Machine parts assembly robot system

To reduce labor and maintain product quality at production plants, complicated assembly operations need to be automated. This paper describes our approaches to the development of elemental technologies toward realization of assembly robot systems. In addition, we present examples of in-house applications using these technologies.

Preface

In the industrial sector, introduction of robots to production lines to improve productivity has progressed steadily. In the welding and painting lines in particular, where robot automation has been actively pursued, there is an extremely large number of robots in operation. In recent years, moreover, efforts have begun to introduce robots into new areas where automation has been lagging. One of these new areas is automation of assembly operations.

Behind this demand for automation of assembly operations is the need for a response to multiple-item variable-volume production. The manufacturing industries in advanced countries produce a wide variety of products, including customization of standard products, in order to respond to wide-ranging customer needs. This trend has raised the skill and knowledge levels demanded for assembly operations, increasing the burden on operators. Moreover, and particularly in Japan, a declining labor force population due to fewer children and more seniors has made it more difficult to ensure a stable supply of operators and transfer of skills to younger workers. Use of robots to automate assembly operations is expected to provide a possible solution to these issues.

In emerging countries, meanwhile, as represented by the BRICs, manufacturing has centered on mass production items, backed by a relatively low-cost labor force. In the future, however, as their local economies develop, they will be unable to avoid product diversification. When this happens, large costs will necessarily be incurred in manual operations and quality maintenance for each product. The introduction of robots will have major benefits since the automation of assembly processes will ease tooling changes and quality maintenance.

For these reasons, we can expect expansion of the market for automation of assembly operation using robots. But because assembly involves a combination of diverse operations, there are many difficulties to overcome in using robots. Therefore, robot manufacturers are engaged in research and development toward their practical application

We at Kawasaki also continue to be engaged in elemental technologies development centering on hand technologies for assembly that can enable diverse operations, with the goal of realizing an assembly robot

Fig. 1 Chebyshev linkage hand

system. In addition, as a result of these efforts, we have achieved automation of assembly operations at our own plants. In this paper, we present the elemental technologies related to our assembly robot system, and show some application examples in our production lines.

1 Issues of assembly automation using robots

If the basic operations are simple in nature, such as welding or painting, etc., robots often demonstrate abilities superior to those of humans. In many cases, however, the assembly process consists of multiple operations. In such cases, what would be easy for a human often is difficult for a robot, or involves excessive costs to realize.

A summary of the issues for assembly automation using robots can be divided broadly into the three areas listed below.

① Acquisition of dexterity
② Acquisition of flexibility
③ Acquisition of accuracy

We here introduce the elemental technologies that we have developed to address these issues and realize assembly robot systems.

2 Elemental technologies of assembly robot system

(1) Acquisition of dexterity—assembly hand technology

In the past, when robots handled multiple parts or performed multiple operations, the hand (gripper) needed to be replaced at each change of parts or operations. This means that as the number of targeted operations increases, the number of hands also increases, adversely affecting costs, footprint, and tact time.

To resolve this problem, we pursued development of universal servo hands that can be used for multiple parts and operations. We present a few of these here.

(i) Chebyshev linkage hand

Stroke size can be used as an index for evaluating hand dexterity. We developed the Chebyshev linkage hand, featuring a broad stroke (Fig. 1).

Use of the Chebyshev linkage for the hand mechanism* achieved a broad stroke compared to the compact hand body. This design enables parts of diverse sizes to be handled. Furthermore, the linkage joints are all composed of rotating joints that enable easy sealing and clean room applications. We also incorporated such general features of servo hands as strength adjustment of gripping force and measurement of open hand width.

* Chebyshev linkage mechanism: A linkage mechanism where a quasi-straight operation is obtained from a rotation operation.

(ii) Nail attachment

Even advanced-function servo hands cannot cover all kinds of diverse parts alone. Therefore, we developed a nail attachment to be mounted on the hand that enables handling a wider variety of parts (Fig. 2).

The nail attachment is automatically removed and attached by the robot on the existing finger part of the hand. We mount attachments with differing nail shapes in accordance with the size and shape of targeted parts, enabling handling of diverse parts.

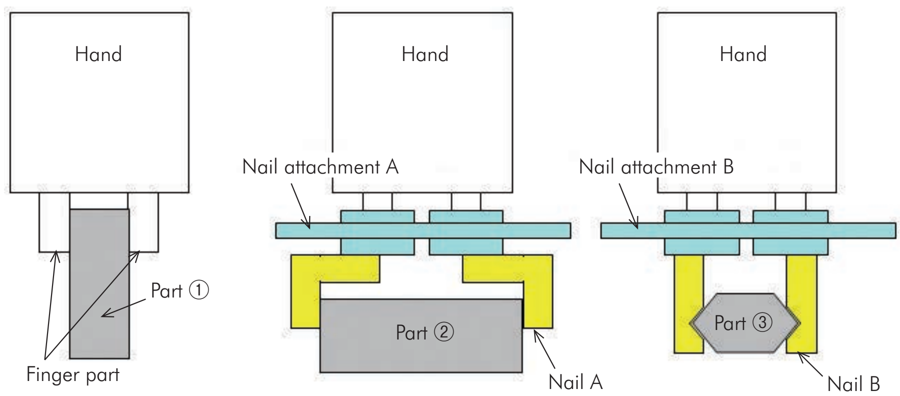

Fig. 2 Nail attachment

To fix the attachment in place, we use our own independently developed spring mechanism, and to drive the attachment, we use the existing hand actions. This eliminated the need for air or other additional drive sources, achieving lower costs and faster speeds than existing tool changers.

(2) Acquisition of flexibility—error absorption mechanism

In assembly operations, the robot often comes in contact with the products, or the hand presses against gripped parts. When this happens, even a slight error in assembly position can impose a heavy load on the robot. Therefore, in applying robots to assembly operations, various methods for controlling the pressing force have been adopted, such as use of a force sensor or a compliance device giving flexibility to the hand tips.

However, force sensors are expensive and have a risk of breaking down in assembly operation collisions. Also, compliance devices have the drawback of reduced positioning precision due to floating functions for tolerance of errors.

To address these issues, we independently developed our own compliance device, the error absorption mechanism.

(i) Error absorption mechanism

As shown in Fig. 3, the error absorption mechanism is mounted for use between the robot flange surface and the hand. When the error absorption mechanism is subjected to pressing, a floating effect activates in the hand and the error absorption function is exhibited. Furthermore, the force of a built-in spring enables operations for pressing parts gripped by the hand. This is effective for operations such as screw tightening that require contact between parts with suitable pressing force applied.

In addition, during normal times (when pressing is released), the floating effect remains inactive and the hand side is positioned in the center. This action enables high-accuracy operations for parts picking.

(ii) Pressed state detection technology

When using the error absorption mechanism to perform assembly, we can detect the occurrence of pressing by measuring the amount of displacement. We here offer two examples of configurations for achieving this detection.

① Marker imaging method

As shown in Fig. 4(a), we position markers above and below the error absorption mechanism and use a vision sensor to capture their image. Then, we compare the distance between the two markers before and after pressing to measure the displacement.

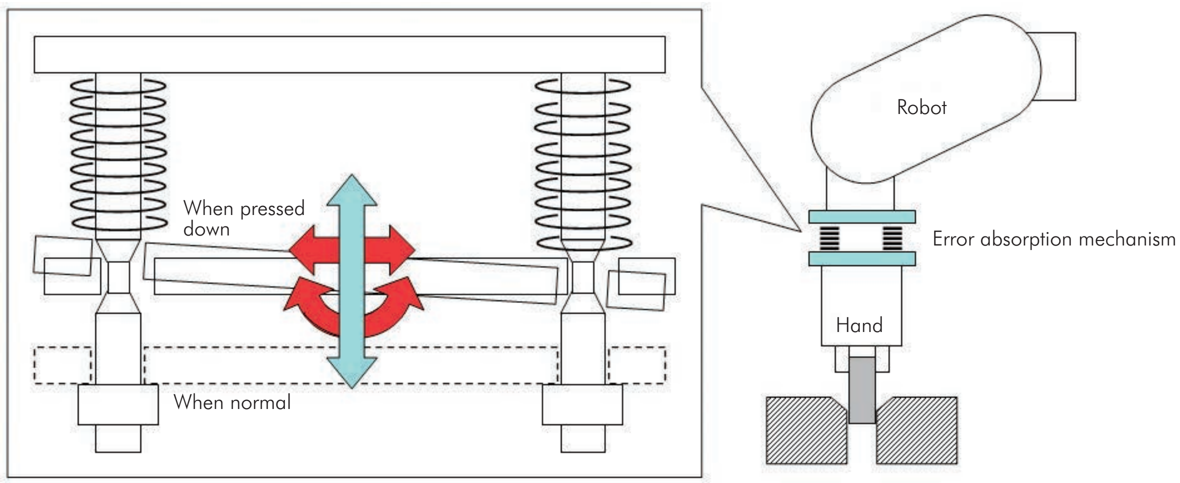

Fig. 3 Error absorption mechanism

② Touch (distance) sensor method

A touch sensor is built into the error absorption mechanism to detect the occurrence of displacement due to pressing.

Since the marker imaging method does not require a sensor on the robot side, we can build a more reliable system. The touch sensor method involves the placement of multiple sensors that enable the estimation of tilt.

This technology lets us determine whether parts have been successfully assembled or not. For example, as shown in Fig. 4(c), if a large displacement has been measured in the course of a parts insertion operation, we can conclude that parts have interfered with each other and the operation has failed. Using these detection results, we can respond with retries of the assembly, etc.

In addition, in assembly of gearwheels involving gear engagement, we can perform such advanced operations as searching for the gear engagement phase with the parts in a pressed state, and judging success by the release of error absorption mechanism pressing.

(3) Acquisition of accuracy—vision sensor technology

One effect expected of automation of assembly operations is implementation of uniform and accurate operations that humans have difficulty performing, to eliminate careless errors and maintain product quality. However, this issue cannot be resolved solely by the installation of robots; coordination with sensors is also essential.

We have long been engaged in the development of vision sensors for robots and have applied them to many production sites. Here, we present an example of vision sensor technology applied to assembly robot systems.

(i) Position detection technology

To ensure performance of accurate assembly operations by robots, the position of the parts to be assembled must be determined to high precision. If the parts size or shape is fixed, then the simplest method is to install tools capable of mechanical positioning. However, with greater diversification of customer needs, the production site increasingly needs to produce diverse products. In such cases, provision of special tools for each part can lead to massive cost increases.

To address these issues, we applied a vision system to the assembly robot system for performing parts position recognition. These are installed on general-use pallets to perform visual recognition of the characteristics of supplied parts and measure their positions. Based on the measured position information, the robot can correct the parts assembly position.

This action achieves accurate assembly operations without the need for preparation of special tools for each product model, contributing to lower facilities costs.

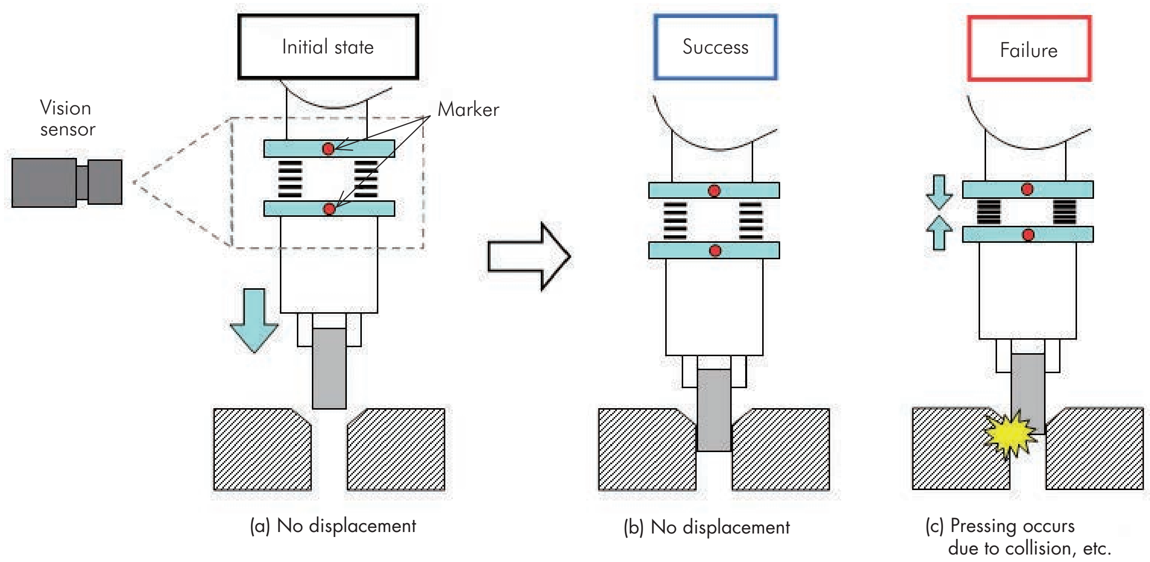

Fig. 4 Determination of assembly success or failure by error absorption mechanism

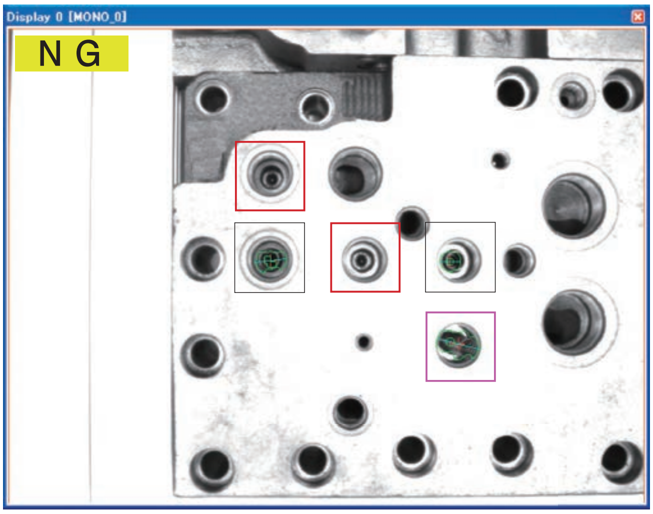

Fig. 5 Spring insertion condition check

(ii) Assembly error detection technology

In assembly operations, if a parts insertion omission or other error is overlooked, it can result in product defects that lead to major losses. For this reason, error detection technology is absolutely essential for automation of assembly operations.

To improve assembly reliability, we developed a system that uses visual recognition to detect the parts assembly condition. Fig. 5 shows a process of checking the condition of springs set into the product.

The position of an uninserted spring is framed in red in the figure. When such an error is detected, we can respond by either retrying the assembly or requesting the operator to make repairs.

In addition, a dropped part detection function can be mounted on the servo hand side as well, which together with visual recognition can improve reliability even more.

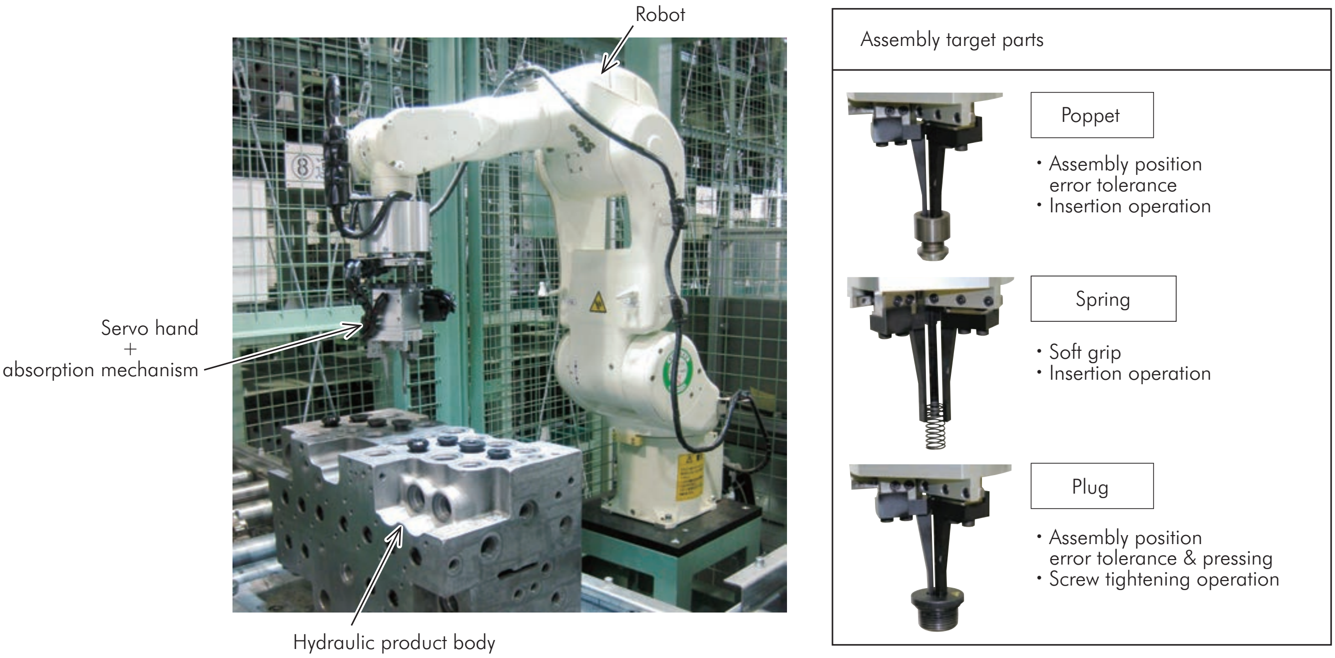

Fig. 6 Robotic assembly system for hydraulic product

3 In-house application example—hydraulic product assembly

Using the above-described elemental technologies for assembly robot systems, we are moving forward with the introduction of robots into various assembly operations inside and outside the company. Here, we introduce an assembly robot system that was installed on our own hydraulic product manufacturing line.

A system overview is shown in Fig. 6. In this system, the assembly targets are three parts—poppets, springs, and plugs (with screws)—with variation depending on the model. Operations include an insertion operation for poppets, with allowance for assembly position errors, a soft grip for springs that will not distort the workpiece, and bringing plugs into contact with the screw thread, with allowance for error, and performing a screw tightening operation. Use of the servo hand and error absorption mechanism achieves with a single tool what has previously required separate tools for each step.

In addition, we installed a vision sensor above the supplied product body to verify the product model and identify positioning deviations. The plugs need to be temporarily tightened by a certain amount to prevent thread seizing by the screw tightener used in the next process. Therefore, we use the vision system to manage the screw tightening amount, through measurement of the error absorption mechanism displacement.

Concluding remarks

With changing societal conditions in recent years, the range of robot applications is spreading from the relatively simple operations seen in the past to more complex operations that have previously been considered too difficult for automation. In this paper, we described the development of elemental technologies for assembly robot systems and presented in-house application examples.

We intend to continue research and development efforts into assembly robot systems, to respond to the increasing demands for automation of assembly operations.

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