# Digital Transformation (DX) Technology to Promote Adoption of Welding Robot Systems

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**Abstract**

*The rapid development of information and communication technologies, as well as the widespread use of AI technologies, is expected to accelerate automation and labor-saving measures in production sites. Kobe Steel has been developing various functions to automate welding operations and increase the ratio of robots used in welding processes. However, the adoption of welding robot systems has resulted in new manual tasks such as teaching and maintenance. By reducing these manual operations, the introduction of welding robot systems can be more effective than ever before, leading to increased productivity. To overcome these challenges, Kobe Steel has leveraged ICT/AI technology to develop an automatic function that generates welding programs, reducing the need for manual teaching work. This feature has been added to the ARCMAN™ Offline Teaching System. A camera has been mounted on the ARCMAN™ PRODUCTION SUPPORT, expanding remote visualization capabilities, which is expected to improve safety by reducing the number of work at elevated areas.*

## Introduction

Kobe Steel has been developing and selling welding robot systems and apparatuses for medium-to-thick plate applications in, for example, construction steel frames, construction machinery, bridges, and shipbuilding, automating the welding process and saving labor. This contribution enhances society's development and improves its customers' production. When welding medium-to-thick plate components, challenges arise due to the large workpieces leading to assembly errors and the tendency for thermal distortion during multi-layer, repeated welding over extended periods. To address these challenges and achieve welding automation, the company has developed technologies such as arc sensors that detect changes in welding current and correct the robot tip position to a pre-taught location. Furthermore, in recent years, Kobe Steel has implemented automation in areas like flare grooves, traditionally performed by skilled welding workers, by measuring root gap with laser sensors and adjusting welding conditions depending on the root gap.[1)]

Thus, the application rate of welding systems has been increased to promote automation. However, introducing welding robot systems has brought about the need for new manual labor, including tasks like teaching work, robot operations, and recovery from short-time breakdowns, which were previously unnecessary in conventional manual welding operations.

To reduce such manual labor, Kobe Steel has provided solutions such as the ARCMAN™ Offline Teaching System to simplify teaching work and ARCMAN™ PRODUCTION SUPPORT, which allows for the visualization of robot production and helps in reducing short-time breakdowns.

This paper introduces functions achieved by adding ICT and AI technology to the software, aiming to reduce teaching work time and improve workability through further visualization of robot production. These functions make welding robot systems easier to use than ever before, promoting the automation of the welding process.

## 1. Teaching-less welding robot system

Before commencing production with a welding robot system, it is necessary to provide instructions for the robot, guiding it on how to weld different parts of the workpiece. This process involves establishing essential welding torch postures to ensure welding quality, avoiding any interference with the workpiece and clamp jigs, configuring sensors to account for potential workpiece misalignment, and defining its overall operation. This task demands a deep understanding of robot operation and welding expertise, especially for intricate workpieces, making it a challenging endeavor not easily undertaken by just anyone.

For more than two decades, Kobe Steel has been steadfast in the development of teaching-less welding systems. In the domain of construction steel frames, bridges, and shipbuilding, teaching-less systems have been successfully integrated, significantly contributing to the automation of welding for many customers[2), 3)] (**Fig. 1**). A key distinguishing feature of this approach lies not only in providing robot location information tailored to the specific workpiece but also in offering optimal welding conditions. This enables production to commence on the same day the robot is installed. Furthermore, in recent years, 3D-CAD is employed for inputting workpiece information, enabling the direct use of data generated during the design phase as manufacturing data (**Fig. 2**). This has led to the realization of a teaching-less system capable of swiftly acquiring workpiece information, even for workpieces with multiple welding lines [4].

Workpieces for which the teaching-less system has already been established often share similar and patterned shapes, allowing their teaching to be achieved by adapting the reference teaching program. However, for complex-shaped workpieces, as found in construction machinery, where patterning is challenging, applying the same method is difficult, preventing the realization of a teaching-less system. Moreover, teaching such complex tasks requires skilled teaching techniques, often resulting in lengthy teaching work durations. In response to this challenge, Kobe Steel has developed functions to simplify the automatic creation of teaching programs and the verification of these programs, thereby reducing the workload for those involved in the teaching process.

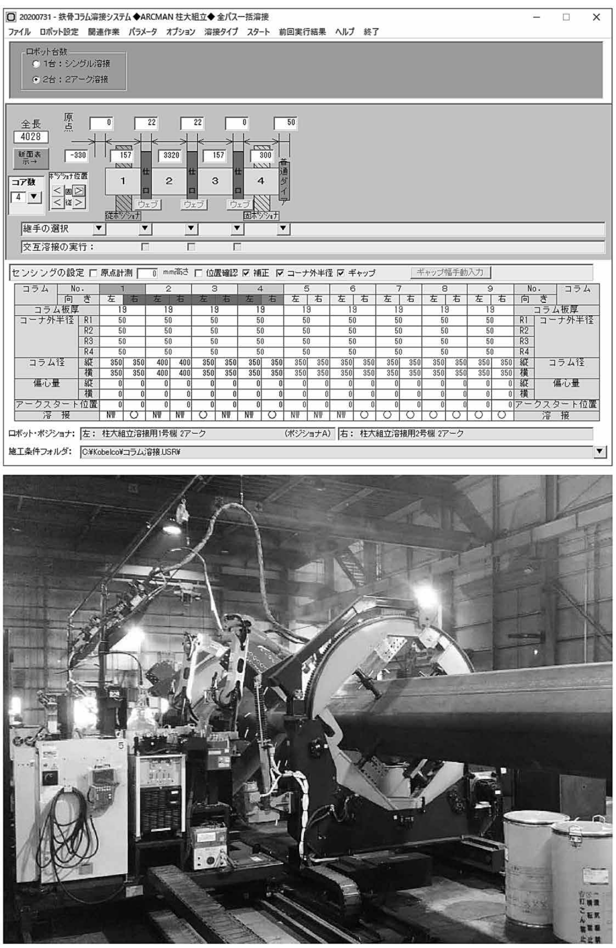

Fig. 1 Structural steel welding systems

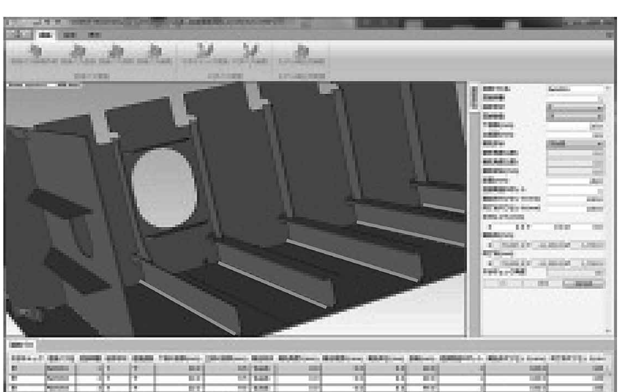

Fig. 2 SMART TEACHING™ for CAM

This section will elaborate on the welding-program automatic generation function, which automatically creates teaching programs offline (Section 1.1), and the cable simulation function, enhancing the accuracy of offline program verification (Section 1.2).

### 1.1 Welding-program automatic generation function

Excavators, a type of construction machinery, consist of a combination of multiple large and intricately shaped workpieces. These workpieces vary in shape for different machine models, making it imperative to develop a multitude of patterns if one were to achieve teaching-less automation using a patterning method, similar to the approach employed in construction steel frames, bridges, or shipbuilding.

The introduction of new machine models with dissimilar shapes presents additional challenges, necessitating the creation of setting patterns for a new reference program in accordance with a new shape.

Hence, an alternative approach has been adopted to automatically generate teaching programs for complex-shaped workpieces like construction machinery. This approach revolves around the “exploration” of robot postures suitable for welding. This has led to the development of a function for automatic program generation to determine the positions and angles for the robot, positioner, and moving apparatus. The exploration approach entails translating the teaching techniques of experienced personnel into rules. Following these rules, the positioner and torch angles are initially determined on the basis of welding positions and welding information. Subsequently, by exploring the robot’s welding postures, multiple teaching program candidates are created (**Fig. 3**). A two-step evaluation process is then carried out, encompassing robot operation evaluation and welding operation evaluation. This process aids in selecting the most suitable candidates for welding, culminating in the automatic generation of teaching programs (**Fig. 4**).

The utilization of this function can significantly reduce the teaching work, which typically takes two days on an actual machine, to just one day. This not only shortens the duration of teaching work, but also may decrease production line downtime. Furthermore, even operators with limited experience in creating teaching programs can readily generate teaching ones that match those made by seasoned teaching personnel.

### 1.2 Cable simulation function

When teaching programs created offline are tested on the actual machine, there are instances where the welding torch cables attached to the robot

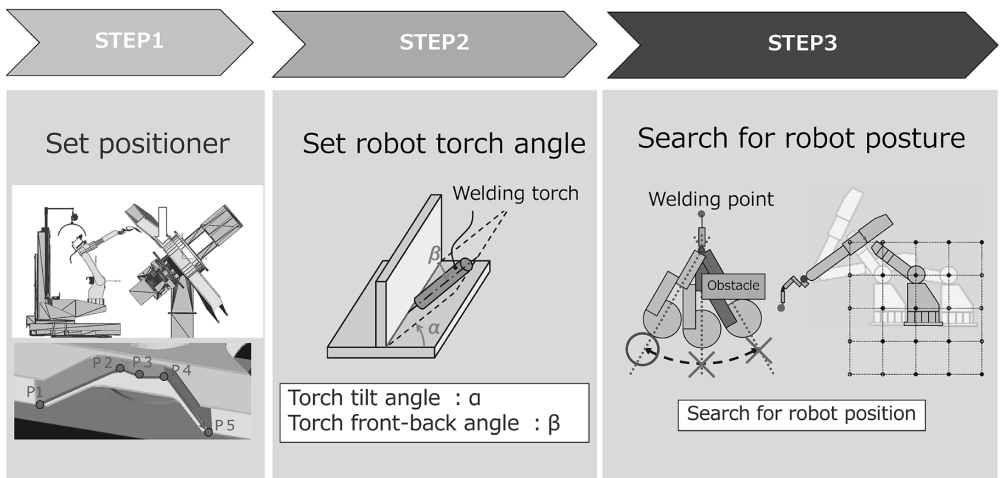


Fig. 3 Flow of robot pose search

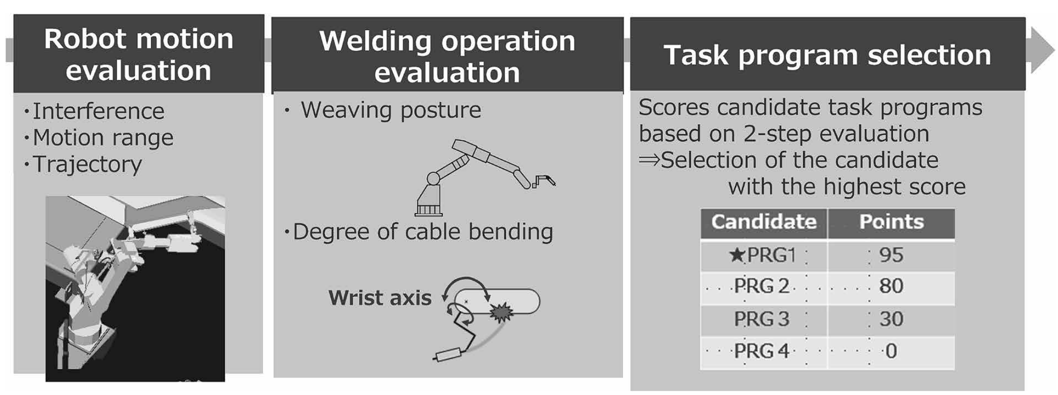


Fig. 4 Automatic selection of work programs on a two-step evaluation

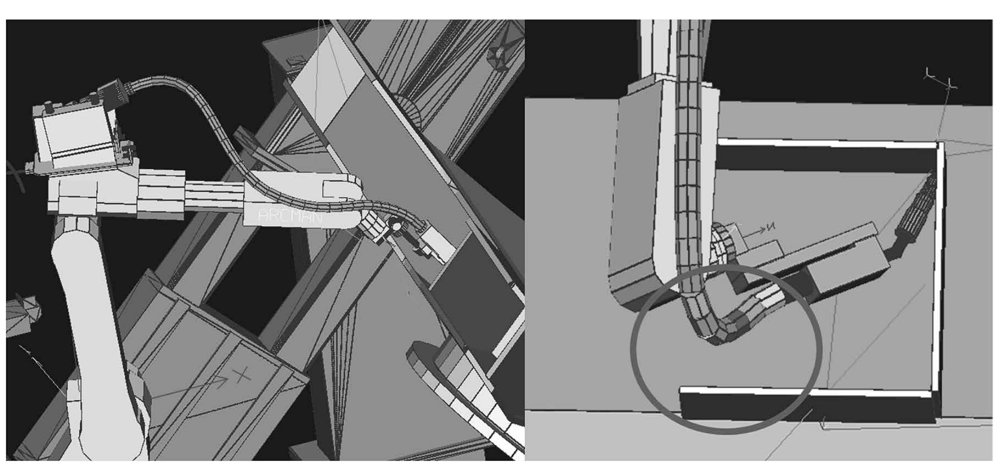

Fig. 5 Cable simulation to check distance between cable and workpiece

interfere, necessitating corrections and re-teaching, which can lead to prolonged teaching sessions. To address this issue, a cable simulation function has been developed, allowing the behavior of the cables to be confirmed offline. **Fig. 5** shows how cable simulation is used to check the cable state in narrow areas that are difficult to assess with the naked eye in the actual system. Particularly, as indicated in the right side of Fig. 5, the relationship between the cable and the workpiece position can be easily understood. As a result, teaching programs without cable interference can be created through offline work, shortening the time required for teaching adjustments in the field.

The cable simulation uses geometric curve calculation logic to represent curves that resemble the actual cable's movements. Therefore, it requires fewer calculations to display the cables, compared with using a physical simulation, which requires precise calculation. This enables fast visualization without causing work stress.

The settings for cable movement include only four simple parameters: (1) the starting and ending positions of the cable, (2) the decision whether or not to use a spring balancer, (3) the selection of the torch cable's stiffness, and (4) the direction in which the cable bends. This makes it user-friendly and easy for anyone to use.

## 2. Production visualization system

Kobe Steel provides ARCMAN™ PRODUCTION SUPPORT, a solution designed to aid in the analysis of short-time breakdowns, welding defects, and production management by aggregating operational data from welding robot systems and rendering welding and production data visually [7)].

This section begins with a discussion of ARCMAN™ View (Section 2.1), which bolsters productivity by linking video information from network cameras with traditional welding and production data. This is followed by the explanation of a work-type determination function (Section 2.2) aimed at preventing erroneous setup due to the robot operator teaching wrong program numbers, through the utilization of images captured prior to production. Additionally, the section introduces the wireless remote monitoring system (Section 2.3), which harnesses mobile computers to enhance work efficiency.

### 2.1 ARCMAN™ View

As an optional feature within ARCMAN™ PRODUCTION SUPPORT, a camera function named ARCMAN™ View has been developed. This function enables real-time display and recording by connecting network cameras to a PC. Since the size of medium-to-thick plate welding systems tends to increase, ARCMAN™ View incorporates a unique function to control the camera, ensuring that the robot's tip always remains centered in the frame by utilizing the robot tip location information (**Fig. 6**, **Fig. 7**).

The videos recorded using ARCMAN™ View can be linked to error information and welding data, facilitating replay covering the time corresponding to specific information. Through this movie-log linkage function, users can readily review the images to verify the welding conditions when errors occur or welding defects manifest, enabling a detailed analysis of the root causes of short-time breakdowns (**Fig. 8**).

Moreover, ARCMAN™ View's images enable operators to manage the robot while monitoring the screen without the need to approach the robot physically. However, due to the limited depth

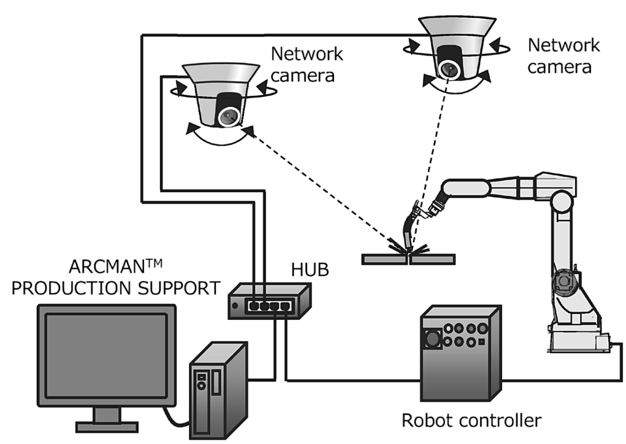


Fig. 6 ARCMAN™ View system configuration

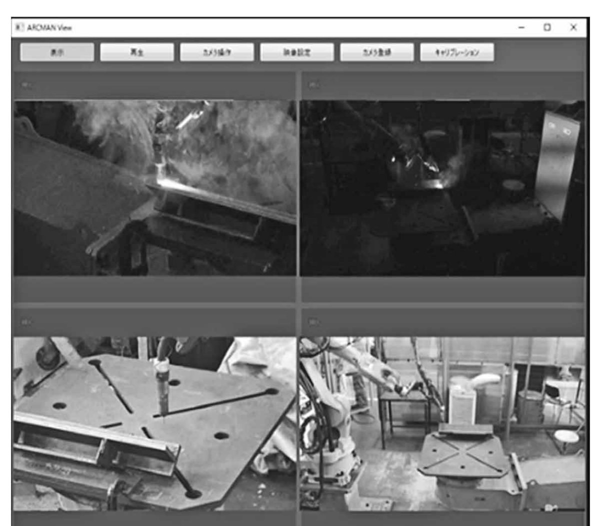

Fig. 7 Sample image of ARCMAN™ View

perception in images, accurately guiding the robot to the welding start position can be challenging. To address this challenge, a touch-sensing function has been devised, allowing the operator to execute it at any chosen time by applying sensing voltage to detect when the wire makes contact with the workpiece. This action triggers the remote sensing function, causing the robot to halt when the wire touches the workpiece (**Fig. 9**). With the help of this function, robot operation from outside the safety fence becomes feasible, thereby reducing the necessity for work in hazardous locations such as elevated areas.

### 2.2 Work-type determination software

In medium-to-thick plate welding systems, there are scenarios where an operator employs a crane to load a workpiece onto the system and manually selects a teaching program for playback via the teaching pendant or control panel. However, operator errors occasionally lead to the unintentional selection of a different program with similar shapes, resulting in issues like welding in an incorrect position or the torch coming into contact with the workpiece.

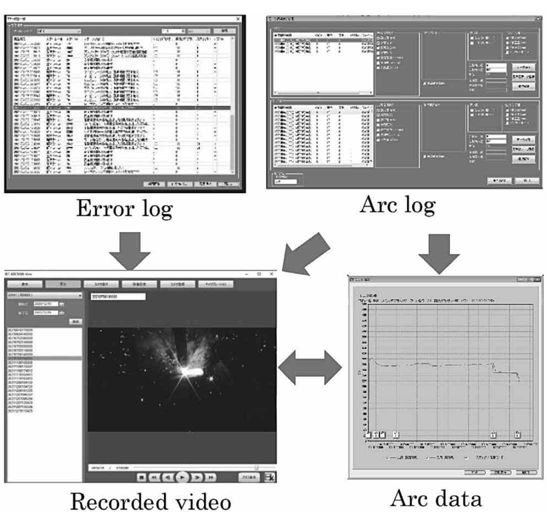

Fig. 8 Concept of log linkage function

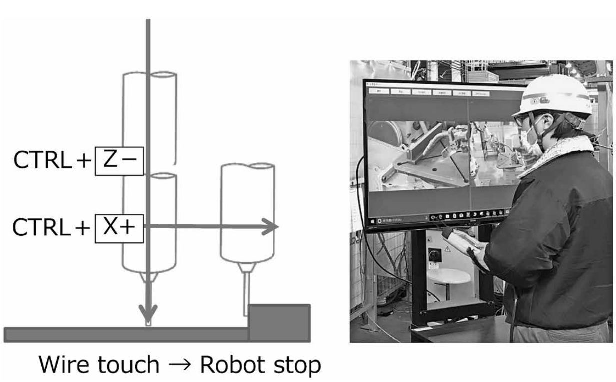

Fig. 9 Concept of sensing remote

One potential solution to this problem involves the utilization of Radio Frequency Identification (RFID). Nonetheless, using RFID for large metal objects like construction machinery necessitates highly precise RFID readers that are less susceptible to radio wave reflections from metal surfaces. This can result in increased initial investment and operational costs.

To tackle this challenge while keeping initial investment and operational costs manageable, Kobe Steel has devised a work-type determination software employing cameras and AI for discrimination. Picture recognition technology, widely explored across various fields, is employed to estimate the types of objects from camera images [5), 6)]. However, even when AI recognition accuracy is on par with or exceeds human capability, achieving 100% accuracy presents certain challenges. To address this, a double-checking function involving both humans and AI has been integrated.

When an operator intends to initiate welding, the operator selects the program based on the work type after loading the workpiece and then activates the playback start switch. The developed work-type determination software establishes communication with the robot as soon as the playback start switch is pressed, identifies the program number chosen by the operator, and captures an image of the workpiece using the camera. By analyzing the captured image, the software distinguishes the work type and verifies whether the combination of the determined work type and the operator-selected program number is accurate. If it's an incorrect combination, the software suspends the playback and prompts the operator for confirmation (**Fig.10**).

In a production environment where the work-type determination software operates, incorporating new workpieces into the system necessitates learning new images of the added work. Traditionally, this process required the expertise of AI developers. To streamline this, a system has been put in place for automatic learning from workpiece images acquired during production. With this system, even in cases with a limited number of initial learning data or low determination accuracy for work types, or when new workpieces are introduced, the software learns and enhances determination accuracy while in operation (**Fig.11**).

### 2.3 Wireless remote monitoring system

Kobe Steel actively pursues the development of a wireless remote monitoring system, which makes use of mobile devices like tablets, alongside the

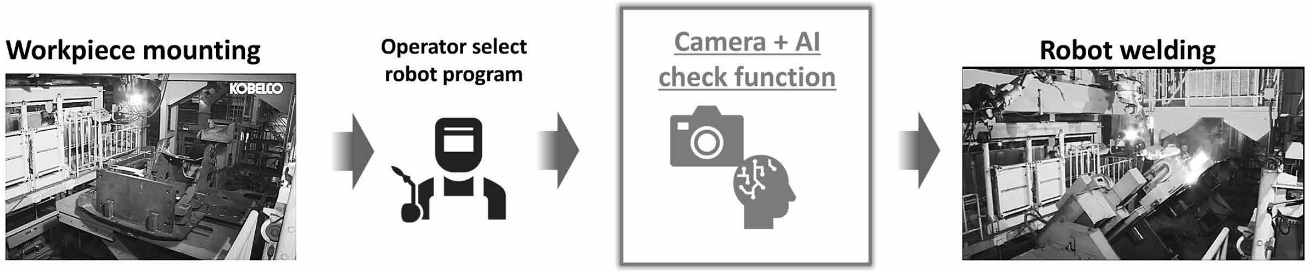


Fig.10 Work type determination software operational flow

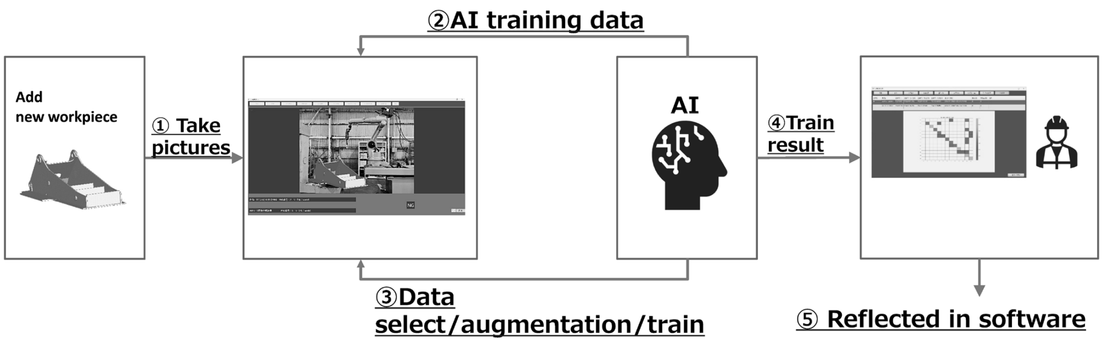


Fig.11 Automatic AI learning flow for new workpiece


Fig.12 SESLA™ and remote application for SESLA™

visualization of welding processes on desktop PCs and laptops. In certain work environments, skilled operators may be required to continuously oversee welding conditions to ensure the quality of the welds.

However, with the recent decline in the number of skilled operators, the inability to manage multiple welding apparatuses simultaneously has emerged as a significant concern, leading to decreased work efficiency. The implementation of a wireless remote monitoring system addresses this issue by enabling remote monitoring of multiple welding systems from a distance. This monitoring system empowers non-skilled operators to operate each welding apparatus, potentially allowing each skilled operator to support multiple operators concurrently.

The wireless remote monitoring system functions through wireless communication between the SESLA™ main unit and industrial mobile computers equipped with Android (a trademark of Google LLC)[8]. It provides real-time monitoring of welding conditions, presenting data in numerical and graphical formats. Moreover, it allows for remote adjustments of welding conditions and the storage of monitoring data in CSV format (**Fig.12**).

It should be noted that the development of the wireless remote monitoring system extends beyond the SESLA™ monitoring system and there are plans to make it available for various systems in the future.

## Conclusions

This paper has presented novel functions that merge Kobe Steel's proprietary expertise in welding technology with ICT and AI technology. The ongoing challenges posed by Japan's aging population suggest a sustained demand for automation and workforce reduction within production sites. In response, Kobe Steel remains unwavering in its commitment to development efforts focused on alleviating labor shortages and relieving operators from physically demanding tasks. The company is steadfast in its mission to enhance the automation and quality of welding, ultimately aiming to boost productivity and safety for its valued customers.

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