Welding Machine "SENSARC™ RA500" with Highly Efficient Welding Processes

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Abstract

SENSARC™ RA500 is an arc-welding machine newly developed with highly efficient processes. It was launched in the summer of 2021 as a higher-end model encompassing the current SENSARC™ AB500. This high-end welding machine is equipped with highly efficient processes and functions suitable for automated welding of medium-to-thick plates for, for example, architectural steel frames, construction machinery, bridges, and vehicles, which are Kobe Steel's specialty. This paper introduces the highly efficient welding methods realized by SENSARC™RA500, including pulsed MAG welding with expanded efficiency, REGARC™ with even lower spatter, and tandem welding specialized for high-speed welding.

Introduction

In the realm of large welding structures, like architectural steel frames and construction machinery, which entail thick plates and canning by multi-layered welding, the demand for enhanced efficiency is unceasing due to the substantial welding volume and prolonged welding processes. Conversely, in industries primarily dealing with thinner plates and single-pass fillet welding, there is a pressing need for improved efficiency through heightened welding speeds. However, achieving heightened efficiency in high-speed welding presents challenges in preserving welding quality, including addressing welding defects, bead appearance degradation, and increased spatter generation, among other issues. To resolve these challenges, Kobe Steel offers a comprehensive solution leveraging its own products, encompassing welding materials, welding robots, and welding machines.

This paper introduces a new cutting-edge welding machine, SENSARC™ Note 1) RA500 (hereafter referred to as "RA500") (**Fig. 1**). The RA500 comes equipped with a range of high deposition welding processes and plays a pivotal role in the welding robot system, making a valuable contribution to overcoming various challenges.

Fig. 1 Outside viewing of welding power source SENSARC™ RA500

1. Features of RA500

Since the early 1980s, Kobe Steel's arc-welding robots have found widespread adoption among customers, both in Japan and other countries, primarily in the medium-thick plate sector. The key requirements for welding systems in this field include: i) improving efficiency (shortening cycle times and increasing operation rates), ii) achieving high-quality welding work, and iii) expanding automation. Improving efficiency is often associated with the "arc time," which makes up 70-80% of the robot's operational duration. To reduce the arc time, it is essential to increase the welding speed. Achieving this necessitates a welding power source with an expanded upper limit of welding current output and appropriately controlled welding current waveforms.

1.1 Welding power source

Table 1 presents a comparison of exemplary specifications between the newly developed welding power source, RA500, and the conventional model, SENSARC™ AB500. Regarding the basic performance, the RA500 has made substantial improvements through revisions to the power circuit and housing design, resulting in a significant expansion of its 100% usage rate. For the DC constant voltage welding method, the rated output has been increased from 450 A to 500 A, and for the DC pulse welding method, it has gone from 400 A to 450 A. This expansion allows for improved efficiency

Note 1) SENSARC is a registered trademark (TM) of Kobe Steel.

Table 1 Comparison of specifications between developed power source and conventional power source

	RA500	AB500
Rated output	100%-500 A DC-CV 100%-450 A PULSE 60%-500 A PULSE	90%-500 A DC-CV 100%-400 A PULSE 40%-500 A PULSE
Physical dimensions	W386×D629×H810(mm) 71(kg)	W370×D663×H685(mm) 69(kg)
Temperature range	Operation -10℃ to 40℃	Operation -10℃ to 40℃
Controller	Control cycle : 12.5 μs Sampling cycle : 2 MHz	Control cycle : 50 μs Sampling cycle : 40 KHz
Connectable device	Welding robot Welding carriage	Welding robot
Industrial network	EtherCAT Ethernet/IP	CANopen

in the high-current range. Furthermore, as explained in more detail below, it has adopted new output control for the extended high current range of DC pulse, enabling both high efficiency and high-quality welding.

The control section of the power circuit has enhanced output control with an increased control period of 12.5 μs (four times longer than the conventional model) and raised feedback sampling frequency of 2 MHz (a 50-fold increase compared with the conventional model). These enhancements have enabled more precise control of arc length and droplet transfer, making it easier to customize welding for different materials and work needs.

Although the external dimensions of the welding power source have increased in height by 125 mm when compared with the conventional AB500 model, the ground contact area ratio has remained at a similar level. To enhance dust resistance, the heating part of the power circuit, the electronic circuit control section, and the cooling part are configured in complete isolation (**Fig. 2**). A side-flow structure is employed for forced air cooling, drawing air in from the sides and expelling it from the front and rear, thereby improving the cooling efficiency. For instance, while the conventional model requires a 300 mm clearance from surrounding obstructions, the RA500 can satisfy the usage rate with only a 50 mm clearance under specific conditions. Additionally, in terms of maintenance, the structure allows cleaning of the heat sink from the front panel. This facilitates cleaning without moving the welding power source from the robot system (**Fig. 3**).

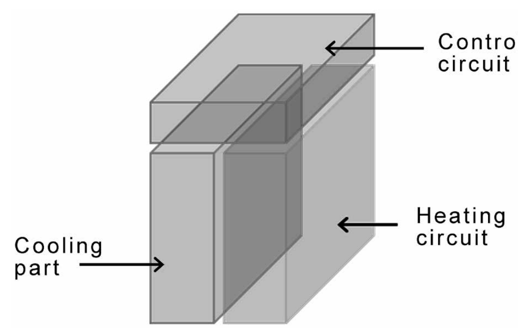


Fig. 2 Layout inside the welding power source

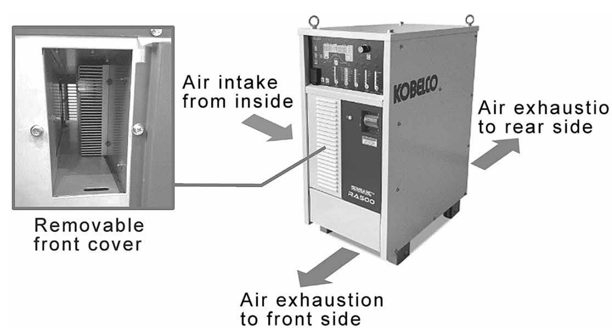


Fig. 3 Side flow structure

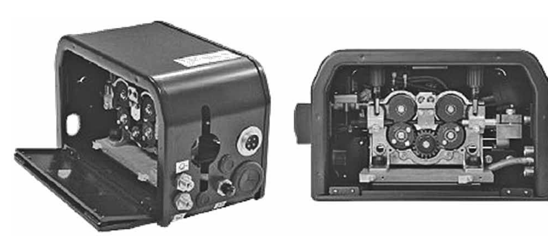


Fig. 4 Outside view of wire feeder

1.2 Wire feeder

The wire feeder is designed with a full-cover structure to safeguard it against unintentional contact with the welding circuit. (**Fig. 4**). Furthermore, the dust resistance of the feeding motor has been enhanced, achieving an IP53 protection rating. The feeder has undergone significant performance enhancements, including a 13% increase in the rated load torque and a durability boosted to 1.5 times that of the previous model (with a load of 1.5 Nm and a feeding speed of 22 mpm). Thus, this feeder seamlessly integrates safety, dust resistance, and durability, guaranteeing robust performance for enduring extended periods of continuous welding, while achieving a maximum feeding speed of up to 30 mpm.

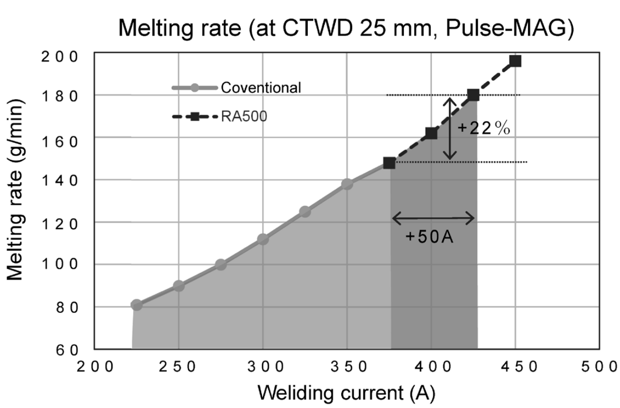
2. Welding process

2.1 Standard welding mode

The arc-welding machine comes equipped with specialized welding modes designed to suit a variety of materials, with a primary emphasis on general-purpose welding materials for mild steel (**Table 2**). The RA500 differentiates between rutile-based wires and metal-based wires, offering dedicated flux-cored wire welding modes for each, with the goal of improving welding quality through precise output control. If necessary, it is also possible to expand and integrate welding modes for materials other than mild steel.

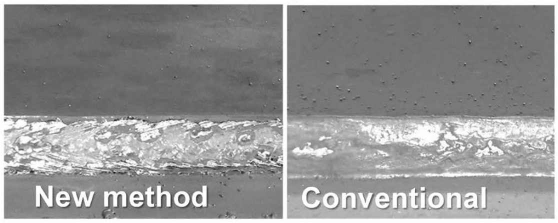
Table 2 Built-in welding mode

Welding method	GAS	Wire materials	Wire diameter (mm)
DC-CV	CO_2	MILD STEEL(SOLID)	1.2, 1.4, 1.6
		MILD STEEL(Rutile-FCW)	1.2, 1.4,
		MILD STEEL(Metal-FCW)	1.2, 1.4,
		STAINLESS(FCW)	1.2
	Ar+CO_2	MILD STEEL(SOLID)	1.2
PULSE	Ar+CO_2	MILD STEEL(SOLID)	1.2, 1.4



Ar80%+CO_2 solid wire, ϕ 1.2 mm,

Fig. 5 Relationship between welding-current and wire melting rate



Pulse-MAG, WFR:22 mpm, CTWD: 25 mm
Travel: 350 mm/min, Solid wire: ϕ 1.2 mm, Conditions: 430 A

Fig. 6 Adhesive spatter reduced by new method

With the expansion of the 100% usage rate, high efficiency is achieved for DC pulse welding, with current conditions exceeding 400 A. **Fig. 5** shows an example of the efficiency improvement for a solid wire with a diameter of ϕ1.2 mm. RA500 has a maximum wire melting rate increased by approximately 20% from the previous 150 g/min to 185 g/min, enabling highly efficient welding work. It should be noted that the 100% usage rate for DC pulse welding is 450 A; however, considering the burden on consumables in the feeding system due to the increased feeding speed of ϕ1.2 mm wire and the stability of molten metal, the upper limit for welding current is estimated to be around 430 A. In general, under welding conditions exceeding 400 A, minor spatter adhesion is observed even in pulse welding. However, RA500 employs optimal pulse output control for this range, significantly reducing such adhesive spatter (**Fig. 6**).

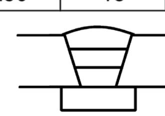
As a specific example of efficiency improvement, the calculated arc time for a 16 mm thick, 50° V-groove butt welding is shown in **Fig. 7**. In this example, the first layer ensures fusion, the finishing layer emphasizes appearance, and the maximum melting speed is applied primarily to the intermediate layer. Even in this example, where the intermediate layer has the smallest proportion, there is an expected reduction of approximately 13% in arc time compared with AB500.

2.2 New pulse control

In RA500, a new pulse control has been adopted for the DC pulse mode for solid wire, enabling stable pulsed arc welding across a wide current range, from low to high currents. This new pulse control is particularly effective in pulsed MAG welding with a ϕ1.4 mm wire. In conventional pulse control, arc length control was performed by base-time modulation (**Fig. 8**), whereas the RA500's arc length control employs peak-current modulation (**Fig. 9**) in the high current range. Specifically, base-time

	Pass	Welding current [A]	Welding travel [mm/min]	Wire feed rate [m/min]	Melting rate [g/min]	ARC time [min/m]
RA500	1	280	280	12	105	10.6
	2	430	290	22	190	
	3	400	290	20	173	13%Up
AB500	1	280	250	12	104	12.0
	2	380	250	18	154	
	3	380	250	18	154	

80%Ar+CO_2 DC-PULSE
ϕ 1.2 mm, YGW15
CTWD: 25 mm



T: 16 mm
V: 50°
GAP: 5 mm

Fig. 7 Comparative examples of efficiency of butt welding

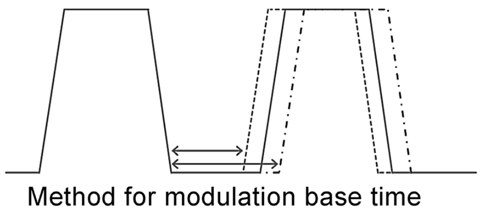


Fig. 8 Conventional method (modulating base-time)

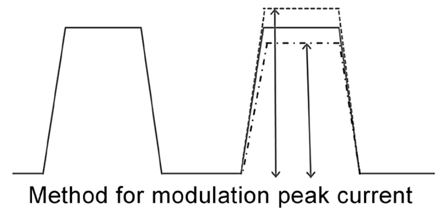


Fig. 9 New method (modulating peak-current)

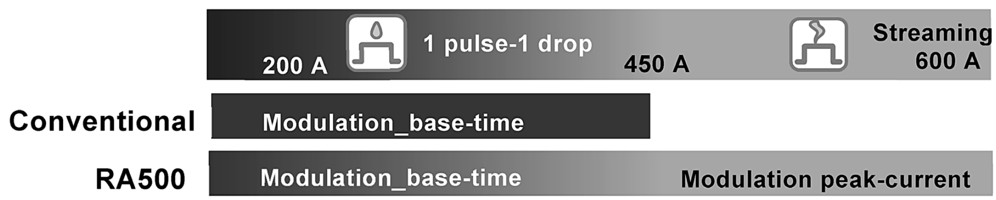


Fig.10 Application image of new pulse control

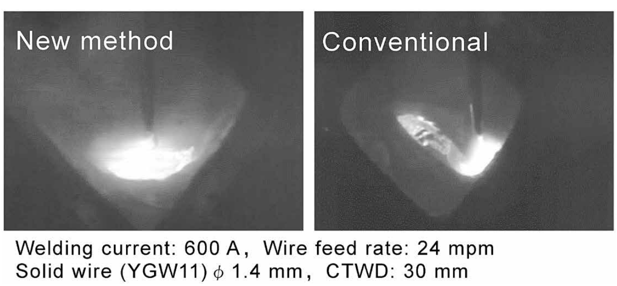


Fig.11 Comparison between new pulse control method and conventional pulse control method

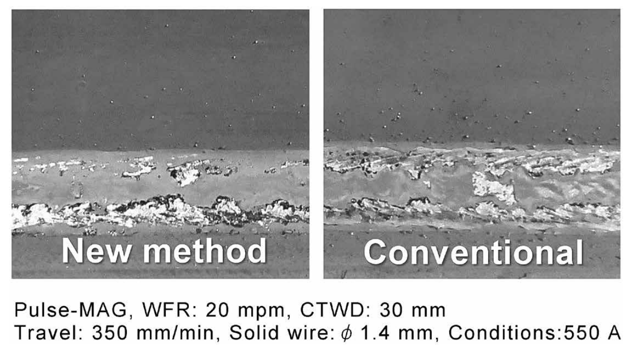


Fig.12 Appearance of welding bead

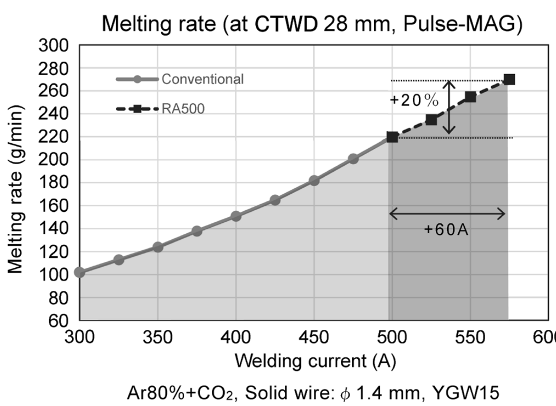


Fig.13 Welding current and wire melting rate

	Pass	Welding current [A]	Welding travel [mm/min]	Wire feed rate [m/min]	Melting rate [g/min]	ARC time [min/m]
RA500	1	280	350	9	109	8.6
	2	560	350	22	260	
	3	450	350	16	189	14%Up
AB500	1	280	350	9	109	9.8
	2	500	290	18	213	
	3	450	285	15	177	

80%Ar+CO_2, DC-PULSE
ϕ 1.4 mm, YGW15
CTWD: 28 mm

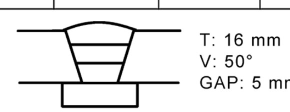


Fig.14 Efficiency comparison example of butt welding

modulation control is applied for currents of 450-500 A or lower, and peak-current modulation control is applied for those of 500 A or higher (**Fig.10**). This effectively suppresses the vibration of the molten pool in high-current welding exceeding 500 A (**Fig.11**), which was a previous challenge, and enables the creation of beads with well-defined toes. This also reduces spatter adhesion to the base metal (**Fig.12**). However, in the high current range, droplet transfer may sometimes become a rotating transfer, and pore defects originating from the atmosphere are likely to occur due to turbulence in the shielding gas. Therefore, careful attention is required.

The recommended upper limit for the proper welding current in this new pulse control process is approximately 560 A (with a wire diameter of ϕ1.4 mm, in parallel configuration). At this current, the wire melting rate is around 260 g/min. This is about 20% higher than that of AB500, whose limit for stable bead formation is at around 500 A. Further increasing the output is possible, but it can make controlling the molten pool more challenging, as the molten metal may flow ahead, making it not advisable. The relationship between the melting speed and output current is shown in **Fig.13**.

As a specific example, the calculated arc time for welding a 16 mm thick, 50° V-groove butt joint is shown in **Fig.14**, where an approximately 14%

reduction in arc time is expected, compared with AB500.

2.3 Tandem MAG pulse

Tandem MAG pulse welding is one of Kobe Steel's longest-standing high-efficiency welding methods and has continued to evolve alongside the development and improvements of welding machines. In the tandem mode of AB500, the tailing electrode pulses in sync with the leading electrode to achieve arc stability equivalent to single electrode welding, despite its double electrode configuration. In contrast, RA500 has reevaluated the control of the tailing electrode to further enhance the arc stability. It should be noted that the RA500 tandem welding system was launched in June 2022.

The tandem mode of RA500 includes a tandem welding mode for flux-cored wires in addition to the mode for solid wires. Tandem welding divides the electrode into two electrodes, offering superior welding speed compared with single electrode welding with the same melting speed. However, further increasing the speed can lead to challenges such as a convex bead shapes and destabilization of the molten pool due to increased deposition amounts. On the other hand, using flux-cored wires results in stable streaming transfer without interference between the electrodes even in the high current range of 400 A or higher, thanks to the effect of flux columns, which is characteristic of the droplet transfer of these wires. This action suppresses the movement of the molten pool, enabling the formation of flat beads even in high-speed welding with a leg length of 8 mm and a welding speed of 1,000 mm/min (**Fig.15**). High deposition applications are also possible. The use of a low-slag flux-cored wire with a diameter of ϕ1.3 mm, under the conditions of a leading electrode at 430 A and a tailing electrode at 400 A, enables a deposition amount of approximately 350 g/min. This is the highest deposition amount in the welding methods hitherto proposed by Kobe Steel (**Fig.16**).

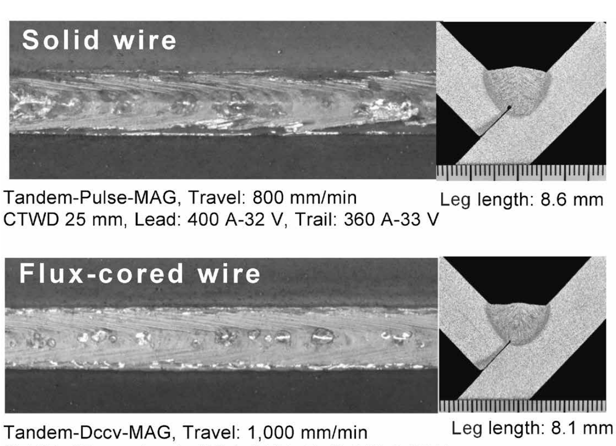


Fig.15 Example of tandem welding method

Another advantage of using flux-cored wire is as follows: In tandem welding where solid wire is generally used, the DC pulse welding method is typically employed. In the tandem welding mode using flux-cored wire, the application of the constant voltage direct current welding method is possible, thanks to the action of the flux columns. This makes the setting of welding conditions easier than in the case of the DC pulse welding method. Furthermore, the application of the DC pulse welding method is not mandatory, making it less prone to the destabilization of power supply due to tip wear (**Table 3**).

2.4 New REGARC™ Note 2)

The common practice in steel frame welding is to use the relatively inexpensive carbon dioxide gas as a shielding gas, and, therefore, welding is mainly performed at high currents to enhance efficiency. Especially within the high current range, there has been a long-standing challenge of increased spatter generation due to the irregular globular transfer of droplets. To address this challenge, Kobe Steel has developed the REGARC™ welding process. In

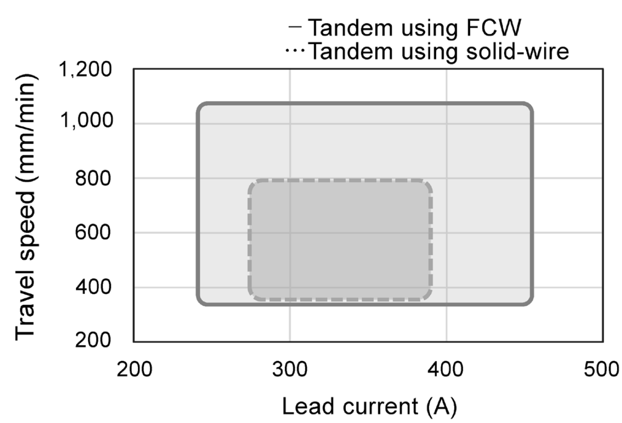


Fig.16 Applicable range of tandem welding method using FCW

Table 3 Advantages of flux-cored wire

	Solid wire	Flux-cored wire
Welding method	Pulse	DC-CV
Bead appearance	Average	good
Tip durability	Average	good
High speed welding	Average	good
Versatile	Average	good

Note 2) REGARC is a registered trademark (TM) of Kobe Steel.

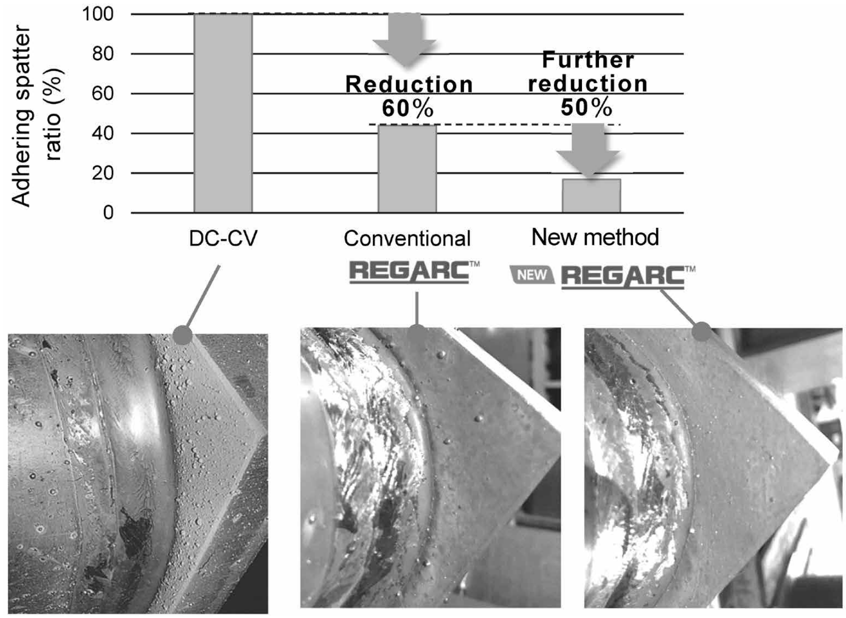


Fig.17 Reduced adhesive spatter amount in new REGARC™

carbon dioxide arc welding, this method involves shaping the welding current into a special pulse waveform at specific times during the droplet formation and detachment processes, thereby suppressing the upward movement of droplets. This allows the droplets to be transferred to the molten pool in an orderly manner before they grow large. This welding method effectively reduces the occurrence of short circuits and the generation of large-sized spatter, and its applications are rapidly expanding.[1)]

RA500 comprises a newly developed output control that enhances the output waveform and arc-length control of the conventional REGARC™ welding process, achieving further reduction of spatter (**Fig. 17**).

3. Application

3.1 Robot function

RA500 serves as a welding machine within Kobe Steel's robot welding systems, featuring an information gathering function when combined with a robot. It includes applications useful for welding machine maintenance, such as recording operating time, welding duration, various alarms, and monitoring parameters like welding current and wire feed speed load (**Table 4**).

3.2 Digital interface

In terms of digital interfaces, RA500 utilizes EtherCAT for digital connection with Kobe Steel's multi-articulated robot ARCMAN™ [Note 3)]. It is also designed to be adaptable to various protocols for digital connection with small and portable robots. For example, plans are in place to establish system integration using EtherNet/IP™ for digital connection with Kobe Steel's ISHIMATSU controller (**Fig. 18**).

Table 4 Combination function with robot

Maintenance information	・Welding operation time ・Temperature inside the welding power source ・Rotation error of cooling fan ・Fine-adjustment of welding ball removal control ・Motor overcurrent warning detection level ・Voltage detection error sensitivity adjustment
Welding information	・Wire-feed load monitor ・Welding current monitor ・Welding voltage monitor

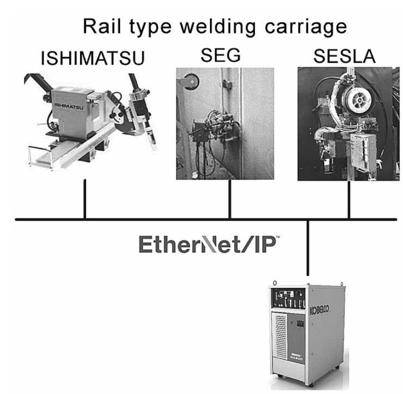


Fig.18 Cooperation with rail-type welding carriage

Note 3) ARCMAN is a registered trademark (TM) of Kobe Steel.

Furthermore, RA500 is equipped with Anybus® CompactCom, enabling the development of various digital communication protocols (a total of 11 protocols including Modbus, DeviceNet) tailored to other automation apparatuses. There are plans to gradually expand the range of protocols that can be used for digital communication interfaces.

Leveraging this digital communication interface and the robot functions described in the previous section, RA500 incorporates welding condition instructions for automation equipment connections, such as arc start and crater handling. Additionally, considerations are being made for functions like recording and monitoring welding information that cannot be executed by various automation equipment alone. In the future, there may also be functions that allow for reviewing work records specific to welding portions.

Conclusions

This paper has introduced the newly developed high-end welding machine, SENSARC™ RA500. Alongside the welding processes and functions introduced in this paper, the ongoing development of new welding processes will continue. Plans are in place to incorporate AXELARC™ [Note 4)], a non-short-circuit-type wire feeding control method for carbon dioxide gas processes, into RA500, with the aim of commercialization in the fiscal year 2024 and beyond. Kobe Steel will strive to contribute to solving problems so as to improve welding quality and efficiency together with welding materials and welding equipment while expanding other functions.

References

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2) Y. Kitamura et al. Abstracts of the Welding Society National Conference. September 8-10, 2022, Welding Society, 2022, pp.282-283.

Note 4) AXELARC is a registered trademark (TM) of Kobe Steel.