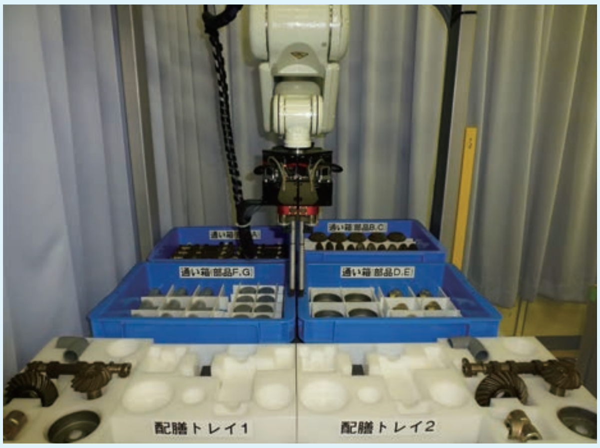
# Catering hand system for a high variety of workpieces




*We are promoting research and development into universal hand systems capable of handling a variety of workpieces as a core technology for expanding the scope of robot applications. In particular, we aim to realize robot-based automation of catering operations in assembly and outfitting processes, which has previously been considered difficult, through the use of universal hand technology and technology to integrate it as a system. This catering system is scheduled to be introduced and commissioned in our plants in FY2012.*

## Preface

In assembly plants for automobiles and other transportation machinery, or for machinery and devices mounted on such, catering is a process where robot application is lagging. Catering refers to an operation to collect the requisite number of part groups required for assembling a single device in a multi-item assembly line, arranging them on a tray, and supplying it to the assembly operator. This scene is shown in Fig. 1.

Compared with assembly operations that require touch, sight, and other advanced human intelligence, catering in many cases does not require so much proficiency. As a result, there has long been demand for the application of robots in this area of operation. In addition, with the recent mainstreaming of the multi-item line production method in manufacturing, demand for robots has grown still more to prevent catering mistakes due to careless human error. Even though human proficiency is not required, one factor behind the difficulty of using robots has been the failure to realize a robotic hand system suitable for catering.

To date, hands mounted on industrial robots have mainly been the air chucking type, air suction type, and electromagnetic type, etc. These types all require different claw shapes and air pressure adjustment for each part type, making them unsuitable for catering, which demands handling of a variety of type of parts.

The following solutions have been proposed for handling multiple types of parts.

① Enable exchange of hands.
② Attach multiple hands.
③ Install a universal function in the hand.


Fig. 1 View of catering operations

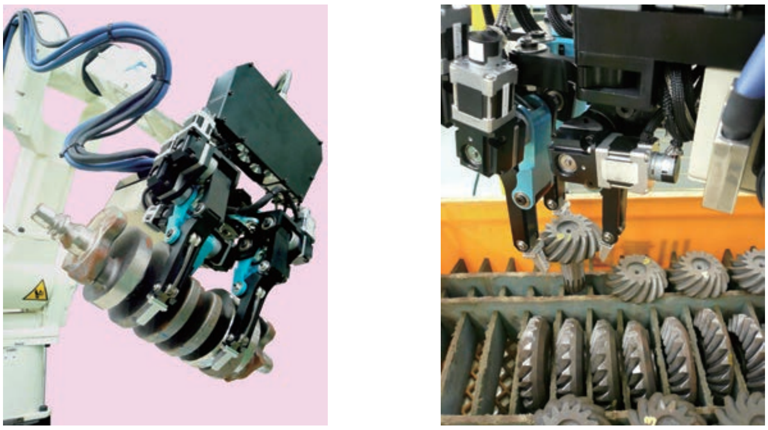


Fig. 2  Ealier version of the humanoid hand (2007)

Method ① is effective for cases where the number of part types is limited.  At higher numbers, however, the increased system costs and cycle time delays can no longer be ignored.  Method ② has the problem of the hands interfering with the surroundings when attempting to pick up parts stored in cramped environments.  Method ③ has been the subject of active research and development efforts in both academia and industry.  However, because of problems with cost and reliability and difficulties with teaching, etc., it has not come into widespread use.  In recent years, however, examples of its practical use have gradually been increasing.

At Kawasaki, we commenced serious research and development into a universal hand for industrial use in the early 2000s, and displayed a prototype device for the first time outside the company at the International Robot Exhibition in 2007.  At the time, we modeled the robot hand after the structure and function of a human hand, to give it universality.  A partial view is shown in Fig. 2.  Later, we restricted the application to catering use, performed functional analysis, and developed a universal hand system specialized for catering.

## 1 Issues toward realization of catering hand

An example showing parts to be catered for a motorcycle production line and their storage environment is shown in Fig. 3.

The characteristics are as summarized below.

① The part types (size, shape, material) are highly variable.

② Parts are collected and packed into storage boxes, and partitioned by frames, etc.

③ Within the partitioned spaces, the parts are loaded in random positions and orientations.

While the previous humanoid universal hand could

Fig. 3  Example of workpieces catered at a motorcycle plant

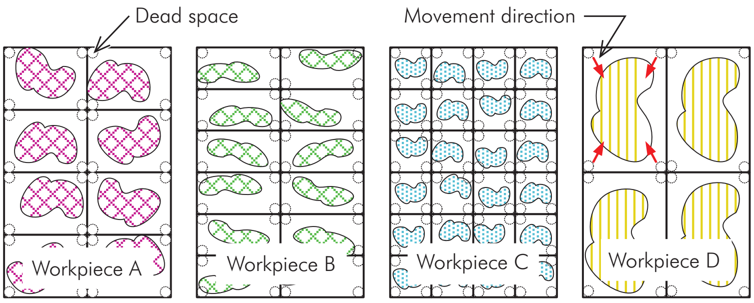



Fig. 4 Analysis of workpiece storage situation

respond well to ①, it was incapable of responding to ②. For the humanoid universal hand, with its freedom of fingertip bending, the finger joints became thicker so that the claws could not be inserted into the narrow gap between the partitions and the workpiece. In addition, one method for responding to ③ is to use a vision sensor to measure the variability in parts position and orientation, and then correct the position of the claw insertion. In this case, a camera must either be installed in each parts storage box or be mounted on the hand. The former would require a large number of cameras and, to ensure a field of view for the camera, the storage boxes would need to be placed in a larger environment. The latter, on the other hand, would necessitate a wait time in the robot operation to allow for measurement of the variability.

## 2 Development of 4-claw catering hand

### (1) Policy studies toward issue resolution

While the type of catered parts and the storage environments vary, two common points as listed below can be found.

① The partitioned spaces are square.

② Beveling has been performed on parts corners.

In other words, parts of whatever shape, no matter how they are placed, will always result in a dead space in the four corners of the partitioned space (Fig. 4).

If we insert claws into the respective dead spaces, and move them horizontally toward the center, the parts will be moved toward the center and finally fixed in place. In other words, regardless of the parts shape or the random positions, we can complete handling with the same simple operations sequence. In addition, since handling is performed with four claws, a form closure (objects are fixed in place by point contact with surroundings with zero friction force) can easily be formed on the horizontal surface, so that parts can be securely fixed even with thin claws and weak gripping force.

From the above analysis, it appears that a configuration consisting of four claws is suitable as the basic form for a catering hand. Moreover, two degrees of freedom are needed for adjusting the vertical pitch and horizontal pitch of the four claws. For complex-shape parts, in bringing all four claws into contact it appears that four or more degrees of freedom for the hand are favorable.

### (2) Hand characteristics

(i) Main functions and specifications

Based on this policy, the main specifications for the developed hand are shown in Table 1, and the configuration diagram is shown in Fig. 5.

Table 1 Main Specifications

| | |
|---|---|
| Horizontal stroke (mm) | 160 |
| Vertical stroke (mm) | 60 |
| Fingertip strength (N) | 100 or more |
| Open/close time (s) | 0.3 |
| External dimensions (mm) | W160×D190×H115 |
| Weight (kg) | 3.5 |

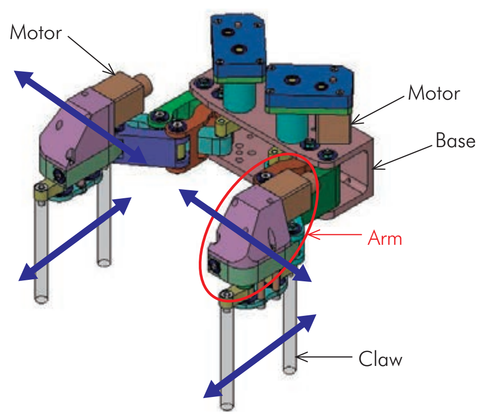



Fig. 5 Hand

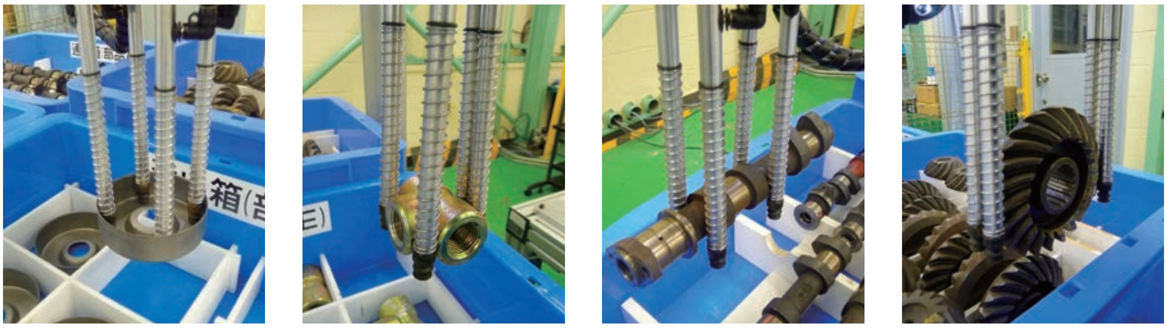


Fig. 6  Picking parts of different shapes

The hand employs a mechanism with four degrees of freedom mounting four servomotors, enabling independent control of the operations shown by arrows in the figure. Therefore, the claw's vertical pitch and horizontal pitch can be adjusted to match the size of the square partition space. In addition, if the claw's vertical pitch is closed all the way, we can change the hand to a 3-claw hand or 2-claw hand. A torque control function on the servomotors can be used to easily adjust the gripping force, enabling internal gripping and external gripping. As a result, parts of various shapes and hardness can easily be picked up from within narrow partitioned spaces (Fig. 6).

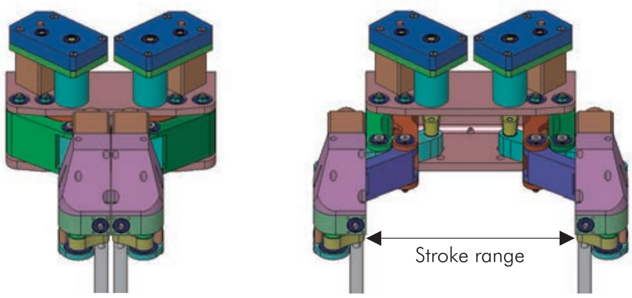
(ii) About the structure

The hand consists of a base, two arms, four claws, and four motors. The two arms are attached to the base, and the motors drive the arms in a horizontal direction. In addition, a motor and two claws are mounted on each arm. This motor drives the top claws in an arc in the opposite direction with each other.

The two arms use our unique Chebyshev linkage finger mechanism*. As a result, we can ensure a powerful gripping stroke with a compact base size, enabling gripping of parts of various sizes even in cramped environments. When a ball screw, etc., is used to design the hand, the stroke is normally restricted to half the base size or less. In our hand, however, the stroke is almost the same as the base size (Fig. 7).

In addition, the height of the structure is kept low to enable entry into shelves where the parts storage boxes are placed (Fig. 8).

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




(a) Fully closed position (b) Fully open position

Fig. 7  Arm stroke

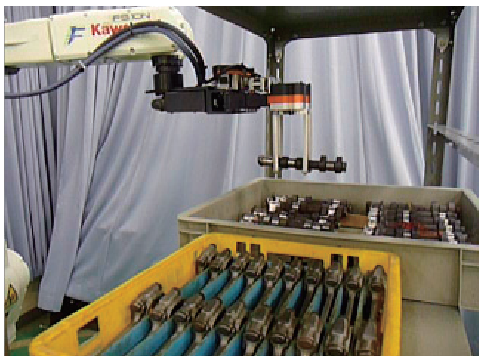


Fig. 8  Entry into shelves

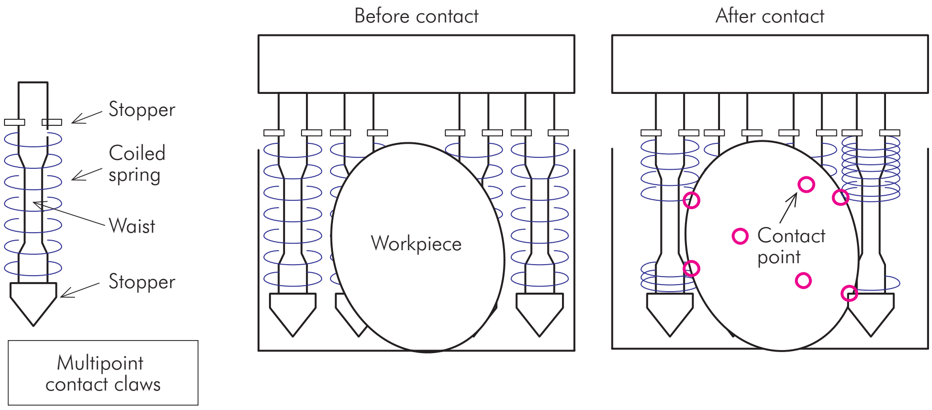



Fig. 9  Structure and function of multipoint contact claws

(iii) Stabilization of vertical direction
While incorporating four claws ensures stable gripping of workpieces in the horizontal direction, gripping in the vertical direction is obtained through friction with the claws alone.

To ensure a stable holding of the workpiece in the vertical direction without relying on friction, we developed a multipoint contact claw configured with a waisted shaft sheathed in a coiled spring. When this claw contacts the workpiece and further force is applied, the coil spring is distorted up or down, moving away from the workpiece and increasing the contact points. In other words, horizontal movement of the claws alone forms a 3D form closure and a stable state (Fig. 9).

Since the multipoint contact claw is configured with a simple structure using a general-purpose coil spring, we have avoided a larger claw diameter to enable insertion into narrow gaps.

(iv) Suction function
For handling plastic materials or other such parts where gripping could scratch the surface, we have enabled air suction holding in addition to the normal gripping. In other words, we created a hollow structure in the claws and attached air suction pads onto the tips. In addition, to avoid drooping or snagging in the air piping when the arm or claw moves, we have installed guide holes inside the arm to enable compact piping.

If the parts are light, two or four items may be picked up at the same time, enabling reduction in the cycle time for catering operations (Fig. 10).

**(3) System configuration**
The controller for governing the hand movement is encased separately from the robot controller, and they communicate directly with each other via an RS232C cable.

Fig. 10  Holding by suction

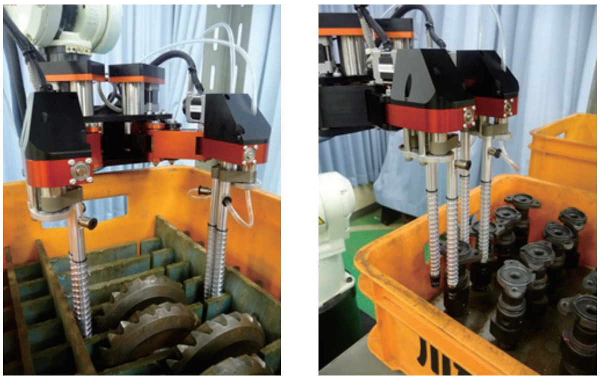


Fig. 11  Catering tests

The robot controller queries the hand controller at specified intervals regarding the motor position and torque and other statuses (normal/abnormal, servo on/off, etc.), and the hand controller responds. The robot controller uses this information to continuously monitor the hand, and sends various operations commands to the hand controller according to the robot operations program. Operations commands include a jog feed from the current position, jumping to the teaching position, gripping based on a set force, and origin point setting, etc.

In addition, as a useful tool for increasing efficiency during teaching operations, we enabled various hand operations as well as status monitoring on the robot teaching pendant screen. Furthermore, we have a direct teaching function where manual force can be used to directly adjust the pitch between claws or pressing force in relation to actual parts or storage boxes.

So while the hand system that we have developed is a multi-axis system, it does not require special training on the part of the user, and enables intuitive and easy operation.

## 3 Application study example

For the seven types of machine parts catered to our motorcycle plant, we performed an application study using actual storage boxes. We verified that the catering operation could be performed for all the parts without the need to exchange the claw shapes (Fig. 11).

Doctor of Engineering
Professional Engineer (Mechanical Engineering)
**Masayuki Kamon**
Control System Department,
System Technology Development Center,
Corporate Technology Division

**Yuuki Takayama**
Control System Department,
System Technology Development Center,
Corporate Technology Division

Doctor of Engineering
**Tetsuya Kubota**
Control System Department,
System Technology Development Center,
Corporate Technology Division

**Yoshitaka Seta**
Kawasaki Robotics (Tianjin) Co., Ltd.

## Concluding remarks

With the advances in recent years of robot-related equipment technologies, operations where robots can act in place of humans have steadily increased. However, as with the catering operation, even light operations that at first glance appear to be simple with no skill requirements can require advanced sensor systems or large-scale peripheral equipment when a manual labor operation is entirely converted to robot operation, and in many cases the cost benefit is lost.

To solve these issues, Kawasaki has adopted an approach of translating manual labor operations into the perspective of robot operations. For example, we translated catering operation as “an operation for picking undefined items from square partitions,” which is an interpretation that can be easily applied to robot operations, and then we pursued a simple yet versatile device that can perform the operations.

There is increasing demand to apply robots for operations requiring human manual skills and environmental recognition functions based on the five senses. We intend to continue providing the best solutions for operations where robots are in need, based on a knowledge of what they are capable of.