
20 gear caused by the axial deviation.

[Claim 5] The robot according to claim 1, wherein the controller is configured or programmed to acquire a measurement value representing a temperature of the robot
25 arm including the drive mechanism, and compensate for the

influence of the axial deviation due to the thermal expansion based on an acquired measurement value.

[Claim 6] The robot according to claim 5, further
5 comprising:

a temperature sensor to measure the temperature of the robot arm including the drive mechanism; wherein

the controller is configured or programmed to:

acquire the measurement value based on
10 measurement by the temperature sensor; and

compensate for the influence of the axial deviation due to the thermal expansion based on the acquired measurement value.

15 [Claim 7] The robot according to claim 6, wherein the drive mechanism includes a motor configured to serve as a drive source of a drive force for the drive mechanism, and an encoder to detect rotation of the motor;

the temperature sensor includes an encoder
20 temperature sensor in the encoder; and

the controller is configured or programmed to compensate for the influence of the axial deviation due to the thermal expansion based on the measurement value estimated from a measurement result of the encoder
25 temperature sensor.

[Claim 8] The robot according to claim 7, wherein
the temperature sensor includes the encoder
temperature sensor and an ambient temperature sensor to
5 measure an outside air temperature of the robot arm; and
the controller is configured or programmed to
compensate for the influence of the axial deviation due to
the thermal expansion based on the measurement value
estimated from each of the measurement result of the
10 encoder temperature sensor and a measurement result of the
ambient temperature sensor.

[Claim 9] The robot according to claim 2, wherein the
controller is configured or programmed to compensate for a
15 change in a length of the robot arm due to the thermal
expansion and the rotational deviation of the robot arm
caused by the axial deviation due to the thermal
expansion.

20 [Claim 10] The robot according to claim 1, further
comprising:
a substrate holding hand at a distal end of the robot
arm.

25 [Claim 11] The robot according to claim 1, wherein

the robot is disposed in a clean room.

[Claim 12] The robot according to claim 1, wherein the robot is disposed in a vacuum environment.

5

[Claim 13] A robot controlling method comprising:

acquiring a measurement value representing a temperature of a robot arm driven by a drive mechanism including an inclined gear including teeth extending in a direction inclined with respect to a rotation axis
10 direction of rotation as viewed in a radial direction of the rotation; and

compensating for an influence of an axial deviation of the inclined gear in the rotation axis direction due to thermal expansion of at least one of the robot arm or the
15 drive mechanism based on an acquired measurement value.