KJ series common platform type painting robots

Painting robots are used in a wide variety of industries including automobile manufacturers. This paper presents the KJ series painting robots, capable of being used in all types of painting applications, as well as painting system solutions we provide as a painting robot supplier.

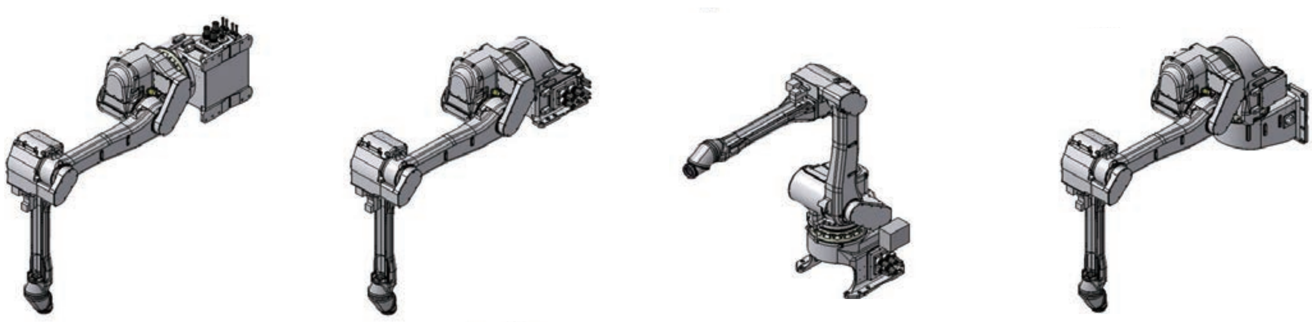
Preface

Painting robots are used in a wide variety of fields including the automobile industry. The robots are used for such purposes as reducing the manufacturing cost through manpower saving, relieving operators or workers from the so-called "3D" (dirty, dangerous, and demeaning) work, reducing manufacturing cost by reducing the usage of paint, and stabilizing painting quality. In addition, it is rare to use the painting robots standalone; they are normally used as a system in combination with a variety of equipment such as painting booth or painting equipment.

At Kawasaki, we are developing standalone robots and robot systems in response to the efforts and needs of the end users and painting-related manufacturers, while also pursuing development and improvement efforts from the standpoint unique to a robot manufacturer.

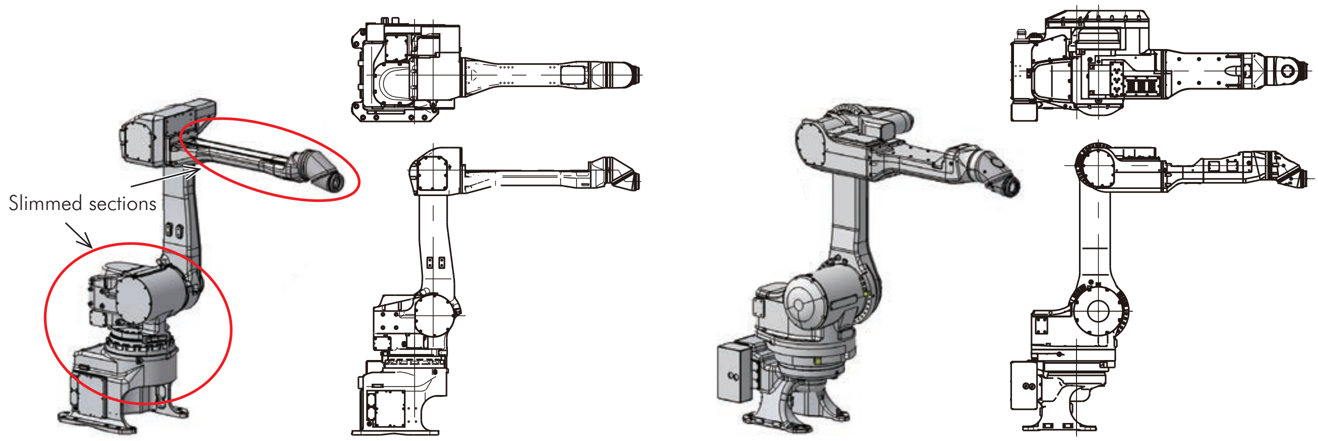
1 New KJ series painting robots

We are lining up the K series as explosion-proof painting robots that can be used in combustible gases including paint solvents. We have developed the KJ series as a line of common platform type painting robots designed to improve functionality and integrate existing models, with efforts to launch the KJ264 and KJ314 currently underway.



KJ264 (wall mounting) KJ264 (shelf mounting) KJ264 (floor mounting) KJ314

Fig. 1 KJ264 and KJ314



(a) KJ264 (floor mounting)

(b) Existing large model KG264

Fig. 2 Comparison of new model with existing models

Common platform type refers to the type compatible with various application conditions of the robot, and it is aimed at eliminating the necessity of model selection that used to be required depending on the usage condition. The KJ264 has only six axes as with existing models, but the KJ314 has seven axes including one axis newly added to the base section to widen its application range. Fig. 1 shows external views of the KJ264 and KJ314.

(1) Support for various installation conditions

Since the painting robot is used in combustible gases, it is used mainly in a dedicated booth. Also, in recent years, the trend has been for the robots to be installed on the wall of the booth or on the shelf inside the booth to make effective use of their motion range, and also to prevent the robots from getting dirty from paint blowing back. Existing robots are designed mainly to be installed on the floor (floor mounting), and when they need to be installed on the wall (wall mounting) of the booth, a cradle is added in the booth to make this possible. There have also been requests to install the robots on a shelf-shaped cradle (shelf mounting), which have been addressed by creating a special model for that. In contrast, as shown in Fig. 1, KJ264 can support all installation conditions just by changing the base section.

(2) Making the robot body slimmer and lighter

Demand for smaller painting booths is very high since a reduction of maintenance costs. A problem that may occur by reducing the size of the painting booth is the interference with the robot, but slimming of the robot body is one way to prevent the interference. Also, the wrist section and the upper arm section of the robot must be slim so that they can be inserted from the opened door of an automobile body to paint the inside of the door.

As such, the structure of the new KJ series painting robot was fully reexamined, and the robot was made to have the exterior slimmer than the existing models (Fig. 2). Since the existing KG264 robot for automobile painting is large, it is not suitable for interior painting. However, with the KJ series featuring a slimmer body, interior painting has now become possible with a large robot for automobile painting. Also, since the KJ series is now as slim as the medium-sized KF264, it can now be used for the general industries as well.

In addition to slimming the robot, the material of the robot structure was changed to aluminum from steel, achieving drastic reduction of weight from 800 kg or more (the weight of existing robots) to 550 kg. This reduction in weight produces various advantages. For example, it makes it easier to install the robot at an upper portion of the painting booth, and the booth structure can be built with less materials because the required strength of the booth wall can be reduced.

(3) Slimming by integral construction of the paint hose

The painting robot is used by attaching a painting device such as spray gun at the tip of its wrist, and tubes for supplying paint or thinner to the painting device have to be placed along the body of the robot. These tubes also cause interferences, so how to place these tubes along the robot also becomes an issue. To address this issue, a reducer having a hollow structure is used at the rotating axis in the base section, and in addition to the tubes, a harness for supplying the power and communication is passed through

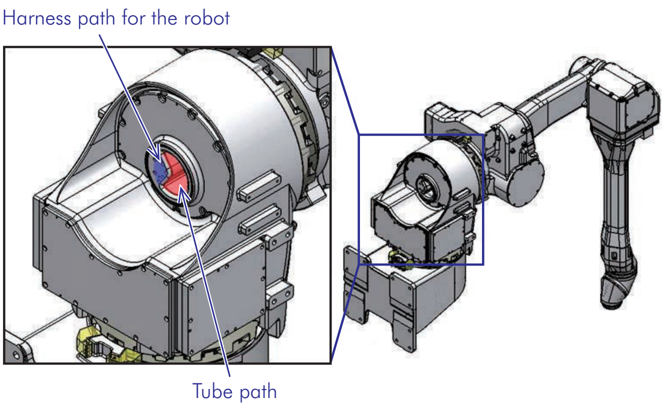


Fig. 3 Harness and tube path at the base section

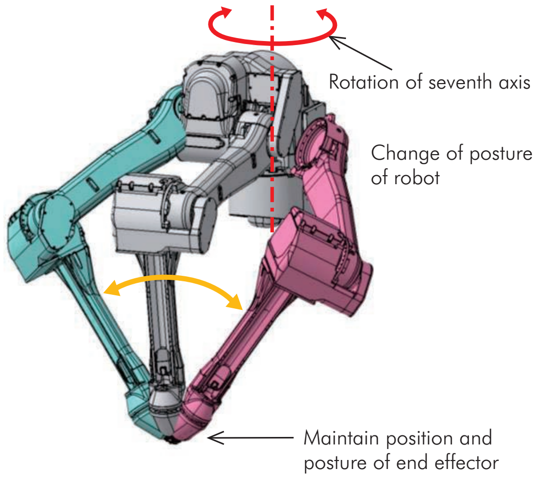


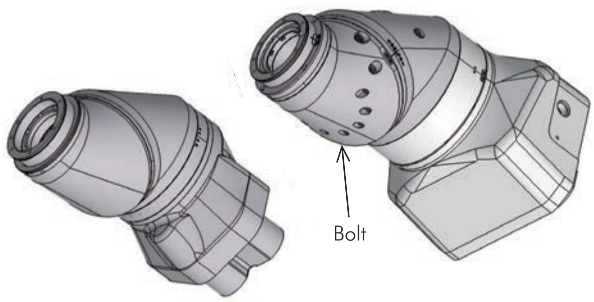
Fig. 4 Posture changes by seventh axis

the hollow part (Fig. 3). Such a hollow structure was also used with the existing models, but it was only possible to pass either the harness or the tubes, so it was getting in the way for slimming.

When the harness or tubes are passed through the center of the rotating axis, they will be twisted by the movement of the robot, so it is required to prevent damage by decreasing the amount of twist per unit length. Coexistence of harness and tubes was enabled by employing a structure that partially relieves the twisting force on the harness outside the hollow section.

(4) Space-saving with the seven-axis KJ314

To save the space while maintaining the range of movement of the robot, it is required to prevent the interference between the robots, interference between the robot and the object to be painted, and interference between the robot and the painting booth walls. Also, with the six-axis robot, the number of postures of the robot is limited to one when the position and posture of the end effector of the robot are specified with six degrees of freedom. This disables changing of the posture of the robot to clear the interference. Previously, space-saving was limited because of these problems, but it has now become possible to give a degree of freedom for changing the posture of the robot by adding a seventh axis (swing axis) as a redundant axis, enabling it to clear the interference (Fig. 4). It increases the cost to add the redundant axis, but by limiting the function by conditioning the seventh axis to be actuated only when changing the posture, the increase of the cost is minimized.



(a) KJ264 (floor mounting)

(b) Existing large model KG264

Fig. 5 Comparison of wrists of new and existing models

(5) Enhancement of cleanability by flattening of wrist

The wrist is the closest part to the painting device, and it easily gets dirty with the blow back of the paint. The object to be painted will be rendered defective if the paint attached to the wrist peels off and attaches to the object. Therefore, it is necessary to make the wrist hard to get dirty, and easy to clean. With the existing type of wrist, bolts are used on the surface of the wrist, making it easy for the paint to accumulate and hard to clean. By modifying the assembly procedure and placement of the bolts, the KJ series is structured using no bolts on the surface of the wrist (Fig. 5).

Fig. 6 Explosion-proof type teaching pendant

2 Robot controller

This section describes the features of the robot controller E25 used to control the KJ series, and new features added for the KJ series.

(1) Explosion-proof E controller

The new KJ series painting robot uses the cutting edge explosion-proof E controller E25 as its robot controller. The E25 has a teaching pendant with color LCD panel (Fig. 6), and in addition to performing various settings and monitoring the status of the robot using the LCD panel, it also can adjust the setting values for the painting device using the graph display. The program instructions and teaching operation procedure are compatible with the older version explosion-proof C controller, making it easy to replace with the older version controller.

(2) Swing axis control – using the world coordinate system

Normally, the guidance operation perpendicular to the robot is performed along the coordinate system referenced on the robot base section (base coordinate system), but the coordinate axis direction changes depending on the angle of the swing axis on the system with the swing axis. Therefore, the guidance operation in perpendicular direction is made possible using the fixed coordinate system with the rotation center of the swing axis (world coordinate system) instead of the base coordinate system (Fig. 7).

The coordinate value in the teaching data and the

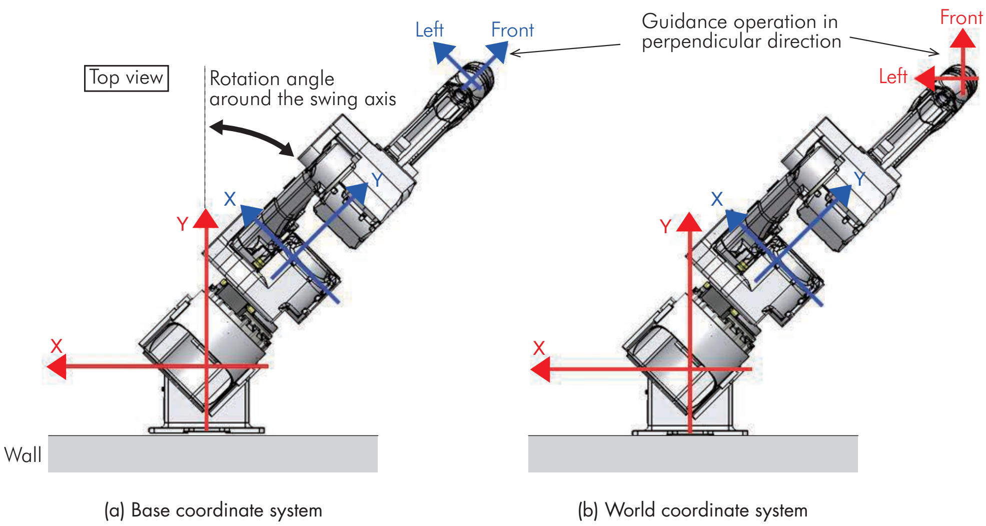


Fig. 7 Coordinate system for KJ314

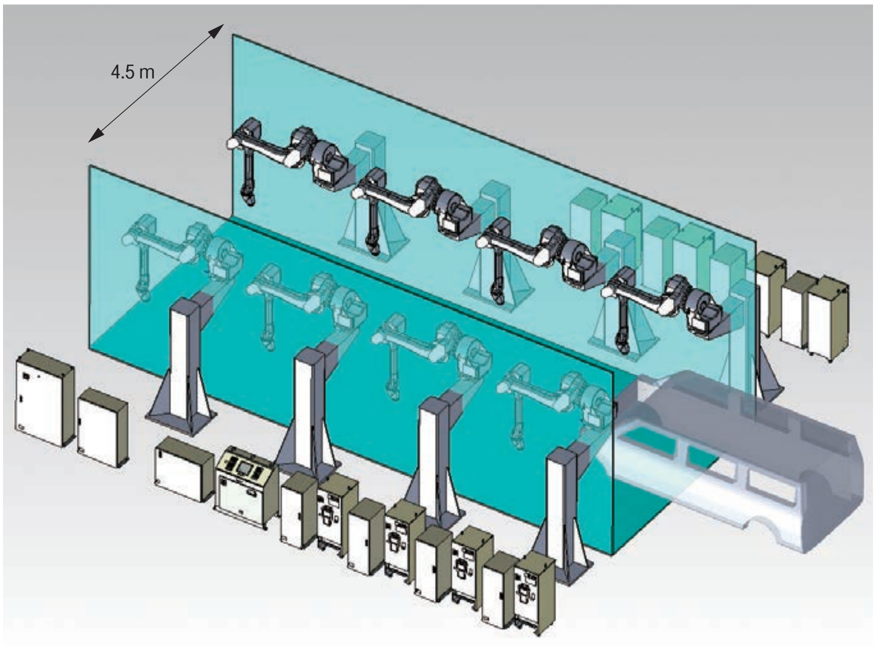


Fig. 8 Painting system for outer body of automobile

direction of the following operation to the conveyor are also set using the world coordinate system, eliminating the difference of operation due to existence of the swing axis.

(3) Variable acceleration and deceleration control – speeding up the posture change

The painting robot performs operation to change the posture drastically while almost keeping the tip of the tool stationary when switching the discharge direction of the paint. With this operation, it is necessary to perform the posture change as fast as possible within the tolerance of the motor torque for each axis. The KJ series determines the optimal acceleration and deceleration at the time of posture change by considering the posture of the operation start point and the end point using the improved variable acceleration and deceleration formula.

3 Painting system solution

(1) Painting system for outer body of automobile

With the painting for outer body of automobile, which is the most popular application for KJ series, it is becoming common to adopt the robots to reduce the usage of paint and improve painting quality. The floor-mounting type robots were used for painting the top side of the automobile body when the robots were first adopted, so a booth width of 6 m was required. However, in recent years, placing the wall-mounting or shelf-mounting type robots higher than the automobile body has made it possible to reduce the booth width to 4.5 m (Fig. 8).

The part that requires the most energy in the painting process is intake and exhaust of the painting booth, so reduction of the booth width and the booth length results in reduction of energy cost, which in turn is contributing to a reduction in CO_2 emissions.

(2) Painting system for inner body of automobile

It is required to shorten the booth length by narrowing the spacing between the robots, while avoiding interference with the narrow opening of the automobile body or between the robots when painting the engine compartment, trunk room, and the inside of the doors. For this reason, the use of robots for inner body painting applications is delayed compared to the painting of outer body of automobile. Featuring a slim arm and a large hollow wrist, and leveraging the interference check and prediction functions enabled with the offline programming simulation function, the KJ264 can be used to construct an optimal painting robot system for inner body painting (Fig. 9).

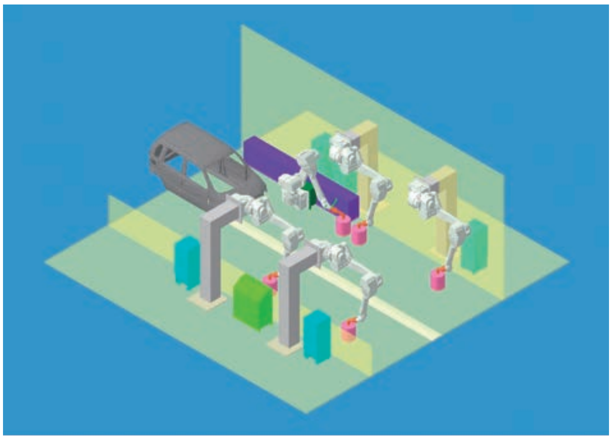


Fig. 9 Painting system for inner body of automobile

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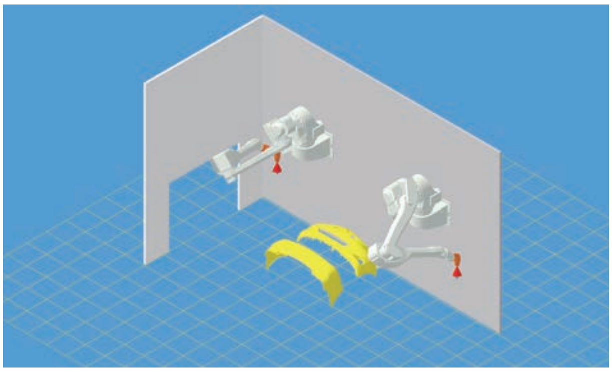

Fig. 10 Painting system for automobile bumpers

(3) Painting system for automobile bumpers

Currently, floor-mounting type painting robots are adopted for painting of the automobile bumpers, requiring a booth width of 5 m, but by placing the KJ314 above the bumpers and utilizing the swing axis, we have made it possible to narrow the booth width to 3 m (Fig. 10).

Concluding remarks

We believe the important mission for suppliers of robots and robot systems is to relieve as many operators as possible from painting work, while enabling cost reduction and high-quality painting. Also, reduction of VOCs (volatile organic compounds), CO_2, and other factors that impact the environment is a global challenge that needs to be tackled continuously and in close partnership with the paint, painting equipment, and painting facility manufacturers. Although the amount of contribution that robots alone can make toward reducing environmental impact is limited, the impact will be large when taking into consideration the positive effects that can be had on an entire facility as a system solution.

We hope to contribute to the society by continuing to provide better products and systems.