Features of New Robot Controller, CB-type Controller, for ARCMAN™ Welding System

Takeshi KOIKE*1, Shuichi INADA*1, Atsushi FUKUNAGA*1, Naoki KIDA*1, Tsutomu ONE*2

*1 Welding System Dept., Technical Center, Welding Business
*2 Production Systems Research Laboratory, Technical Development Group

Recently, the needs for welding automation have become more diversified and advanced, requiring a robot controller with higher performance and improved functions. Hence, we have developed a new controller, the CB-type controller, which features high performance, highly-sophisticated functions, and ease of use. This paper introduces these three features. In addition, the potential of the CB-type controller is described along with the example of a new arc-sensor control system under development.

Introduction

During the welding of medium and heavy plate, multi-layer welding is performed over a long period of time to overlay multiple layers of weld metal. This results, among other things, in the need for an arc sensor technology for tracking the displacement of welding lines due to thermal strain, etc., and vibration suppression control technology for the sound performance of welding using weaving. In recent years, the requirements of welding automation are becoming more sophisticated due to changes in the structure of welding targets, changes in the steel material used, the lack of skilled welders, and so on. In response to these needs and to support further evolution in the welding of medium and heavy plate, we have pursued performance upgrading, functional upgrading and simplification. It is against this backdrop that the CB-type controller has been developed for delivering solutions in welding automation around the world on the basis of the concept, "Welding from start to finish anywhere in the world." (**Fig. 1**, **Fig. 2**)

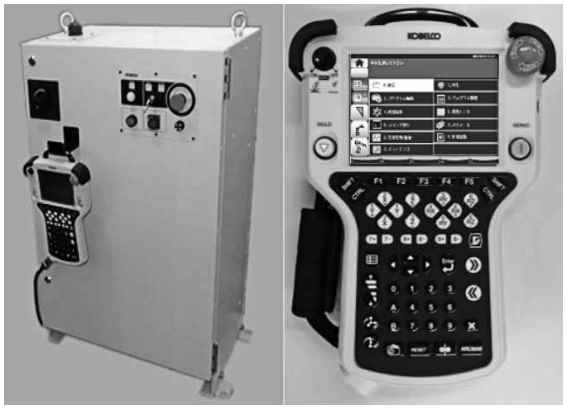

Fig. 1 CB-type controller and teaching pendant

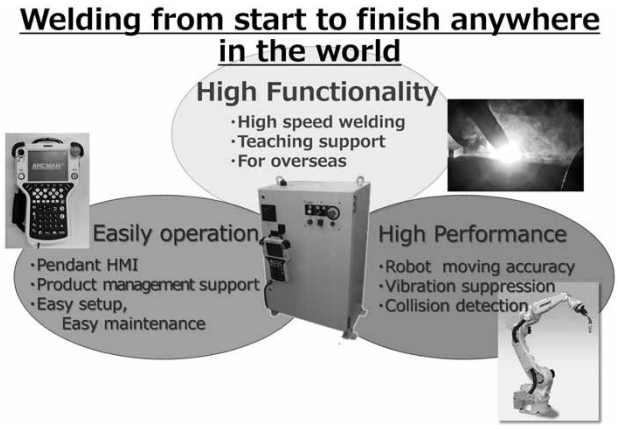

Fig. 2 The concept of CB-type controller

This paper presents an overview of the advantages of the CB-type controller, which has been in the market since April 2016, and takes up the supporting technology, as well as the future potential of this newly developed controller.

1. Advantages of CB-type controller[1)]

The main advantages of the CB-type controller are (1) high performance, (2) high functionality and (3) ease of use. This section describes these three advantages.

1.1 High performance supporting welding of medium and heavy plate

The CB-type controller has improved CPU performance with a renewed internal architecture, in which the user interface and real-time controller are optimally separated. In addition, EtherCAT® (Registered trademark of Beckhoff Automation GmbH & Co. KG, Germany) has been adopted for the communication with the manipulator, peripheral devices, and welding power source. This has improved the high-speed, high-accuracy synchronous communication performance necessary for a welding robot with upgraded performance and has realized control performance more than three times greater than that of the conventional types.

The "touch-sensing with welding wire" function, used for detecting the displacement of welding targets, requires the robot to stop abruptly at the moment when the welding wire comes in contact with each welding target. Such an abrupt stop,

however, can cause the robot to vibrate, leading to an error in positional detection. One way to reduce this error may be to perform positional detection after the vibration stops; however, the waiting time involved in stopping can cause the problem of increased tact time. Hence, the CB-type controller exploits the advanced model-based control technology[2] that has been modified for reducing the vibration and waiting time, thus decreasing the touch-sensing time by 20% compared with the conventional models (**Fig. 3**, **Fig. 4**).

1.2 High functionality to meet various welding needs

The improved hardware performance has enabled the provision of many functions that demonstrate strengths in automating the welding of medium and heavy plate. The following introduces some of the newly added functions.

1.2.1 Weaving customization function

An oblique-weaving function, independent voltage setting for vertical and lower plates, and end-stop time setting have enabled horizontal fillet welding with a leg length of 6 mm with neither undercut nor overlap, even at a high electric current of 450A and high-speed welding condition of 70 cm/min.[3] (**Fig. 5**, **Fig. 6**)

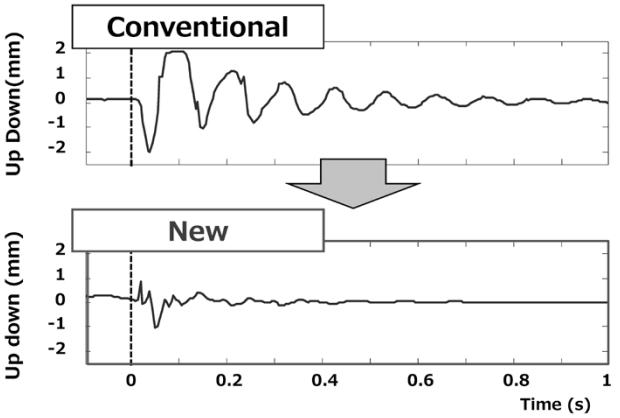

Fig. 3 Vibration duration after wire touch sensing

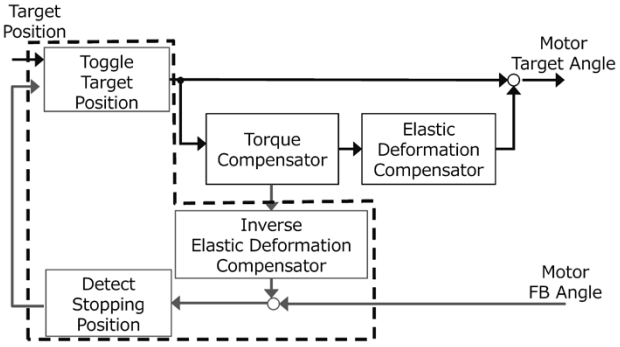

Fig. 4 Example of model-based control

This function is also effective in improving the shape of the reinforcement beads of single bevel grooves. **Fig. 7** and **Fig. 8** show examples in which oblique weaving is applied to the second pass of 2-layer 2-pass welding performed on workpieces with a plate thickness of 8 mm and a groove angle of 45°.

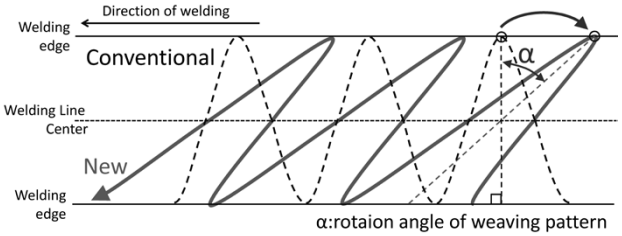

Fig. 5 New back-and-forth weaving pattern

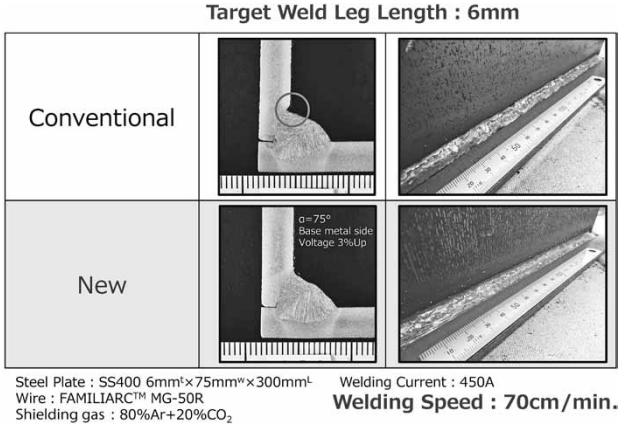

Fig. 6 Weld bead shape and appearance

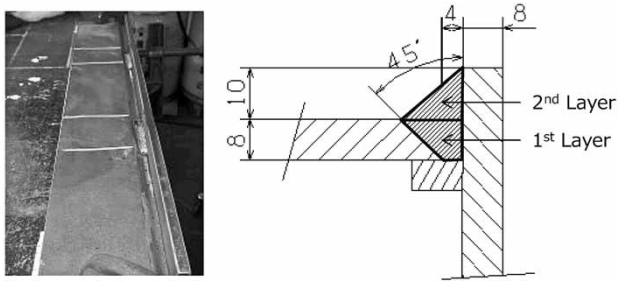

Fig. 7 Groove configuration of test plate

Fig. 8 Weld bead shape with bevel groove

1.2.2 Visual support for production status

If any problem occurs during the operation of a welding system, the accurate and objective acquisition of information before and after its occurrence is the key to early problem solving. In order to acquire this information, a robot-operation log and welding-result log are stored inside the controller. Although this function has been provided in conventional controllers, the CB-type controller has an increased internal memory capacity and has a log saving capacity 20 times that of the conventional controllers, enabling the acquisition of more detailed information.

Furthermore, the visualization of operational data and error occurrence status in cooperation with Kobe Steel's production support PC software (AP-SUPPORT™) can contribute to promoting the improvement of productivity, computerization and visualization at production sites (**Fig. 9**).

1.3 Simplification realizing favorable operability

A new teaching pendant has been developed, which, while inheriting the operability and high responsiveness responsible for the popularity of the conventional devices, is also light, easy-to-see, and easy-to-touch. Thanks to this pendant, even first-time users of the Kobe Steel's welding robot system can make inputs easily and intuitively (**Fig.10**). The following describes the advantages of the teaching pendant.

1.3.1 Light Weight

The pendant has not only a body weighing 0.95 kg, the industry's lightest class, but also considerations such as optimum weight balance that have been taken into account in the design. Moreover, a significant reduction in burden has been realized in the teaching/confirmation of welding work, which used to take a long time and impose a heavy burden on operators. More specifically, a forward switch for the teaching program has been added on the back of the teaching pendant,[4] and two enabling switches (optional) have been provided so that the teaching pendant can be held by either hand (**Fig.11**).

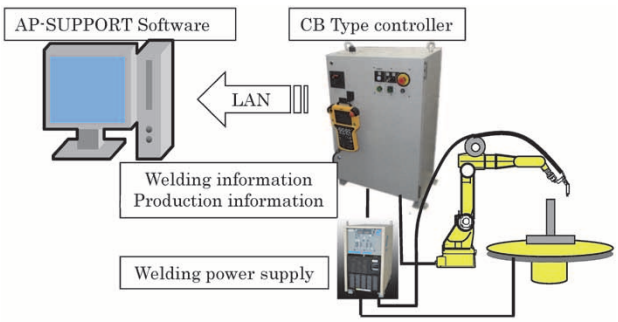

Fig. 9 Cooperation with AP-SUPPORT™

1.3.2 Intuitive operation and display

The intuitive input based on icons and touch panel (**Fig.12**), as well as the robot-teaching commands that are color-coded separately (**Fig.13**), have realized an operating environment that is user-friendly even for beginners.[5]

Moreover, the cross arrangement of keys,[6] matching the direction of robot operation, has

Fig.10 New teach pendant for CB-type controller

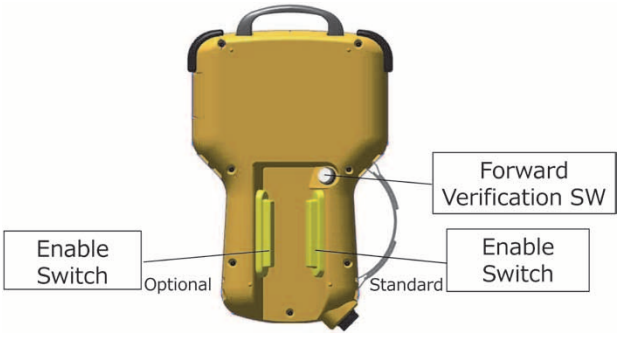

Fig.11 Switch arrangement on rear side

Fig.12 Touch panel screen

Fig.13 Coloring of robot teaching commands

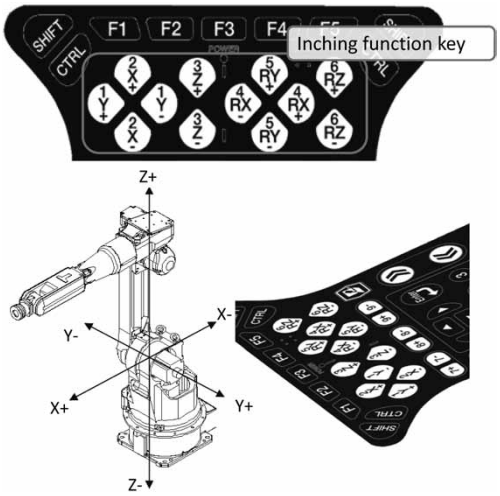

Fig.14 New cross arrangement of inching keys

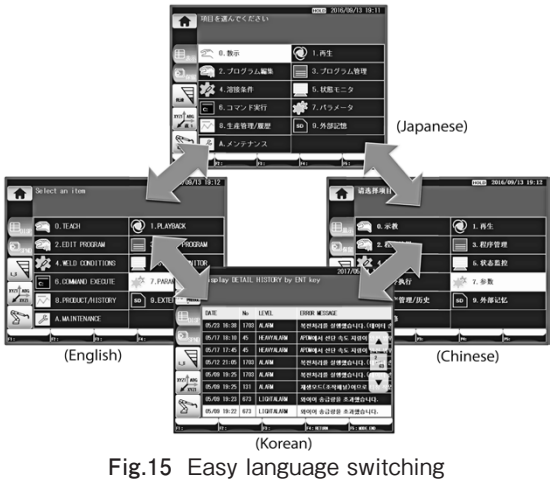

Fig.15 Easy language switching

improved operability during the inching movement of the robot (**Fig.14**). This feature is expected to reduce operational errors significantly.

1.3.3 Easy language switching

The operational displays are given in Japanese, English, Chinese, as well as in Korean. The languages can be switched instantly on the touch panel (**Fig.15**). This switchability takes into account the start-up and maintenance work done by Japanese staff at overseas factories.

2. Future prospects of CB-type controller

The welding of medium and heavy plate essentially requires further improvement in the performance of the arc-sensor function for tracking the weld lines displaced due, for example, to the thermal strain during welding. To this end, the upgraded capacity of the CB-type controller has been fully exploited.

In general, an arc sensor function using the feedback of welding electric current detects the displacement of weld lines on the basis of a difference in the electric current between the left and right ends of weaving. However, the electric current varies widely, limiting the ability to improve the accuracy of an arc sensor based only on the electric current values at the left and right ends.

Hence, the feedback values of continuous electric current during weaving are used to develop a method of obtaining the amount of displacement by regression fitting based on the least-square method. A simplified model, expressed by the following equation (1), has been used:[7]

$$I(t) = p_1 \sin(\omega t) + p_2 \sin\left(2\omega t + \frac{\pi}{2}\right) + p_3 \quad \cdots\cdots\cdots (1)$$

wherein $I(t)$ is an electric current waveform vector for the latest weaving cycle at time t, and the regression coefficient, p_1, corresponds to the displacement in the left and right directions. This model has been verified for five patterns of horizontal fillet welding; i.e., no displacement, displacements of 2 mm and 5 mm on the vertical plate, and displacements of 2 mm and 5 mm on the lower plate. **Fig.16** shows the relationship between the regression coefficient, p_1, and the displacement amount, confirming that p_1 increases as the amount of displacement increases.

A small standard deviation of the estimated displacement is considered to indicate a stable estimation of displacement. The standard deviation of the estimated displacement can be obtained by dividing the standard deviation of coefficient p_1 in each displacement amount in Fig.16 by the slope of the average value. In comparison with our conventional technique based on the difference in electric current at the left and right ends,[8] the standard deviation of the estimated displacement has decreased by approximately 8% in the case of Ar-CO_2 gas welding and approximately 40% in the case of CO_2 gas welding.

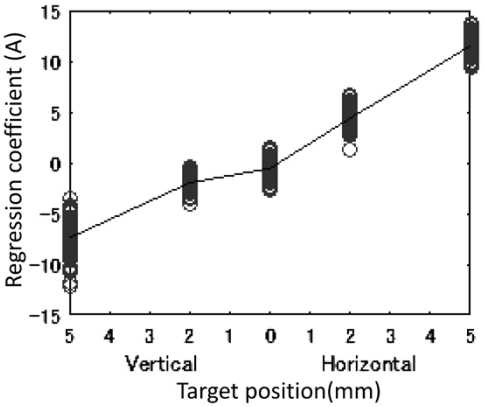

Fig.16 Relationship between regression coefficient and target position

Conclusions

This paper explains the functions and potential of a newly developed robot controller, the CB-type controller. The capabilities of the CB-type controller are being exploited in the control of new manipulators, ARCMAN™ note 1) -A30/A30S and ARCMAN™-A80.

In order to solve all welding issues, Kobe Steel will strive to make use of the CB-type controller, pursuing performance upgrading, functional upgrading and simplification to meet user needs and make new proposals to promote easy-to-operate, high-quality welding around the world.

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note 1) ARCMAN™ (ARCMAN™) is a registered trademark of Kobe Steel.