Application Examples and Function Improvements of the Wrist Joint Module “i-WRIST™”

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NTN developed an angle control device that uses a parallel link mechanism which is a type of constant velocity joint[1)-7)] and started mass production under the product name “ i-WRIST™” in August 2018[8)].

Since then, we received many inquiries for improved automation, labor savings, improved appearance, improved inspection process and acquired more advanced needs for product specifications. We have just developed the upgraded product to meet these needs and have significantly improved its functions. We would like to introduce the upgraded product.

1. Introduction

The use of industrial robots is expanding at a tremendous rate as a means of boosting productivity due to increasing demand for automation and labor-saving methods. The shortage of labor is becoming a serious issue in Japan due to its shrinking population, and installation of industrial robots is gaining traction as a means of overcoming this issue.

In 2012, **NTN** announced its angle control equipment based on its proprietary parallel link mechanism. It was marketed for greasing and cleaning applications that require fast and precise changes in position that industrial robots have difficulty with. After changing the name to “i-WRIST™” Wrist Joint Module from 2018 (product registration in 2019), **NTN** began mass-production with the aim of targeting visual inspection applications of automotive and electronic components that had relied on manual labor in the past.

This article focuses on visual inspection applications developed by **NTN**, as well as the features, functionality and examples of compatible systems for the further enhanced i-WRIST™ “IWS Series.”

2. i-WRIST™ Overview

Fig. 1 shows a conceptual diagram of i-WRIST™, which identifies the parallel link mechanism and drive mechanism that control its positioning. The three motors mounted on the drive mechanism are under synchronous control to achieve two-degree of freedom angular positioning (bending angle, swing angle).

Controlling two of the three rows of link systems (1st to 3rd link systems) of i-WRIST™ can be used for unique angular positioning, however motors mounted to the link systems of all three rows eliminate backlash in the drive mechanism and achieves greater positioning accuracy.

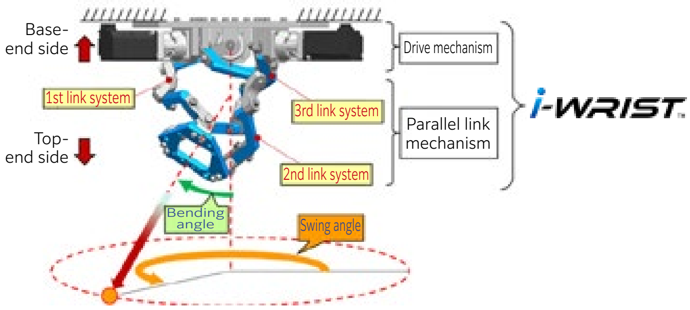

Fig. 1 Schematic of i-WRIST™

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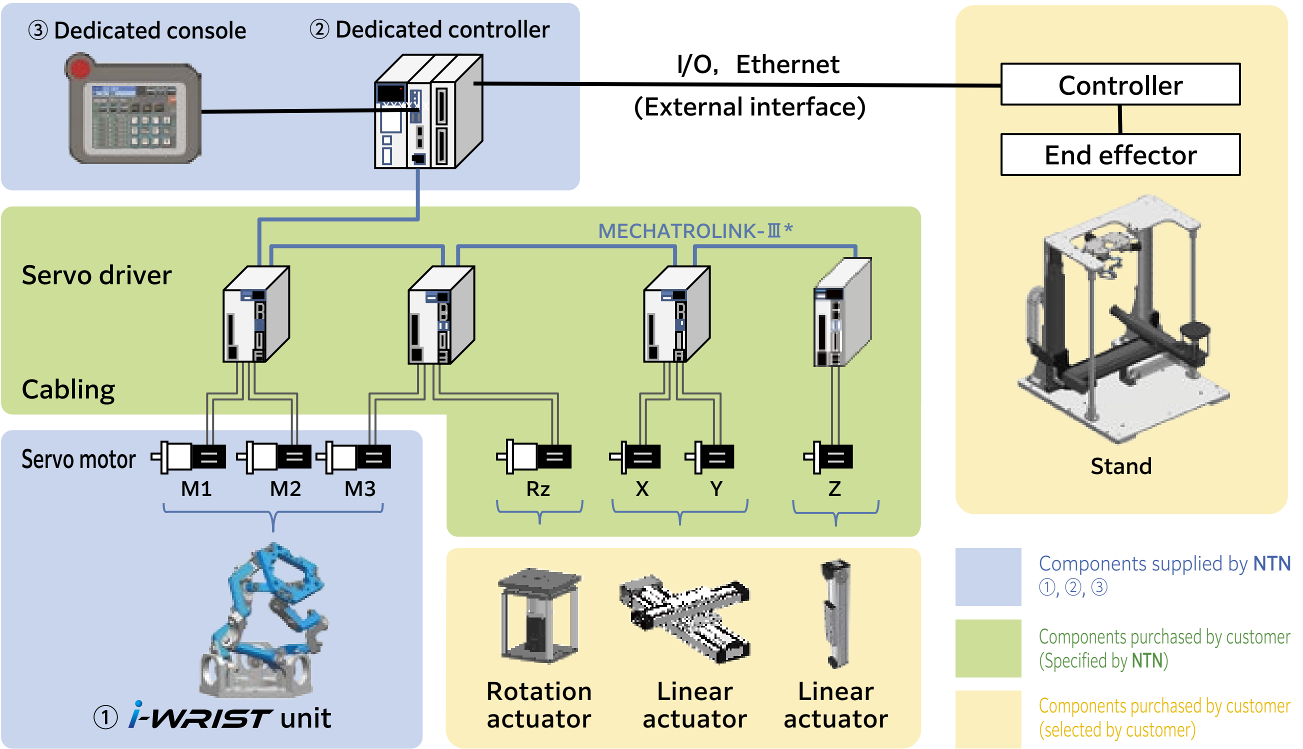

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Fig. 2 Configuration example of automation equipment

Fig. 2 shows a basic configuration example of automation equipment that includes i-WRIST™. i-WRIST™ is incorporated into the equipment with a combination of linear actuators and rotation actuators. **NTN** supplies ① i-WRIST™, ② Dedicated controller and ③ Dedicated console as a set, while the overall equipment is designed and made by the user or a system integrator.

2.1 i-WRIST™ Features

Production sites are implementing more methods that use automation and labor-saving technologies based on robots. Yet as robots are not perfect and suffer from a range of issues, user’s automation and labor-saving efforts often do not go as planned, which required more time and cost to develop dedicated devices.

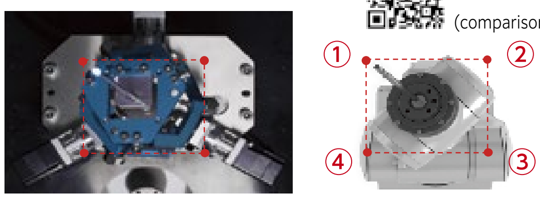
i-WRIST™ provides three main features that can resolve these issues faced by production sites.

1) High-speed operation

Conventional wrist joint modules with pan and tilt mechanisms move slowly when approaching workpieces from many directions for visual inspections of complex shapes, which meant there was a limit in the reduction of takt time. i-WRIST™ controls minute changes in position at high speed, making it possible to achieve further reductions in takt time.

A comparison of i-WRIST™ with pan and tilt mechanisms is shown by the movement required for approaching the four points in **Fig. 3**. The operating pattern was set as ① → ② → ③ → ④ → ① → ④ → ③ → ② → ①. The results show that i-WRIST™ completed the pattern in 1.4 seconds compared to the pan and tilt mechanism at 4.0 seconds, verifying that i-WRIST™ moved 2.8-times faster.

(comparison video)



a) i-WRIST™　　b) Pan and tilt mechanism

Fig. 3 Operation pattern for comparison with view from the end effector side

2) Ease-of-use

The majority of industrial robot manufacturers generally use their own proprietary robot language, which required specialist knowledge for the programming when changing over or teaching the robots.

In contrast, changing configuration parameters or teaching i-WRIST™ can be performed on the dedicated console screen, eliminating the need for any specialist programming language expertise. Operating patterns are created using the dedicated console screen shown in **Fig. 4** to enter each coordinate directly for the i-WRIST™ or associated linear actuators. Another method involves moving i-WRIST™ or linear actuators to their desired positions using JOG operations and then registering the coordinates. **NTN** also provides software **(Fig. 5)** for creating operating patterns efficiently using a computer. These i-WRIST™ operations can be acquired by simply taking a half-day course.

Fig. 4 Operation screen of dedicated console

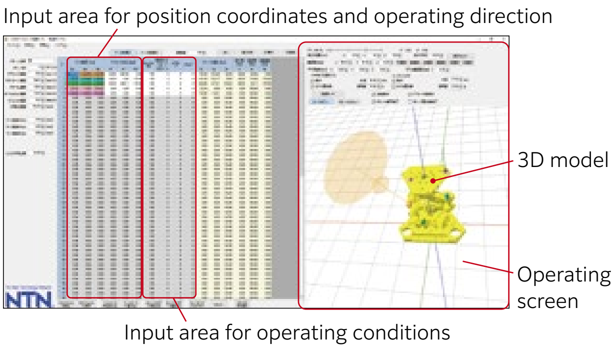


Fig. 5 Point data edit software

3) Space efficiency

The problems with using robots to achieve automation is the installation space or the major changes required to existing production lines.

i-WRIST™ is designed to be used with a combination of linear actuators and rotation actuators. The configuration of the system that rotates workpieces requires around half the stroke of the linear actuator (XY stage), which makes the overall system size more compact. To operate on a workpiece around ø100 mm and a height of 100 mm in size, **NTN** managed to design a system size with a width of 800 mm and a depth of 850 mm, meaning automation equipment can be installed in the space where manual labor is performed **(Fig. 6)**.

Fig. 7 also shows an example image comparing the installation size when building automation equipment using a conventional robot (multijoint robot) or i-WRIST™. This example illustrates how using i-WRIST™ means a system can be built using around half the space.

As such, i-WRIST™ can help resolve problems such as insufficient space at a production site.

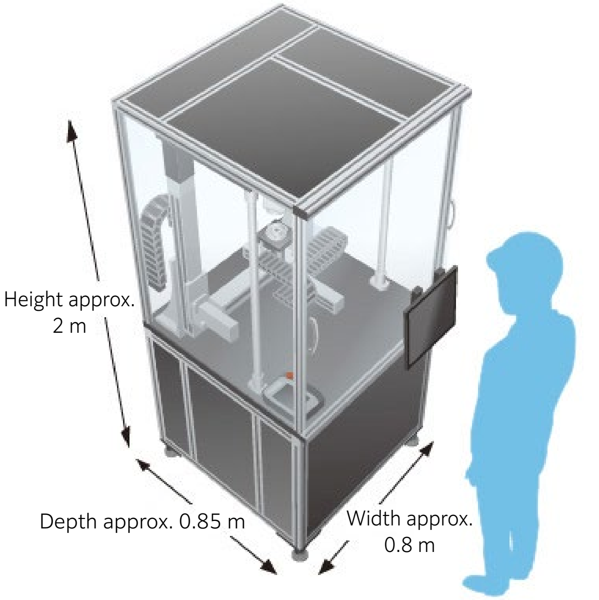


Fig. 6 Compact equipment (image)

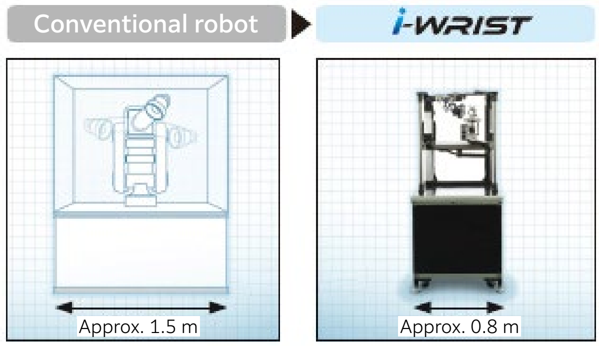


Fig. 7 Installation size comparison example of automation equipment (image)

3. Example Application of Visual Inspection System

Since beginning mass-production of i-WRIST™ in 2018, **NTN** has mainly marketed it for visual inspection applications. In particular, it has been praised for its capability of approaching workpieces with complex shapes from many directions at a high speed. Specific examples of target workpieces include aluminum diecast components, forged parts, pressed moldings and resin moldings.

3.1 Example of Off-line System Configuration

Fig. 8 shows an example configuration of a visual inspection system designed as an off-line system. In this configuration, i-WRIST™ is installed on a stand in a downward attitude, and a camera and lighting unit are mounted to the end of i-WRIST™. The workpiece is moved and rotated with linear actuators (XYZ stage) and a rotation actuator.

This configuration allows workpieces to be approached from multiple directions with angle changes of i-WRIST™ and workpiece movement/rotation, which means the linear actuator (XY stage) stroke can be shortened for a more compact overall system size.

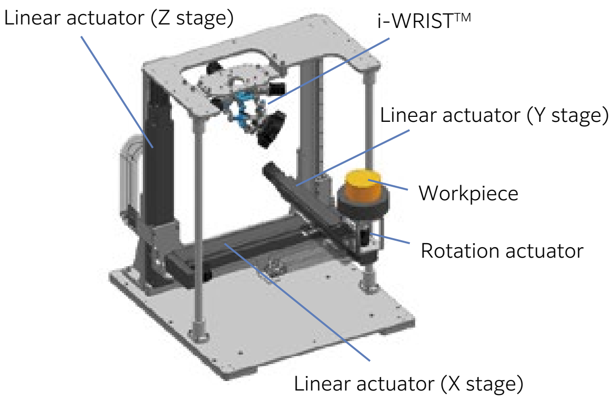


Fig. 8 Configuration example of off-line system

3.2 Example of In-line System Configuration

Fig. 9 shows an example configuration of a visual inspection system designed as an in-line system. In this configuration the i-WRIST™ with a camera and lighting unit is mounted in a downward attitude to the linear actuator (XYZ stage). This allows it to approach workpieces from many directions while they are moving along an existing conveyor belt.

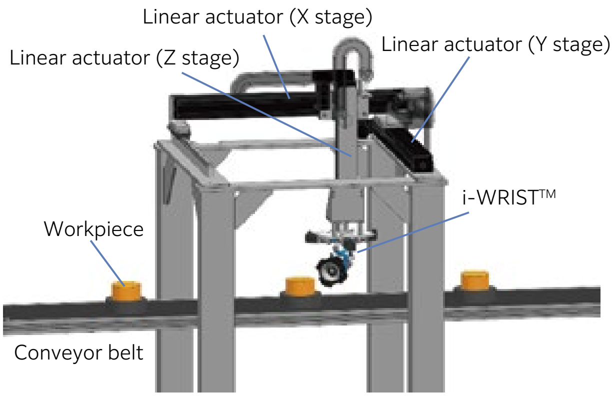


Fig. 9 Configuration example of in-line system

4. i-WRIST™ "IWS Series"

While the product had been marketed toward visual inspection applications until now, the i-WRIST™ "IWS Series (hereafter, IWS Series)" has been developed to address new needs.

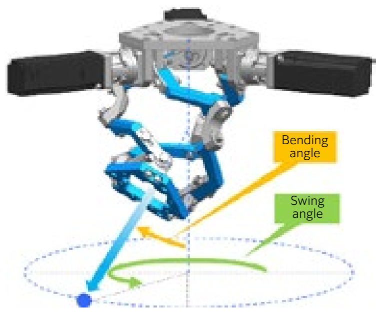
The main functions of the IWS Series are as below.

4.1 i-WRIST™ Installation Direction

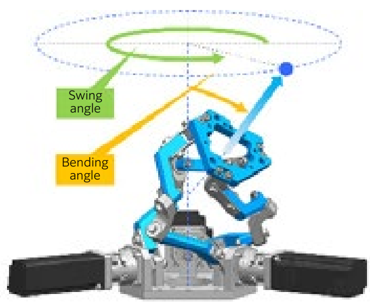
Fig. 10 shows the typical installation directions and definitions of coordinates for the bending angle and swing angle.

When mass-production began in 2018, the installation direction was limited to that shown in **Fig. 10** a).

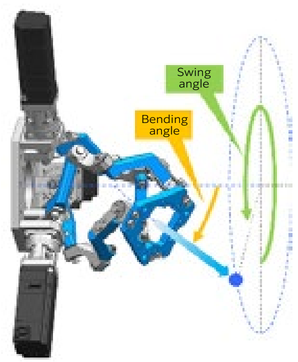
The IWS Series has extended functionality for calculating the i-WRIST™ angle and coordinates of associated actuators that are used, to also enable installation in the upward **(Fig. 10** b)**)** and vertical **(Fig. 10** c)**)** directions.



a) Downward



b) Upward



c) Vertical

Fig. 10 Installation direction

4.2 Compatible System Configurations

The IWS Series significantly expands on the various possible system configurations of i-WRIST™ and the associated linear actuators and rotation actuator that can be used.

Devices that can be mounted to i-WRIST™ had been limited to the end effector (camera and lighting unit for visual inspection applications), however with the IWS Series, workpieces can now be mounted. This gives users a much broader range of system configuration options to select from.

There are two i-WRIST™ coordinate systems: a "base coordinate system" based on the orthogonal coordinates of the entire system, which defines the angle of the i-WRIST™ and rotation actuator as well as the position coordinates of the linear actuators; and a "work coordinate system" based on the orthogonal coordinates of the workpiece that defines the position and working direction of the workpiece. Similar to the previous designs, the system has been developed using the software included in the dedicated controller for calculating the coordinates of the entire system. This allows coordinates to be calculated for the system without the need for users or system integrators to develop and test complex coordinate calculations.

Fig. 11 shows typical examples of system configurations compatible with the IWS Series. Users can select a configuration to suit their desired application.

Configuration examples (1) and (2) are system configurations that are compatible with the previous system, and correspond to the configurations shown in **Fig. 8** and **Fig. 9** above.

Configuration examples (3), (4) and (5) are extended system configurations that are now available with the IWS Series. Configuration example (3) rotates i-WRIST™ with the rotation actuator so that the direction of the end effector can be adjusted to suit the position of i-WRIST™. Example (4) is a configuration for handling workpieces and is suited to visual inspections of small, lightweight workpieces like resin molded parts. Configuration example (5) has i-WRIST™ installed on a rotation actuator at an inclined angle, where the rotation actuator is actually mounted on a linear actuator to enable positioning in the XYZ stage directions. This configuration means workpieces can be viewed from a lower angled approach, and in visual inspection applications, means inspections can be performed around almost the entire workpiece.

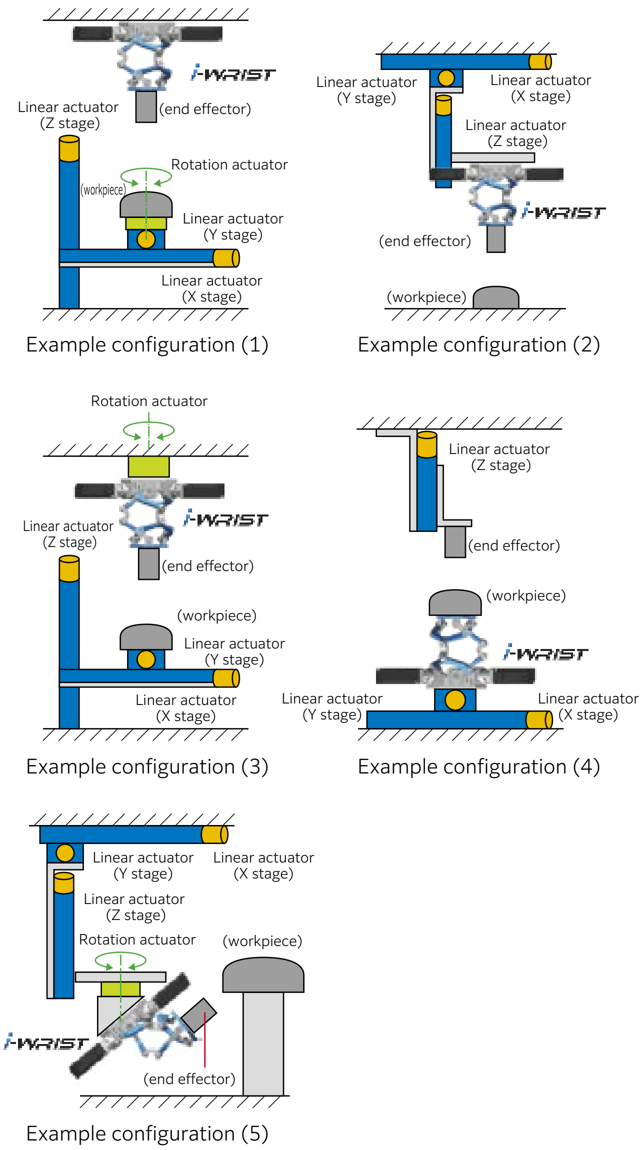


Fig. 11 Typical examples of system configurations

4.3 Compliance with Safety Standards

IWS Series has been designed with specifications that meet 'ISO10218-1 (JIS B 8433-1)' standards for the safety of industrial robots.

The first area of compliance with the IWS Series is the addition of a motor with a brake for the servo motor that acts as the i-WRIST™ drive mechanism. In the event of a power outage or an unexpected alarm being triggered, the brake stops the motor from rotating so there is no unexpected movement.

Operating modes have also been defined clearly as "Auto mode," "Manual low-speed mode" and "Manual high-speed mode" to comply with safety standards for industrial robots. An example of this is when users switch from auto mode to manual mode to perform teaching—operation will be forced to manual low-speed mode. The dedicated controller software has been updated to ensure that the movement speed of the linear actuator is 250 mm/s or less as specified in the safety standards.

As i-WRIST™ is a module product (embedded system) that forms part of automation equipment, users or system integrators are expected to install appropriate safety and protective devices stipulated in ISO10218.

4.4 External Interface

The IWS Series helps to boost convenience and versatility with greater support for external interfaces.

The external interface of the previous i-WRIST™ only included a parallel input/output (I/O) for connecting with the user's controller. Operating patterns created in advance via teaching using the dedicated console can be specified with I/O signals from the user's controller, which provides compatibility with sequential control that issues commands to begin automated operation. The I/O provides faster communication speeds than serial communications such as "Ethernet" and other industry networking protocols and enables control using relatively simple signals, a feature that has always been highly regarded by users.

In addition to the existing I/O, the IWS Series also includes "Ethernet" to significantly increase the amount of possible data communications such as connecting to user controllers from multiple FA equipment manufacturers. This means point data (coordinates) of operating patterns can be loaded and written to the dedicated controller from user's controllers to increase the flexibility of operating commands. For instance, after a workpiece is loaded onto visual inspection equipment and scanned with image processing, the coordinates and angles for approaching the workpiece can be changed before automatically starting inspection operations. Another practical example is completing visual inspections with a specific sequence of operating patterns, and then performing additional inspections at a desired coordinate or angle.

5. Summary

Since the development of the angle control equipment in 2012 based on the proprietary parallel link mechanism, **NTN** has been marketing it for greasing and cleaning applications. To take full advantage of its capabilities, i-WRIST™ was developed and started being mass-produced in 2018 for visual inspection applications. Feedback received after mass-production has now been included as standard specifications and developed as the IWS Series.

With further declines in the working population in the future, demand for automation is expected to grow even more for applications like visual inspections that had previously relied on manual work. In addition to visual inspection applications, **NTN** is also focusing more on development of robotic products that can help enhance automation and labor-saving technologies at worksites as well as increase productivity and quality as a way of contributing to society.

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Photo of authors (Representative)

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