The Traverse Unit-less Compact Arm, NTS/TTS Series: Simple Installation in Semiconductor Manufacturing Equipment through Standardization

We have developed a semiconductor transportation robot used to transport wafers in semiconductor manufacturing equipment. In recent years, we have been developing versatile products that can accommodate various customer requests simply by changing the hand, with the "Common Platform" concept.

This time, we developed the NTS and TTS series, which realizes the standardization of not only hardware but also software for compact units that require fewer wafer pods.

Introduction

Semiconductors were mainly in demand for computer memories and other products in the past, but are currently used in more products such as mobile phones. In 2017, the demand for semiconductors is expected to increase in the data center, automobile, communication and other industries.

1 Background

A semiconductor transportation robot is used in an EFEM (equipment front end module). An EFEM is a module that transfers silicon wafers between a FOUP (front opening unified pod), a container that seals and transports them, and processes in the semiconductor manufacturing equipment. Currently, the 2W (two FOUPs) and 3W (three FOUPs) are the mainstream models as a result of optimization of unit processing speed and installation footprint. As this suggests, the semiconductor manufacturing equipment is expected to combine a better processing capacity and compact design.

The NT and TT series[1)] developed under the "Common Platform" concept can address many different customer requirements just by replacing the hands, and they support up to 4W though their arms were made longer to do so. Therefore, there was a demand for a compact robot with shorter arms specially designed for the 2W and 3W to support the design of a more compact semiconductor manufacturing equipment.

2 Product overview

We developed the new NTS and TTS series to support the 2W layout in **Fig. 1 (a)** and the 3W layout in **Fig. 1 (b)**.

The NTS and TTS series have achieved Cleanliness class 1 defined by the International Organization for Standards (ISO), just like their predecessors. They also inherit the features of the NT and TT series. For example, they do not need the traverse unit and allow the user to effectively use the device space by minimizing the installation footprint of the robot.

Specially designed for the 2W and 3W layouts, the NTS and TTS series have shorter arms than those of conventional products, allowing for more compact unit design. **Figure 2** shows that the NTS and TTS series have shorter arms than the NT and TT series, but maintain the same operating range.

3 Hardware

(1) Compact design

Of the two arms in the NTS and TTS series, the lower arm unit incorporates the gear box that decelerates the gear for driving arms and the motor for two axes. The upper arm unit incorporates the gear box that decelerates

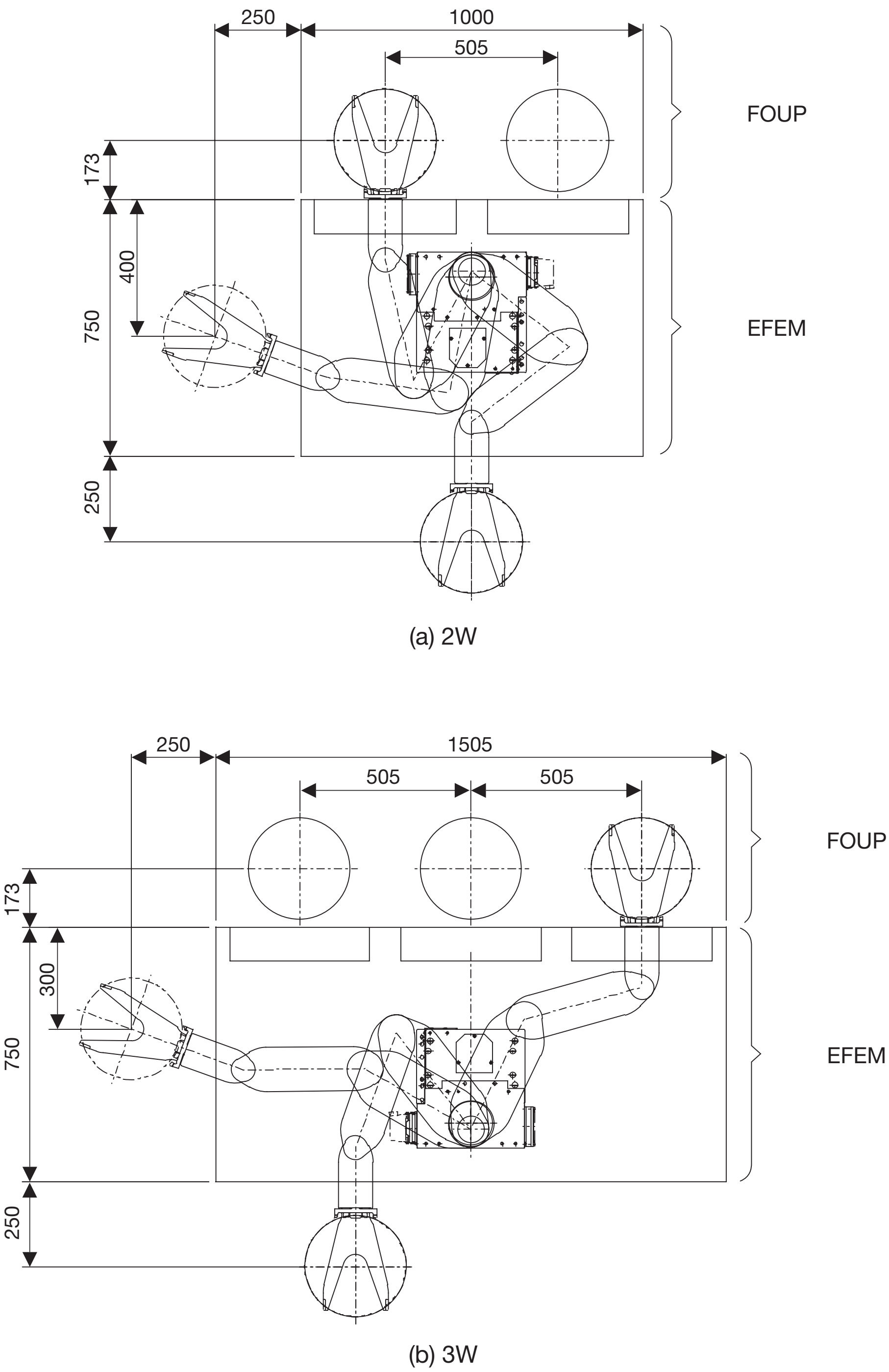
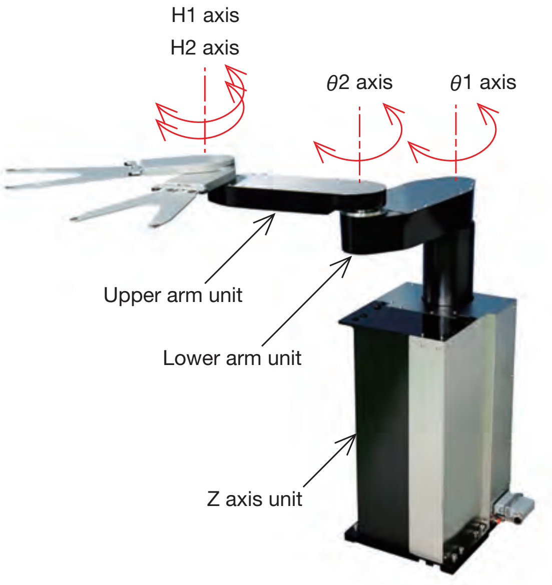


Fig. 1 Layout in semiconductor manufacturing equipment

the gear for driving the hands of up to two axes and the motor. In other word, each axis section has its own drive-train as a unit to realize a very simple structure, inheriting the design concept of the NT and TT series. In addition, because shorter arms mean less load on the drive-trains, we can design a compact gear box by decreasing the speed reduction ratio, and consequently, further shorten the arms.

(2) High degree of freedom for layout

Each arm axis and hand axis can be independently controlled and the approach angle to each access position can be freely specified. The installation position of robots can also be flexibly changed depending on the position of interfering objects in the unit.



Model		NT520	NTS20	TT220	TTS20
Operating range	Z axis (up/down) 〔mm〕	470	470	740	740
	θ 1 axis (rotation) 〔°〕	340	340	340	340
	θ 2 axis (rotation) 〔°〕	340	340	340	340
	H1 axis (rotation) 〔°〕	380	380	380	380
	H2 axis (rotation) 〔°〕	380	380	380	380
Arm length	Lower arm 〔mm〕	440	360	440	360
	Upper arm 〔mm〕	440	360	440	360
	Hand 〔mm〕	350	350	350	350

Fig. 2 NT, TT Series & NTS, TTS Series spec comparison

(3) Cost reduction

We significantly reduced the costs of the NTS and TTS series. We reduced parts costs by optimizing the layout of electric parts on the board or drive units such as the drive-train, and reducing the number of processes needed to form the robot housing. In addition, we standardized the drive unit by optimizing the speed reduction ratio. Through these efforts, we reduced the number of parts both in the Z axis unit and the lower arm unit by 30% from the NT and TT series. Manufacturing the decelerator units ourselves also contributed to cost reduction.

(4) Reduction in lead time

Inheriting the "Common Platform" concept, the NTS and TTS series widely support the 2W and 3W layouts. Specifically, the NTS and TTS series are standardized except for the hands, which interface with the unit. We also standardized all the products that have a long delivery period to reduce the lead time.

4 Standard application software

Application software is implemented to control the robot according to commands from the unit in order to install the robot in the semiconductor manufacturing equipment. In the past, we adjusted control parameters depending on the unit layout and the type of robot to be installed. Therefore, a long time and expertise were required before the unit could be put into production.

So, we developed standard application software that does not need these adjustment items thereby facilitating installation and reducing the lead time.

(1) Examination and design of the operation path according to the unit layout

We register teaching positions and examine the operation path according to the layout of the customer's unit and embed them into the application software before providing a semiconductor transportation robot. As a tool to separate the items that depend on the unit layout from the application software and further facilitate examination, we developed KRET (Kawasaki Robot Easy Teaching).

We realized the following features by implementing robot data implemented in robot control software and a coordinate conversion logic required to calculate the posture in KRET.

- Layout information (such as teaching positions and the operation area of the robot) can be easily registered.
- The posture of robots used for the transport operation can be easily created by entering the hand angle and other parameters.
- Entered information is displayed as a ground plan as shown in **Fig. 3** and the operation can be visually checked with the animation function.

Knowledge of how to embed data registered in KRET into the application software is not required because that data can be output in a file format that the robot controller can load. In this way, data creation required for robot operation is facilitated and automated.

(2) Automatic correction of side motion in linear operation sections

When robot hands are operated on a line trajectory, side motion of the hands occurs because multiple axes are controlled at the same time. Because the space where the robot can operate in the unit is very small, the side motion must be corrected to avoid interference. In the past, we actually operated the robot, measured the side motion, and adjusted the correction parameters. It took a long time to install, measure, and adjust the robot and measurement hardware. In addition, parameters must be readjusted if the operation path is changed due to layout changes or for any other reasons because the side motion depends on the robot posture.

It was for these reasons that we developed a system to automatically correct side motion. As shown in **Fig. 4**, the system dynamically calculates the torque required for operation based on the inertia force, centrifugal force, and Coriolis force derived from the posture, speed, and acceleration during operation and provides it to individual motors to constrain side motion.

This automation eliminates variations that depend on the proficiency of workers and allows us to provide transport performance with stable quality and a short lead time.

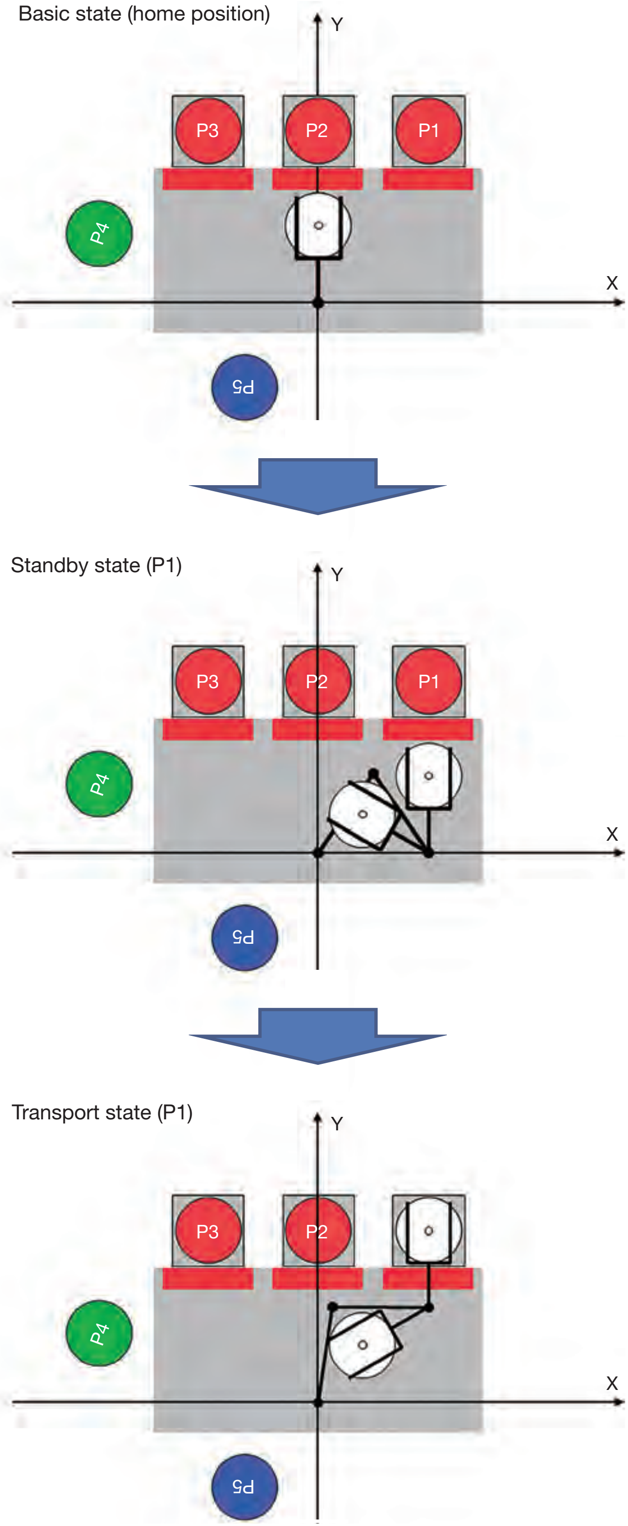


Fig. 3 KRET Operation check image

(3) Automation of adjustment items for homing

Workers are not allowed to casually enter the semiconductor manufacturing equipment once the unit starts production. This is to prevent particles from entering into the unit. Therefore, if the robot stops for some reason, it must return to the defined home position in response to

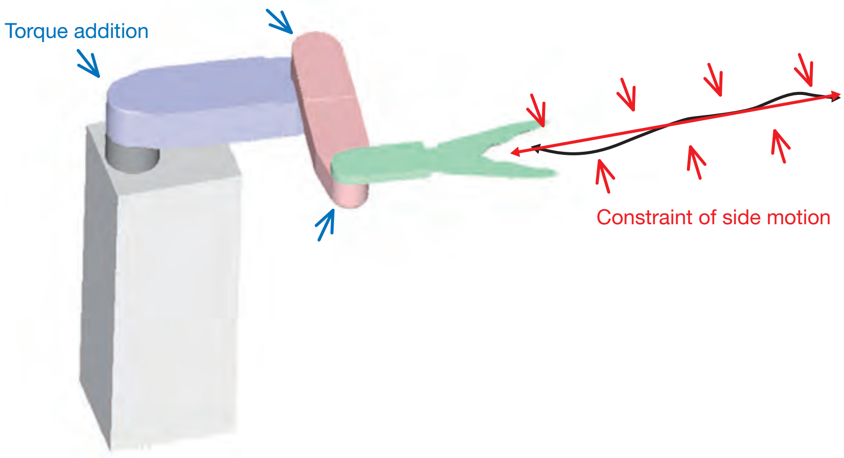


Fig. 4 Side motion correction image

the command from the unit. Our conventional semiconductor transportation robots were able to return to their home positions only when it was determined that the current position is on the transport path so that it would not interfere with the unit during the homing operation. Therefore, the criteria for determining whether the current position is on the transport path had to be adjusted and checked for each project.

For this reason, we developed a function to model the robot and unit layout and automatically return the robot to the home position, while checking for interfering objects. A contour model of the robot is implemented in the application software in advance and the information on the robot operation area registered in KRET is used as the unit layout model. With this function, the robot can return to the home position as described below, checking that the modeled robot does not interfere with the unit layout as shown in **Fig. 5**.

① Select the nearest posture from many different postures that the robot has during transport.

② When models do not intersect by the robot moving directly into the nearest posture, the robot gets into that posture and then moves to the home position along the transport path.

③ When models intersect by the robot moving directly into the nearest posture, the robot moves up to the object that is in the way, avoids it, and then moves to the position to get into the nearest posture. After avoiding the object and getting into the nearest posture, the robot moves to the home position along the transport path as in ②.

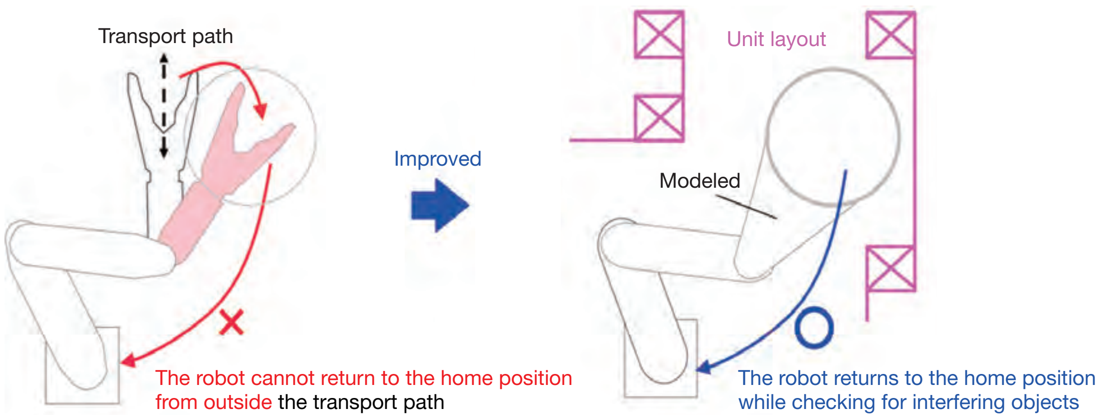


Fig. 5 Conceptual image of homing

Automation of homing eliminates the need to adjust the criteria for determining whether the current position is on the path and the confirmation work associated with adjustment. Because this is area determination, the robot can move to the home position even from a position outside the path without depending on the path.

5 Package software

We developed package software combining KRET and the standardized application software introduced above. Examination results in the application software or KRET can be easily applied to the actual robot using the included terminal software.

We facilitate installation and reduce the lead time by providing this package software to customers.

This software can be easily installed even by new customers because software expertise is not required and it can be provided with a short lead time because adjustment of each unit is not required. In this way, KRET allows customers to examine their layouts by themselves.

Conclusion

Robot systems can now be quickly set up without depending on the semiconductor unit thanks to the new additions to our robot lineup based on the "Common Platform" concept and simplified installation using the standard application software. We will continue to make improvements to provide products that meet many different customer needs with short lead time.

Reference

1) H. Goto, M. Yoshida, M. Inoue, T. Arita, T. Shibata: "NT & NV series advanced semiconductortransferring robot achieving both high speed and ease of use," Kawasaki Technical Review, No.172, pp.25-32 (2012)

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