Ultra-high Payload, High Rigidity Robot MG10HL and Its Use in Production of Airplane Parts

As the global population increases and developing economies expand, the demand for airplanes are expected to increase. However, the majority of their production is still carried out manually and thus, it is required to promote automatization in order to strengthen productivity. In these circumstances, we are working on introducing MG10HL in the production of large airplane panels in order to increase production efficiency to meet the increasing demand and reduce production costs by using automated robots.

Introduction

As the global population increases and developing economies such as those in Asia, South America or Africa expand, it is expected that there will be a demand for nearly 40,000 new airplanes over the next 20 years. On the other hand, however, the majority of airplane production work is still carried out manually, and the productivity necessary for satisfying the future increase in demand has not been secured at this point.

1 Background

Hopes are high for production automation using robots as a means to support the increased demand for airplanes. Robotization will bring various benefits such as improved production efficiency, reduced production costs, stable product quality, and reduced production space.

2 Issues facing the production of airplane parts using robots

The sizes of airplane parts run the gamut from small to large. Automation is limited with only some of the production of large parts being automated by large specialized machines. In order to realize automation using robots, it is necessary for robots to have a large operating range, as well as a payload that can withstand the weight of the work tools and the force generated.

On the other hand, while large robots have a large operating range, their absolute positioning accuracy is difficult to improve as they have large deflections at their movable parts, a result of combining link mechanisms. In addition, in order to improve absolute accuracy, it is also necessary to improve the setting accuracy of equipment or parts other than the robots themselves, such as the transportation systems, which narrows down the selection range for the robot systems.

To address these issues, it is most reasonable to improve the hardware rigidity of the robot arm, while compensating for component errors or deflection in movable parts by using software to improve the spatial position repeatability accuracy and providing a mechanism for correcting the relative positional relationship with the workpiece.

3 Airplane part production by the MG10HL ultra-high payload, high rigidity robot

In the production of large fuselage panels for airplanes, robots are required to have a broad range of motion that enables them to access the entire panel, which has a height of 3 m, high positioning accuracy that enables them to accurately move to the correct machining area, and high rigidity that enables them to maintain their position when a machining reaction force is generated, as well as a load capacity that can withstand the generated machining reaction force. In the FSJ (Friction Spot Joining) system using opposing robots suggested by Kawasaki as a new

† An arm with a unique structure, employing a hybrid link and ball screw drive. It simultaneously achieves a payload of 1 to 1.5 t without a counterweight and reduced body weight.

panel joining method, a large machining reaction force of over 10 kN is generated. Our MG10HL ultra-high payload, high rigidity robot can withstand this force.

(1) High rigidity hardware

The structure and operating range of the MG10HL are shown in **Fig. 1** and **Fig. 2**. The MG10HL needs to have a payload of 1,000 kg, a reaction force resistance of 15 kN, and rigidity that minimizes deflection when a reactive force is generated. To realize these properties, we used high rigidity ball screws in the second and third axes, which have a large effect on deflection, in combination with our unique fixed parallel link structure to simultaneously achieve an operation range and rigidity that accommodates large panels. Compared to the differential reduction gear that is usually used in large-sized robots, the ball screws in the linear motion mechanism make the joint rigidity of the second and third axes approximately twice as great. Meanwhile, we have realized the industry's smallest size and lightest weight by eliminating the counterweight.

Moreover, we have also reduced the cost while realizing a high payload by applying dual control using two

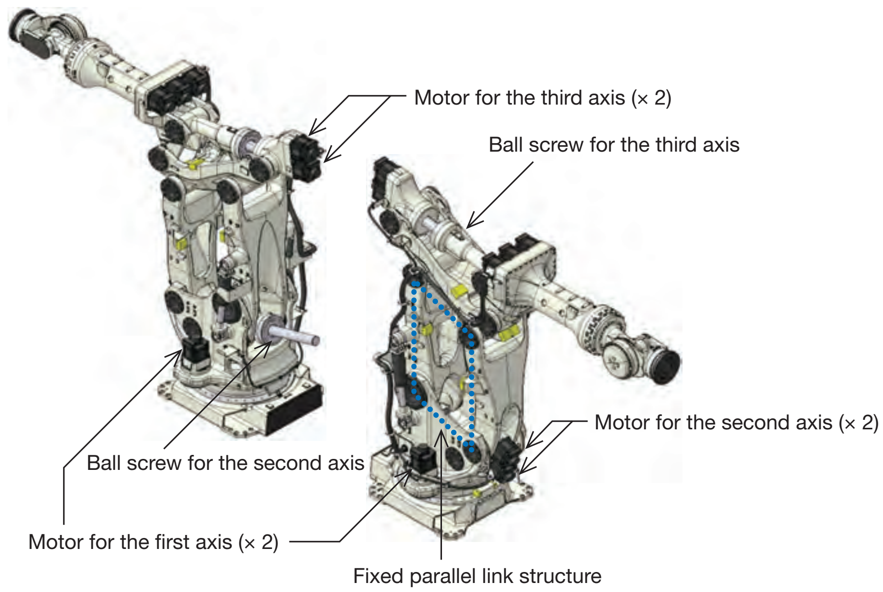

Fig. 1 Structure of MG10HL

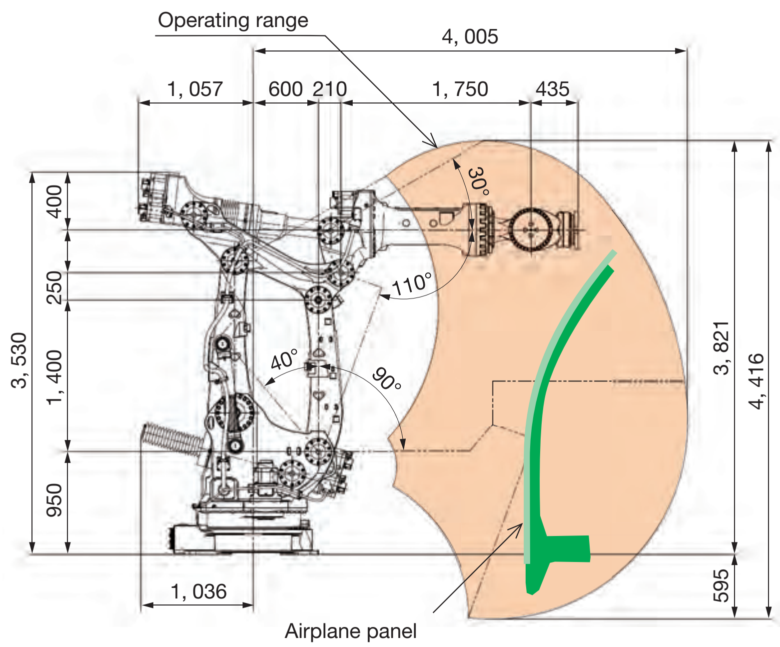

Fig. 2 Operating range of MG10HL

of the standard motors used in our other robots to the first, second and third axes. The same maintainability as that of our previous robots is also ensured with the MG10HL.

(2) Improvement of absolute accuracy using software

Although the MG10HL has a highly rigid arm structure, deflection occurs due to tools or its own weight. Due to this deflection and dimensional errors of parts or assembly errors, deviation from the ideal position occurs. The ideal position refers to the spatial coordinates specified by offline teaching, and the accuracy with respect to this position is what is known as absolute accuracy. We provide a position and deflection compensation function using software for improving the absolute accuracy. The part dimensions and spring constants of the joint and arm are identified by measuring the end position of the robot wrist in several postures and calculating the difference from the ideal position for each robot. Using the identified value, positional compensation is performed as shown in **Fig. 3**. Using this absolute position compensation function, the MG10HL has achieved a high repeatability accuracy of ±0.7 mm with respect to the ideal position within its normal operating range.

4 Case example of applications to airplane part production

(1) Drilling holes in airplane panels

Components of an airplane panel are joined by rivets or other fasteners, and the main wings are connected by large diameter fasteners. In areas where rigidity is required such as at the bases of the main wings, large holes with a diameter of approximately 20 mm are drilled in a panel with a thickness of approximately 75 mm in some cases. When drilling such a large hole, a large reaction force is generated against the worker holding the drill. Therefore, automation of this process is desired.

A robot that drills large holes for assembling components with airplane panels is shown in **Fig. 4**. Although high repeatability accuracy is required in this

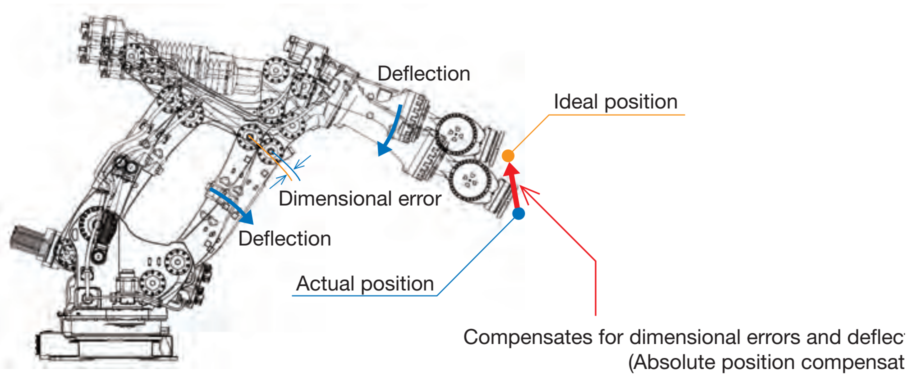

Fig. 3 Compensating for location and deflection

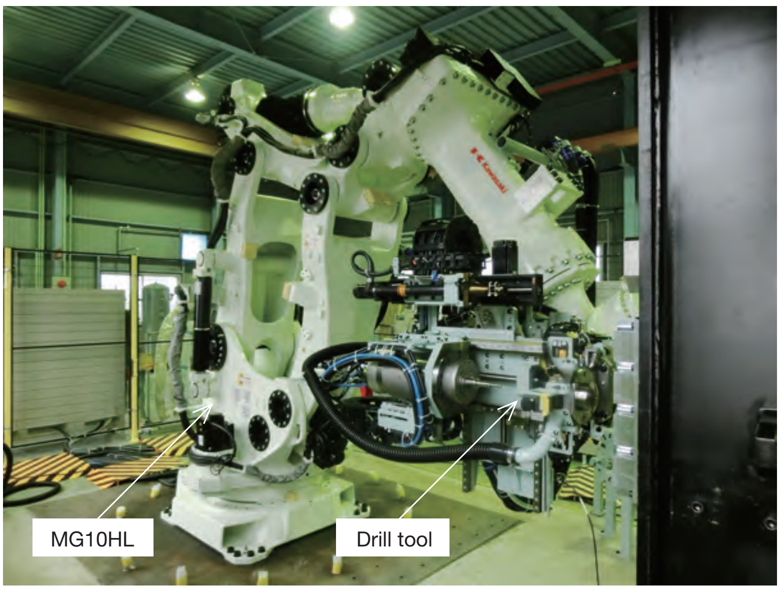

Fig. 4 Drilling robot

application, this is affected by the machining accuracy of the workpiece and the relative positional relationship between the robot and workpiece, as well as the repeatability accuracy of the robot itself. For this reason, the relative position accuracy for the workpiece is ensured by using position compensation technology with two types of sensors, as described below, in addition to the previously described absolute position compensation function.

① Hole position compensation by the two-dimensional sensor
First, the position of the base hole provided near the hole positions in advance is detected by the two-dimensional sensor mounted to the drill tool, as shown in **Fig. 5**. Next, based on the detected position of the base hole, the positions of the holes to be drilled are calculated. In this way, the accuracy of the hole positions with respect to the workpiece is ensured.

② Slip compensation by the force sensor
This function compensates for slipping of the drill tool that occurs when pressing the tool against the airplane panel. As shown in **Fig. 6**, the force sensor is mounted between the drill tool and the robot, and the force that causes the drill tool to slip generated by the pressing reaction force is detected. Based on the value of the force sensor, the robot is operated in the direction that cancels out the slipping to prevent displacement.

These compensation functions give the robot the required repeatability accuracy for drilling holes, as shown in **Fig. 7**.

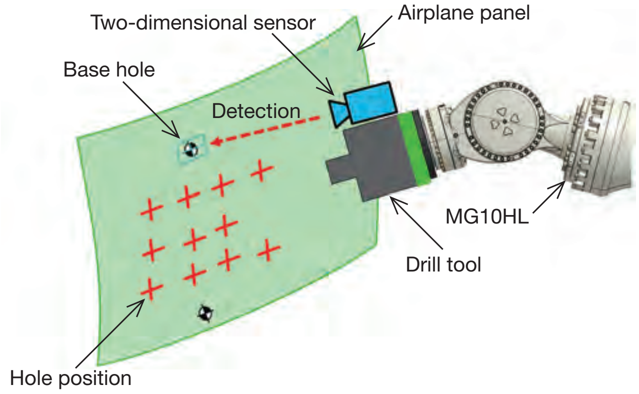

Fig. 5 Sensing base hole positions

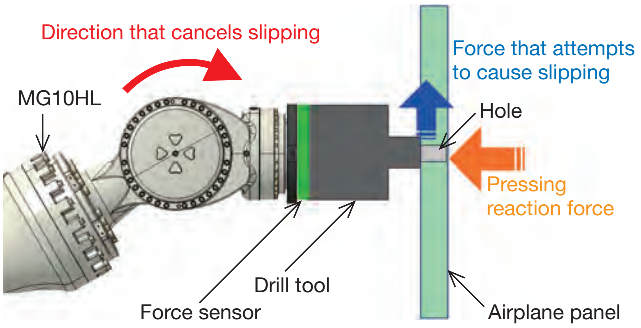

Fig. 6 Mechanism of slip compensation

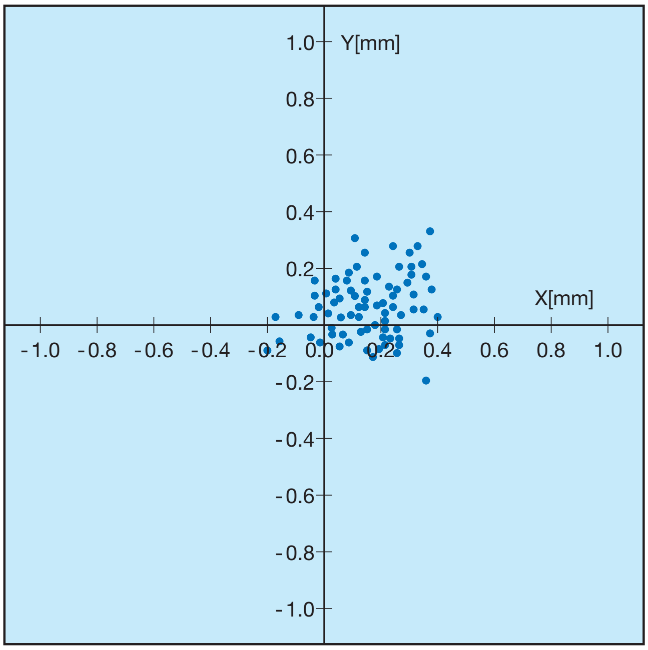

Fig. 7 Repeatability accuracy of positioning

(2) FSJ of airplane panels using opposing robots

As mentioned previously, components of airplane panels are joined using rivets. However, it is expected that the cost of airplane production can be significantly reduced in the future by replacing these rivets with the FSJ system developed by Kawasaki.

To implement it with robots, one robot holding a joining gun is placed on the interior side of the airplane panel, and another robot holding a backing anvil gun is placed on the exterior side of the airplane, as illustrated in **Fig. 8**. FSJ is performed by cooperatively operating these two opposing robots to sandwich the skin material and frame material between the joining gun and backing anvil gun from either side of the airplane panel. The joining gun and backing anvil gun press against each other with a pressure exceeding 10 kN while remaining completely perpendicular to the frame material. In addition, it is also required that axes of the two guns be centered to within 1 mm.

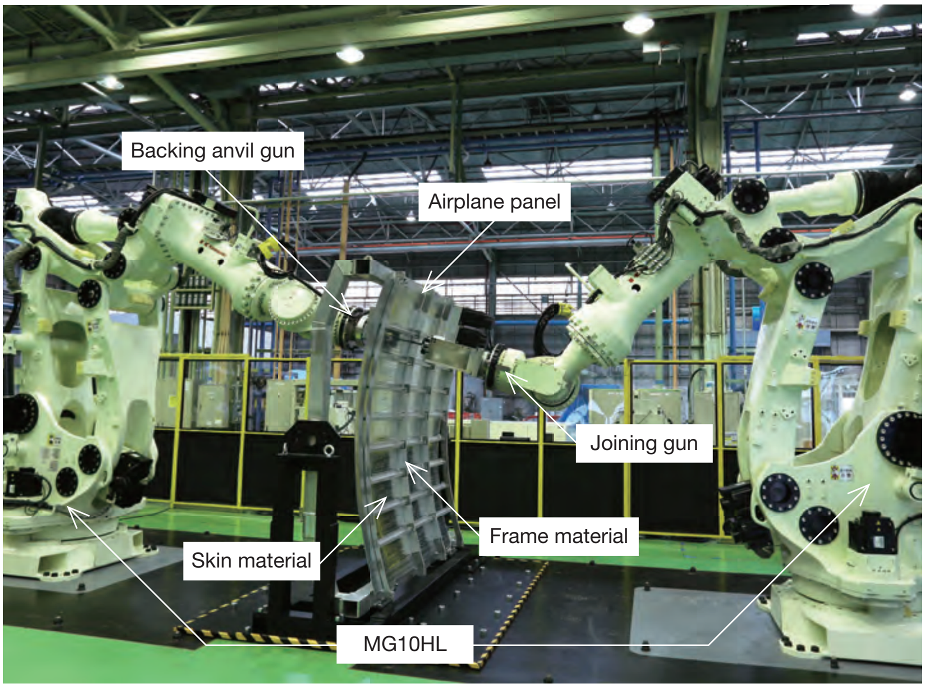

Fig. 8 FSJ System using opposed robots

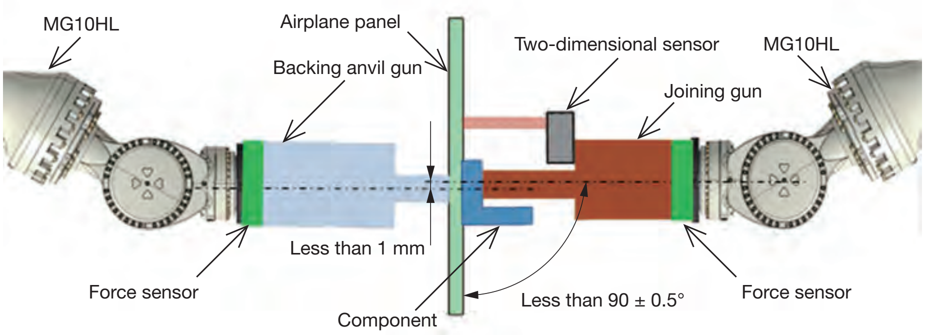

Fig. 9 Compensating for gradient of opposed robots

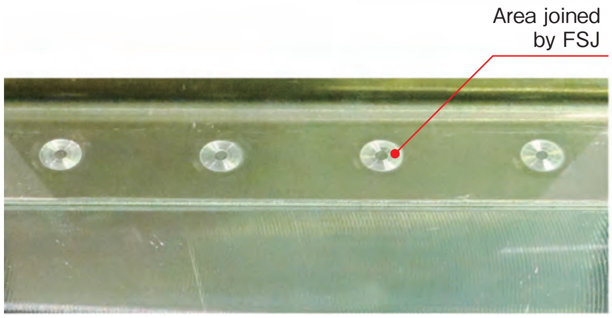

Fig. 10 Work sample of FSJ

To satisfy these requirements, position compensation is performed by two types of sensors described below, as in the case of drilling.

① Position compensation by the two-dimensional sensor
As shown in **Fig. 9**, the joining surface of the frame material is detected by the two-dimensional sensor, and perpendicularity compensation is performed so that the joining gun maintains the specified perpendicularity ± 0.5°.

② Slip compensation by the force sensor
Compensation is performed for slipping of the gun that occurs when it is pressed against the airplane panel during joining.

Figure 10 shows an area joined by FSJ on the inner face of an airplane panel. This joining system also achieves a panel outer face that is smooth enough for practical application, which contributes to improvement of the aerodynamic performance of the airplane.

Conclusion

Robotization has begun in the field of airplane production, a field in which it had not made progress before. We are a manufacturer that operates both an airplane business and robot business, and by integrating technologies that have been accumulated in each field, we will continue to promote automation of airplane production. Meanwhile, we will also apply new technologies produced through this integration to other fields such as the automobile field.

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