BX series new spot welding robots that innovate production lines

Spot welding robots have shown their capabilities in automating production and in raising product quality in automobile manufacturer where the leading users are found. The needs for increased efficiency of facilities and reduced costs have been growing recently. This paper presents the BX series of new spot welding robots that will serve these needs by enabling "space-saving," "concentrated layout," and "increased speed."

Preface

In automobile production facilities, reduction of total facility costs is one of the most important issues. Today, there is considerable demand for slimmer and more compact robots that take up less space, as well as robots with higher operating speeds for greater productivity.

At Kawasaki, we have used the large general-purpose Z series robots for spot welding applications. The Z series has a wide operating range and is capable of mounting a wide range of peripheral equipment, allowing it to be used for assembly and handling applications as well. For spot welding applications, however, the robots only require a set of specified equipment and a limited operation range, and operations mostly involve moving between short-distance teaching points while repeating acceleration and deceleration.

Therefore, we have developed a new series of spot welding robots called the BX series, which features improved robot and welding movements, to enable space-saving, concentrated layout, and increased speed. The BX series consists of the BX100N and BX200L, with a payload capacity of 100 kg and 200 kg, respectively.

1 Achievement of space-saving and concentrated layout

An effective way to reduce costs for automobile production facilities is to shorten the length and narrow the width of the production lines to create a compact facility. This requires reducing the space occupied by robots for a more concentrated layout. The following discussion describes the design features added to realize a smaller footprint and a concentrated layout.

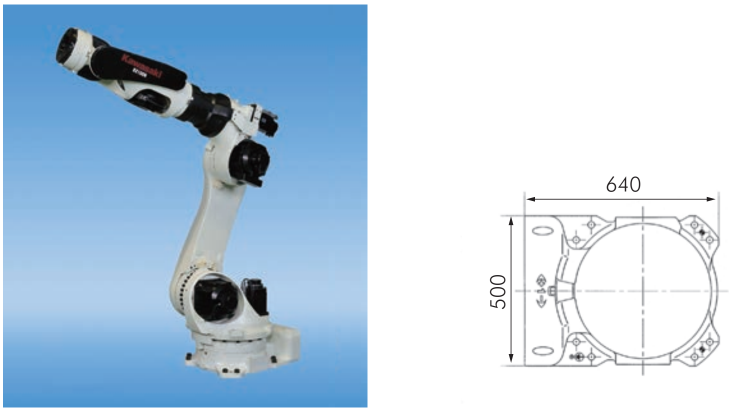
(1) Reduced layout area

The Z series model has additional space for optional wiring and tubing at the robot base to provide expandability for various applications. On the other hand, the BX series is limited to the wiring and tubing sufficient for spot welding, and they are routed through a hollow tube located at the center of the rotation axis. By making this design change, we were able to reduce the installation area to about 52% of the original size. The external view and layout of the BX100N and the existing model ZX165U with similar capabilities are shown in Fig. 1.

(2) Arm length suitable for spot welding application

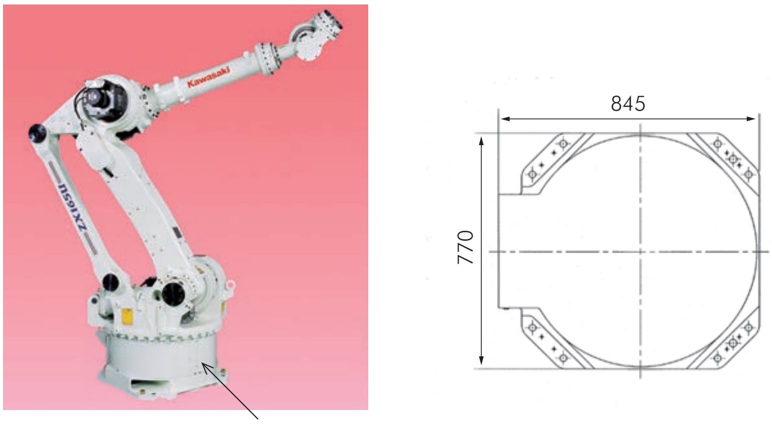
The BX100N has a 2,200 mm reach (maximum reach distance from the center of the robot's rotation axis to the center of its wrist area), and the BX200L has a 2,597 mm reach.

While a longer robot arm length can ensure a broader operating range, it also increases the overhang in the rear side when the arm is folded up. This enlarges the interference area, which makes it difficult to achieve a high-density layout. Therefore, we analyzed the teaching points in past spot welding operations to determine a



Wiring and piping housed in the hollow section at the center of the rotation axis

(a) BX100N



Optional wiring and piping space

(b) Existing model ZX165U

Fig. 1 External view and layout of BX100N and ZX165U

suitable arm length.

The BX100N covers over 90% of the teaching points created for the various spot welding programs developed to date, which means most of the spot welding operations can be handled with this model. In addition, the arm length was shortened and the spring for power assistance on the forward and backward axes was removed to reduce the interference area (Fig. 2).

On the other hand, the BX200L has the same reach as the existing ZX series model and covers virtually all the teaching points, making it a viable replacement for the existing model. At the same time, the interference area of the arm rotation axis has been reduced in the BX200L by replacing the large coil spring for power assistance on the

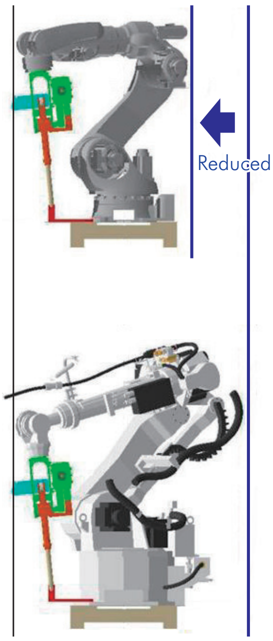


Fig. 2 Reduction in interference area

forward and backward axes with a gas spring. A comparison of operating ranges is shown in Fig. 3.

(3) Built-in spot welding cables/hoses

In spot welding, cables and hoses must be installed from the robot base area to the welding gun mounted at the end of the wrist. Previously, the cables were hung on a hook that was attached to a pole on the arm, or they were taken along the arm (Fig. 4(b)). With these methods, however, a certain distance must be secured between the arm and the cables to avoid interference between them, resulting in a wider interference area when the cables were included. Moreover, since the cables swing when the robot moves, it is difficult to predict cable behavior, particularly in offline teaching, so an even wider interference area had to be assumed.

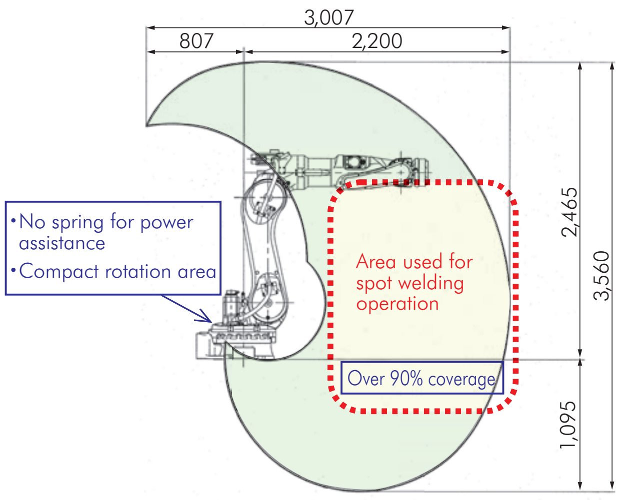
In the BX series, the cables are housed inside the arm to reduce the interference area and eliminate the need to take cable behavior into consideration (Fig. 4(a)). This enabled reducing the distance between the robots and the workpiece, as well as the distance between the robots themselves. It also reduced the amount of corrections required by offline teaching, reducing the amount of time required for line setup or changes.

(4) Compact, lightweight arm

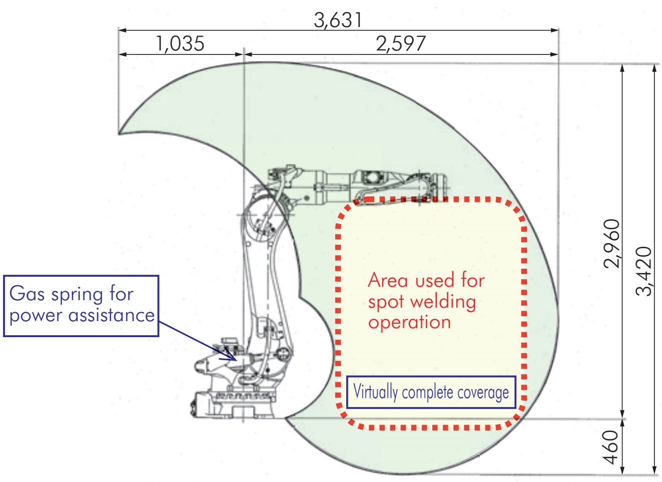
In the BX series, weight reduction was achieved by reducing the number of parts and using strength analysis to reduce part sizes to a necessary and sufficient level. As a result, we managed to reduce the weight of the BX100N by over 45%, and the BX200L by over 30%, compared to existing models.

2 Increasing operating speed

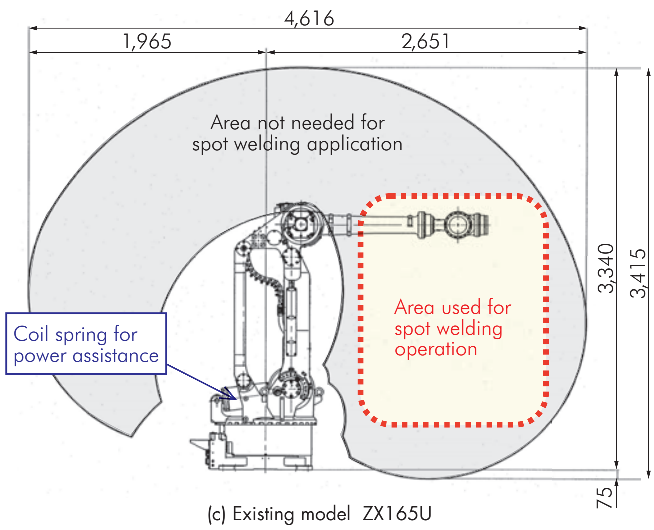
By increasing the operating speed of robots, the amount of workload handled by each robot will also increase. As a result, fewer robots will be required to perform the same amount of work, thus making a shorter production line a possibility. The following discussion describes how we achieve increased operating speed.



(a) BX100N

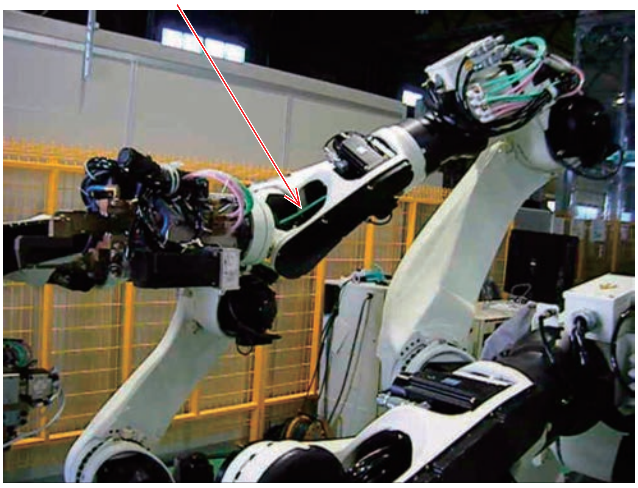


(b) BX200L

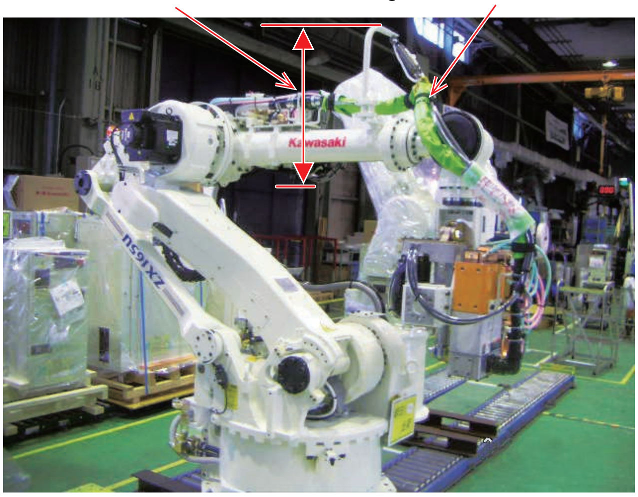


(c) Existing model ZX165U

Fig. 3 Comparison of operating ranges



(a) BX series



(b) Existing model

Fig. 4 Cable and hose processing

(1) Increased robot operating speed

The BX series robots achieve faster operating speeds by using the “variable acceleration and deceleration function” and “variable maximum speed function” described below.

(i) Variable acceleration and deceleration function

Forces such as gravity, inertia, centrifugal force/Coriolis force, and friction act on the robot arm in variable strength, depending on the arm's position, speed, and acceleration. When the robot operates, these variables are calculated to obtain the optimal acceleration and deceleration so that the motor force can be utilized to the maximum extent. While this is not a new function, improvement in the controller's calculation speed has enabled more efficient use of the motor force in the BX series.

(ii) Variable maximum speed function

Servo motors produce less torque in the high speed range due to the back electromotive force generated internally. In addition, reduction gear in each axis increases the resistance torque as the speed increases. As a result, even if maximum electrical power is supplied, the torque available for the robot becomes smaller as the speed increases, so the robot's acceleration and deceleration speeds also decrease. When operating over a certain distance, whether it is better to increase the speed or to keep the speed low and raise the acceleration and deceleration speeds depends on the operation distance. Therefore, the optimal combination of speed and acceleration for achieving the shortest possible operation time is calculated based on the relationship between the speed and the output torque of the robot.

(2) Increased speed in spot welding operations

Robot operations involved in spot welding operations can be divided into “moving between continuous welding points” and “application of pressure on welding points”. The new spot welding control employed in the BX series achieves high speed in relation to these operations.

(i) Moving between continuous welding points

In conventional operations for moving between continuous welding points, the gun axis moves to the clearance position after welding is completed, and then the robot moves to the next welding point, tracing a so-called “wedge-shaped” locus. While this is close to the air gun operation locus and thus makes it easy to track the gun movement, it includes unnecessary movement paths and is not conducive to reducing the cycle time (time required for performing the desired operation). In the BX series, therefore, the robot movement to succeeding welding points is performed simultaneously with the gun axis movement for applying pressure to the welding points, tracing a so-called “arc” locus. This tracing of an “arc” locus enables shortening the movement path between continuous welding points and results in reduced cycle time.

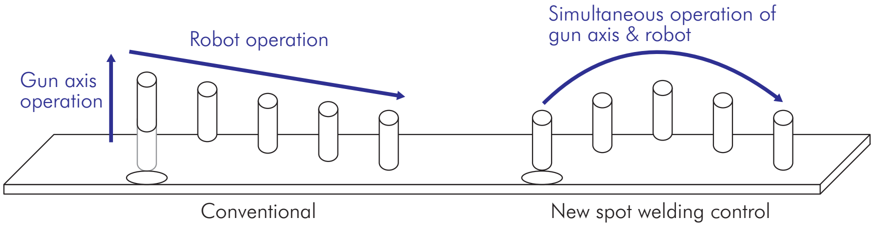
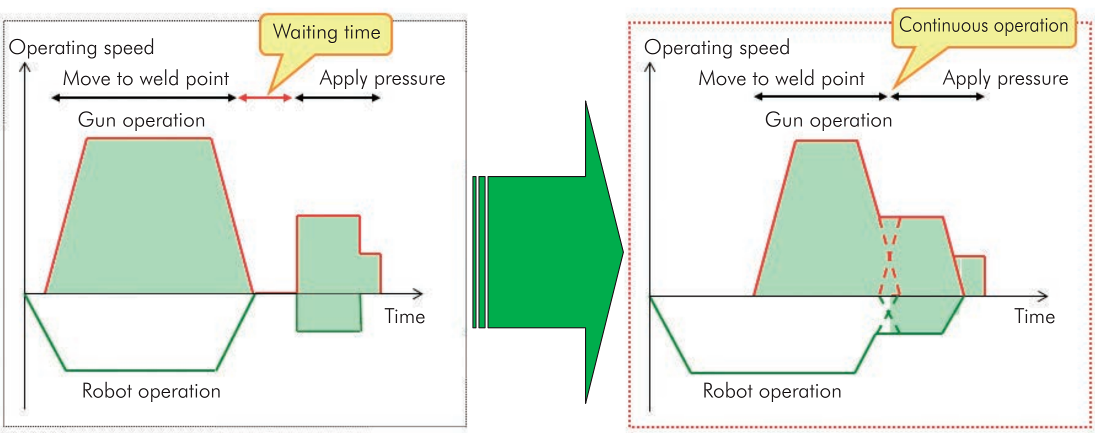


Fig. 5 Operational locus in conventional and new spot welding controls



(a) Conventional

(b) New spot welding control

Fig. 6 Comparison of operational locus between conventional and new spot welding controls

A comparison of operational locus between conventional control and new spot welding control in traveling over continuous welding points is shown in Fig. 5.

(ii) Application of pressure to welding points

In the conventional spot welding control, the robot pauses at the workpiece contact position before applying pressure in order to obtain a stable welding pressure. While a stable welding pressure can be obtained with this method, there is a slight waiting time at the workpiece contact position.

For the new spot welding control in the BX series, the pause at the workpiece contact position was eliminated to enable applying pressure at a constant speed, for a continuous and smooth operation that reduces the cycle time while maintaining a stable welding pressure.

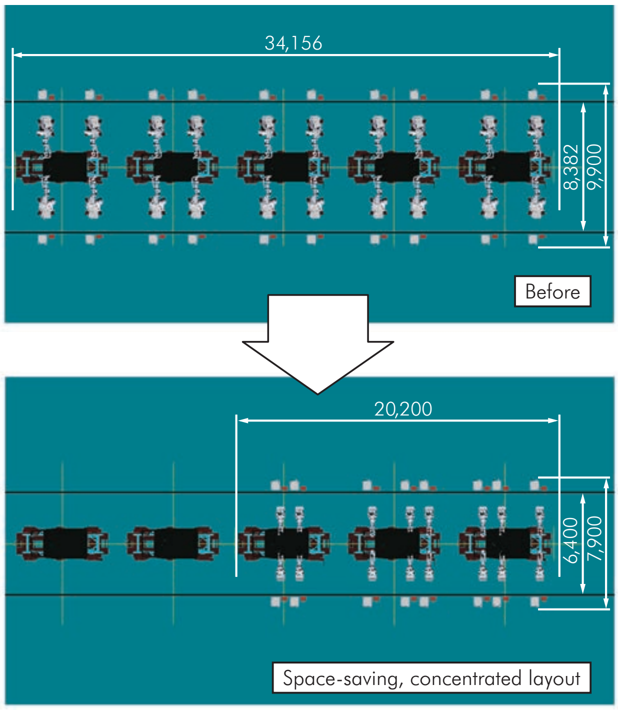
The change in gun axis and robot operation speed during pressure application between the conventional and new spot welding controls is shown in Fig. 6.

(3) Higher speed through optimization of gun axis acceleration and deceleration

In the conventional method of gun axis acceleration and deceleration, the maximum acceleration time presented by the gun manufacturer was used as a fixed parameter. However, this value makes an allowance for a certain margin, and a certain amount of motor torque margin is known to exist even when the gun axis is operated at the maximum acceleration time. For the BX series, the

Table 1 Reduction rate of the cycle time in the BX series

	BX100N	BX200L
Maximum load	24% reduction	20% reduction
100 kg load	23% reduction	21% reduction



Item	Conventional		After adoption	
No. of robots	20	100%	16	80%
No. of stations	5	100%	3	60%
Area (m^2)	286	100%	129	45%

Fig. 7 Effect of space-saving, concentrated layout, and increased speed

optimum gun axis acceleration and deceleration speeds are determined to make full use of the allowed gun axis motor torque, thereby achieving further reduction in the cycle time during pressure application.

(4) Effects of increased speed

Table 1 shows the rate of reduction in the cycle time achieved in the BX series as compared with the existing ZX165U model, which is not equipped with this function, for a continuous welding operation involving 10 welding points pitched at 50 mm intervals.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3 Effect of space-saving, concentrated layout, and increased speed

An example of the effect of space-saving, concentrated layout, and increased speed is shown in Fig. 7. Increased speed has enabled greatly reducing the number of robot units than before, and the installation space has been considerably reduced through space-saving and concentrated layout.

Concluding remarks

By leveraging the know-how and experience cultivated over the years, we at Kawasaki intend to continue developing new technologies and new products that help achieve labor savings, improved product quality, and greater efficiency in production facilities.