High performance pick and place robot “picKstar”

Delta-type parallel link robots targeting the food, medical products, and cosmetics industries have in recent years been released in rapid succession, intensifying competition. This paper presents Kawasaki’s high-speed, high-rigidity pick and place robot “picKstar”, which offers superior performance compared to other competitor products.

Preface

Facility investment in the manufacturing sector was suppressed by the global economic recession of 2008, and the number of industrial robots installed declined sharply at automobile and semiconductor-related companies, which make up our main customer base. While the market has slowly recovered since 2009, we determined that new industries should be cultivated in addition to automobiles and semiconductors in order to generate a stable income not affected by economic fluctuations.

We turned our attention to solar power, which is attracting interest as a renewable energy, and to the food, medical, and cosmetics industries, where demand is solid and not easily affected by economic fluctuations. With a focus on pick and place operations, where automation is most in demand, we developed the proprietary delta-type parallel link picKstar robot (Fig. 1), which achieves the industry’s top performance for high speed and high reliability.

1 Characteristics

The three processes most representative of automated facilities for food, medical products, and cosmetics are the picking, packing, and palletizing operations (Fig. 2). We

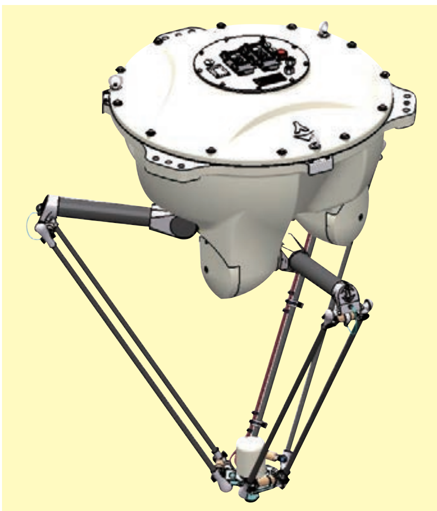


Fig. 1 picKstar

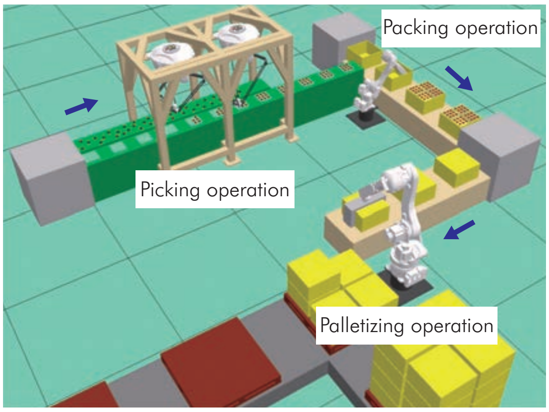


Fig. 2 Picking, packing and palletizing

developed picKstar for the picking process, which comes at the top of the three operations, and it features the following characteristics.

(1) High-speed performance

One major characteristic of the delta-type parallel link robot is the placement of the motor, reduction gear, and metal frame, etc., in the base area, and the use of lightweight CFRP (carbon fiber reinforced plastic) arms in the movable part, to achieve high-speed motion. However, since force applied to each of the robot's mechanical elements near the outer edge of the motion range increases by a greater proportion than in the center of the motion range, achieving high-speed motion over a wide range required that we both lighten the structural members of the movable part and ensure strength capable of handling loads at the outer edge. Therefore, we optimized in various combinations the motor power, drive system structure and strength, robot arm rigidity, elastic force of the spring unit, and strength of the mechanical parts at the end of the robot arms which move at high acceleration and deceleration rates, to achieve high-speed operation over a wide range.

(2) High rigidity

The second characteristic is high-speed operation. In general, high rigidity is required to maintain vibration damping while operating at high speeds. Therefore, we performed detailed studies into the types, direction, and laminated structure of fiber in CFRP used in the robot arm (Fig. 3), and ensured sufficient rigidity in the structural members of the moving parts other than the robot arms, thereby achieving levels of stopping performance and vibration damping unseen in this type of robots. As a result, we were able to reduce overshoot and vibration to enable highly reliable picking, earning high marks from customers in solar-cell-related wafer picking applications that require extremely high positioning accuracy and low vibration.

(a) Upper part of the arm

(b) Lower part of the arm

Fig. 3 CFRP arm

(3) Reliability against lubricant leaks

The markets where picKstar is utilized are industries handling solar cells, food, medical products, and cosmetics, etc., where lubricant leaks are not tolerated. Therefore, we have taken two main measures for picKstar's gearbox to achieve superior reliability in regards to lubricant leaks (Fig. 4).

(i) Internal pressure relief mechanism

When the robot performs continuous operations, the pressure inside the gearbox rises, increasing the risk of lubricant leaks from parts mating faces as well as rotating and sliding parts, etc. Therefore, we incorporated a mechanism into picKstar for relieving the rise of internal pressure, reducing the risk of lubricant leaks.

(ii) Double seal structure

The locations with the highest frequency of lubricant leaks are the rotating and sliding parts. We installed two layers of oil seals in these parts to reduce the risk of lubricant leaks.

(4) Tolerance to chemical washing

Since the robot is used for food, medical products, and cosmetics picking operations, we expect that it will be subjected to spray washing and chemical washing for sanitary requirements. For this reason, advanced sealing performance, and chemical tolerance for the exposed parts, are required. For sealing, we use a seal structure at the boundary between the robot interior and exterior to achieve IP67 waterproof and dust-proof protection, and also designed a curved frame structure for the robot exterior that leaves few bumps and protrusions for particles to become trapped in during washing. In addition, for chemical tolerance, we have designed the coating for the base section of the robot's main body and surface processing for the movable parts to give tolerance to the strongly alkaline sodium hydroxide cleaning agents commonly used in the industry for washing, and also to some weakly acidic cleaning agents.

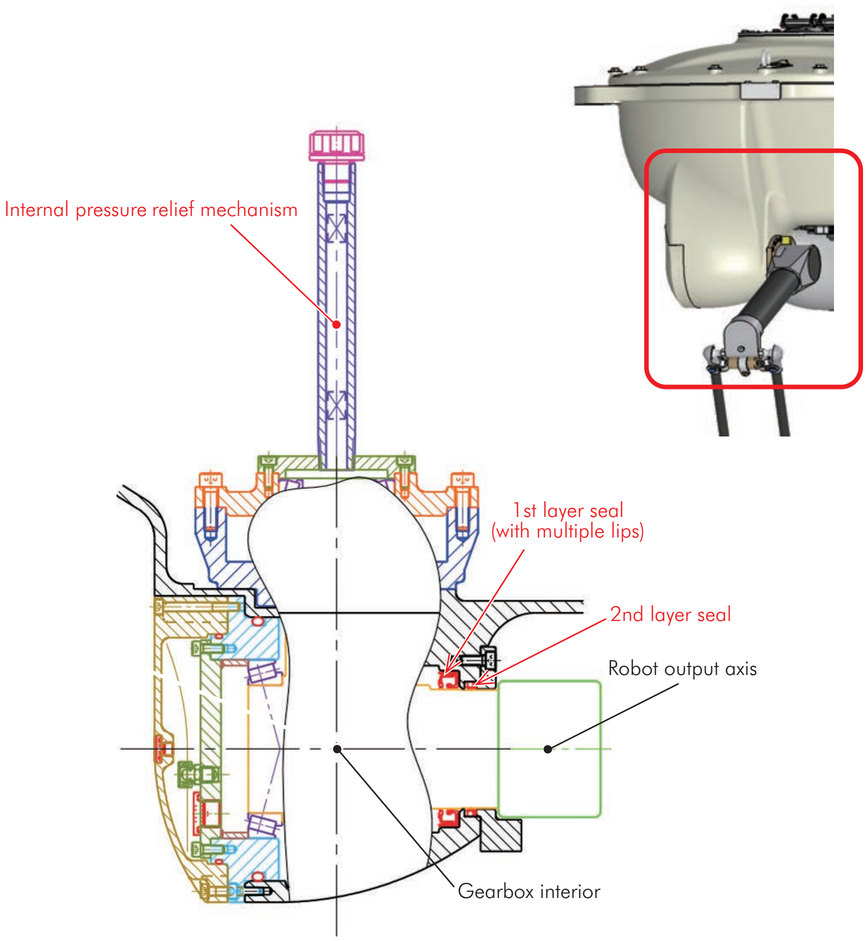


Fig. 4 Measures against lubricant leak (gearbox configuration diagram)

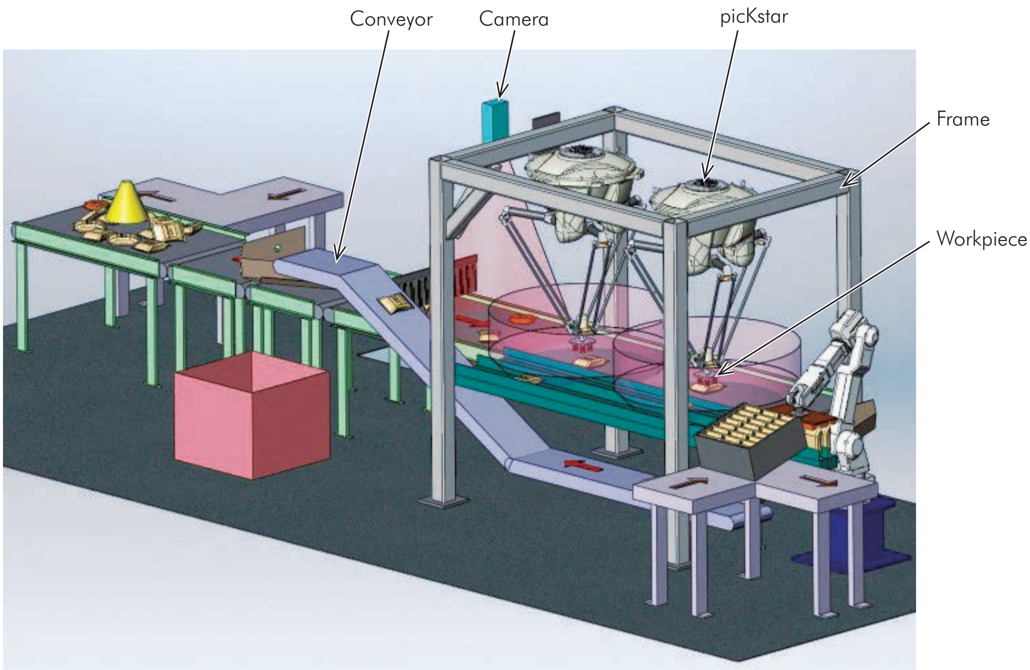


Fig. 5 System layout example of picKstar

2 System configuration

In this section, we introduce an example using an image processing system with multiple robots and conveyors. A system layout example using picKstar is shown in Fig. 5, and a system configuration example is shown in Fig. 6. The following discussion describes an image processing system and data management in a picKstar system configuration.

(1) Image processing system

The image processing system operates as follows.

① The target object (workpiece) to be processed is fed to the robot.

② An upstream camera detects the workpiece position and orientation, and transmits this information to the robot.

③ When the workpiece arrives, the robot picks it up and transfers it to the transport conveyor in the predetermined alignment.

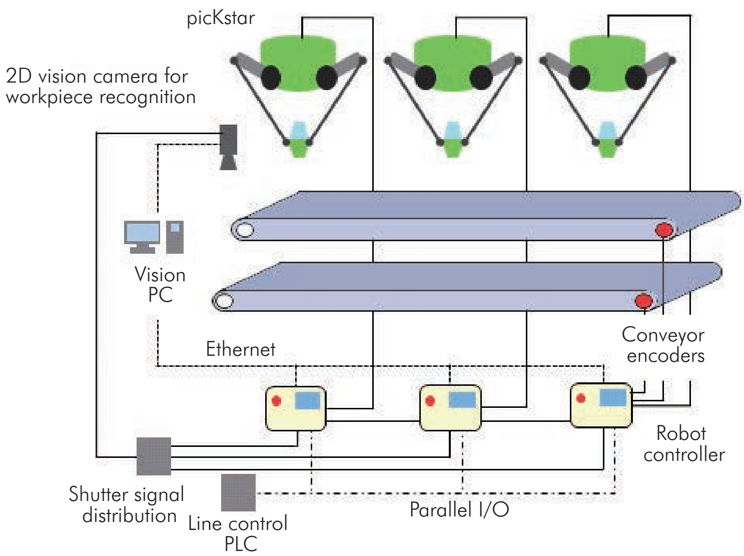


Fig. 6 System configuration example for image processing system

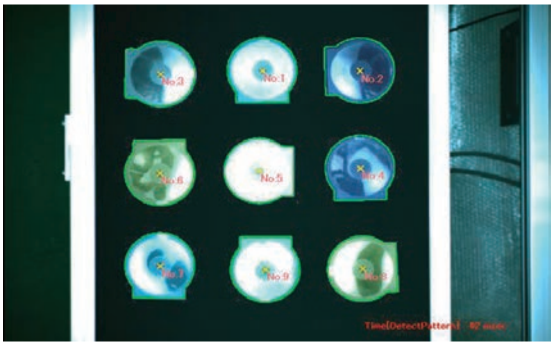


Fig. 7 Example of pattern matching screen

Fig. 8 Example of image binarization screen

④ An image recognition camera captures the image of the workpiece fed to the robot to discern its position and orientation.

At this time, if lens distortion correction is needed for the incorporated image, the distortion is corrected and detection is performed. The detection process can be performed with the following two methods.

① Pattern matching method, which uses edge information to recognize the workpiece against model registration (Fig. 7).
② Method using binary images to compare and detect area, circumference, and other characteristics (Fig. 8).

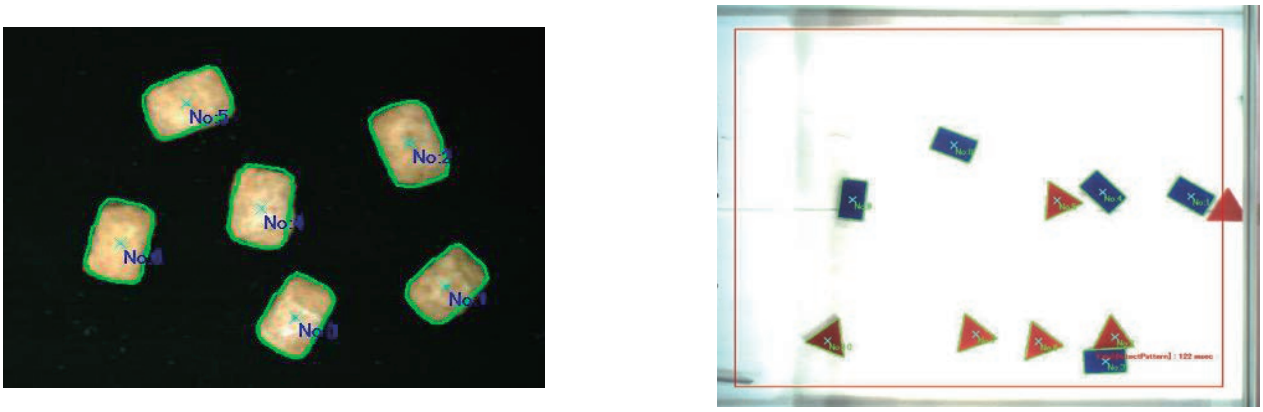
In some cases, these processes can also be used in tandem. New detection methods could also be added. The system also features an interference check function for checking for obstructions when the detected workpiece is removed by clasping, a color discrimination function, and a local shape detection function, etc. The workpiece information detected with these functions is converted into the robot's real coordinate system and sent as measurement results to the robot. The measurement results can be sent at the same time to multiple robots in accordance with specified distribution settings.

(2) Data management between robots

An external interface unit can be used to send between the robots such information as the placement patterns and the number of workpieces to be placed on the discharge conveyor. Moreover, even if one robot has stopped for some reason, the other robots can be used as backup for the operations of the stopped robot, enabling a flexible response to unexpected situations.

(3) Example of practical image recognition

As examples of actual applications of work image recognition, Fig. 9 shows processed images of frozen food items (deep-fried food) and plastic pieces with different shapes and colors. The system takes in the workpiece



(a) Frozen food items (binarization process)

(b) Plastic pieces (pattern matching)

Fig. 9 Example of work image recognition

Fig. 10 Example of gripper

image to recognize the shape of the workpiece, and then detect the center of gravity and orientation. Size discrimination is also possible, enabling operations such as sorting fed workpieces by size.

In addition, we have developed hands (grippers) that can be applied to various workpieces (Fig. 10), and we have earned high marks from customers for their performance as well.

Concluding remarks

Since commencing development of this robot and peripheral systems, we have obtained much technical knowledge through various application evaluations including projects involving actual customers. We intend to continue development toward satisfying potential customer needs, and to pursue further performance improvements.

Tetsuya Nakanishi
Technology Planning Department,
Robot Division,
Precision Machinery Company

Youjirou Imai
Research and Development Department,
Robot Division,
Precision Machinery Company

Hisashi Moriyama
Research and Development Department,
Robot Division,
Precision Machinery Company

Kazuhiro Minami
FA System Department,
FA and Clean Group,
Robot Division,
Precision Machinery Company

Toshihiko Miyazaki
FA System Department,
FA and Clean Group,
Robot Division,
Precision Machinery Company

Jun Takebayashi
FA System Department,
FA and Clean Group,
Robot Division,
Precision Machinery Company

Seita Ohno
FA System Department,
FA and Clean Group,
Robot Division,
Precision Machinery Company