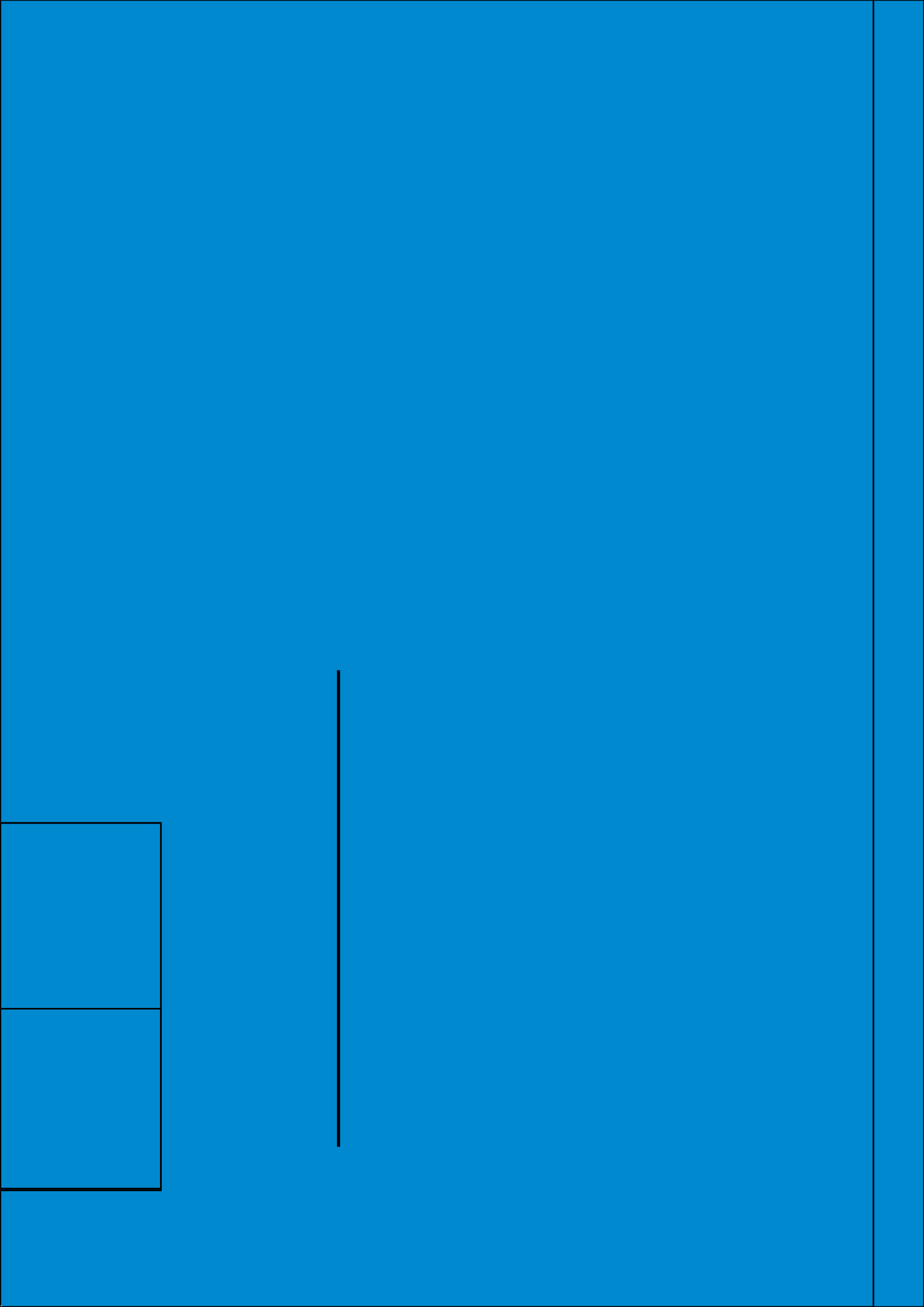
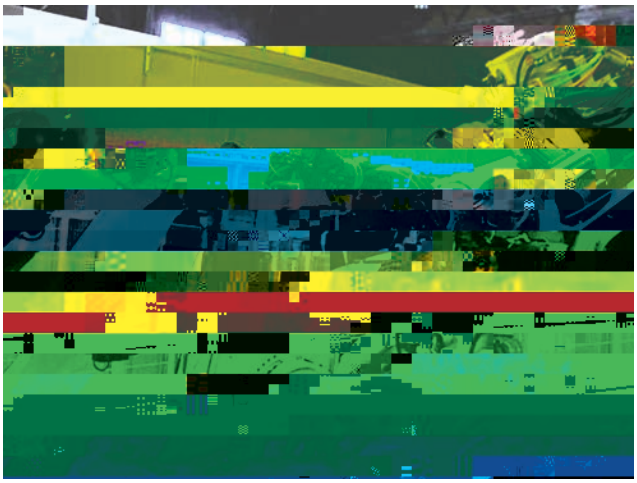




(1) Increased robot operating speed

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

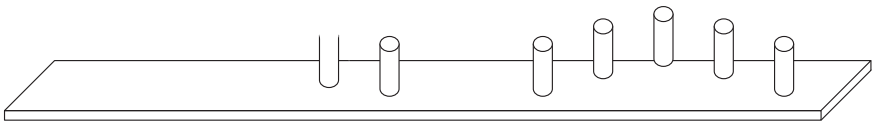
Servo motors produce less torque in the high speed range due to the back electromotive force generated internally. In addition, reduction gear in each axis increases the resistance torque as the speed increases. As a result, even if maximum electrical power is supplied, the torque available for the robot 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.



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

optimum gun axis acceleration and deceleration speeds are determined to make full use of the allowed gun axis