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Author(s)	Sugitani, Yuji; Kanjo, Yoshihiro; Ushio, Masao
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High Efficiency Processes in Automatic Welding†

Yuji SUGITANI* , Yoshihiro KANJO* and Masao USHIO**

Abstract

The recent trends of high efficiency welding processes in automatic welding systems in Japanese heavy industries are reviewed. Metal type flux cored wires with CO2 shielding, high speed rotating GMAW and He mixed MAG have been applied in thick materials with high deposition rates. High current, 2-tandem one side GMAW robots have been developed, with adaptive welding parameter control for change of groove width and joint slope, and applied in curved shell assembly in shipyards. High speed 2-tandem GMAW on primer coated fillet joints has been applied with decreased incidence of blow holes. As for tandem SAW, 4-tandem one sided high speed processes in shipyard, and 3-tandem very deep penetration processes for steel box column assembly have been developed and applied. Non-consumable nozzle electroslag, and simplified electrogas welding have been applied in column assembly. Narrow gap welding processes with GMA, SA and TIG have been applied for heavy thick material. Multi-robot welding systemization has been developed for fabrication in heavy industries.

KEY WORDS: (GMAW) (SAW) (Automatic Welding) (High Efficiency) (Heavy Industry)

1. Introduction

In automated or robotized welding systems, application of high efficiency welding processes are innecessary to achieve more efficient welding production. Improved efficiency of welding processes has been achieved by various means, i.e., through the welding process itself, through one sided welding, tandem welding, narrow gap welding, multi-head / multi-torch apparatus, etc.

Welding automation was started with tandem one side SAW applied in shipbuilding in around 1965. Since 1980, it had progressed remarkably with GMAW based on technological innovations, i.e. flux-cored wire for CO_2 arc welding, and MAG welding with Ar based shielding gas, as well as transistorized power sources, arc welding robots and various kinds of welding sensors.

This paper is focused on the trends of high efficiency welding processes in automatic welding systems in Japanese heavy industries.

2. High Current, High Deposition GMA Welding Process

2.1 Helium mixed gas

Around 1990, high current MAG welding processes with Helium mixed shielding gases were reported. T.I.M.E. process utilizing a 4 component gas (Ar, He, CO_2, O_2) and another process utilizing a 3 component gas (Ar, He, CO_2), both provide stable rotating metal transfer at more than 400A welding current with 1.2 mm diameter wire. Frequency of the rotation is several hundred Hz. High deposition welding can be obtained with good bead appearance, pan-shape penetration and less spatter. This process has been applied in thick material fields, e.g. building frames, bridge fabrication, construction machinery, heavy machinery, etc.[1-4]. But it seems to be not widely spread in Japan.

2.2 Flux cored wire

Metal type flux cored wire had been already applied for MAG welding in Europe. In Japan, application of this kind of wire for CO_2 welding has been increased for groove welding, one side welding, fillet welding of thick material, etc. It has the advantage of double the deposition rate with about 200 g/min at 500 A welding

† Received on May 30, 1998
* Tsu Labs., NKK Corp.
** Professor

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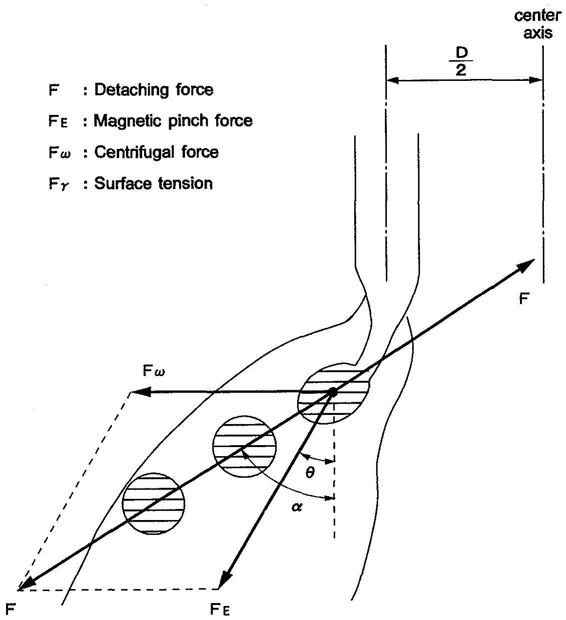

Fig. 1 Deflection of high speed rotating arc.

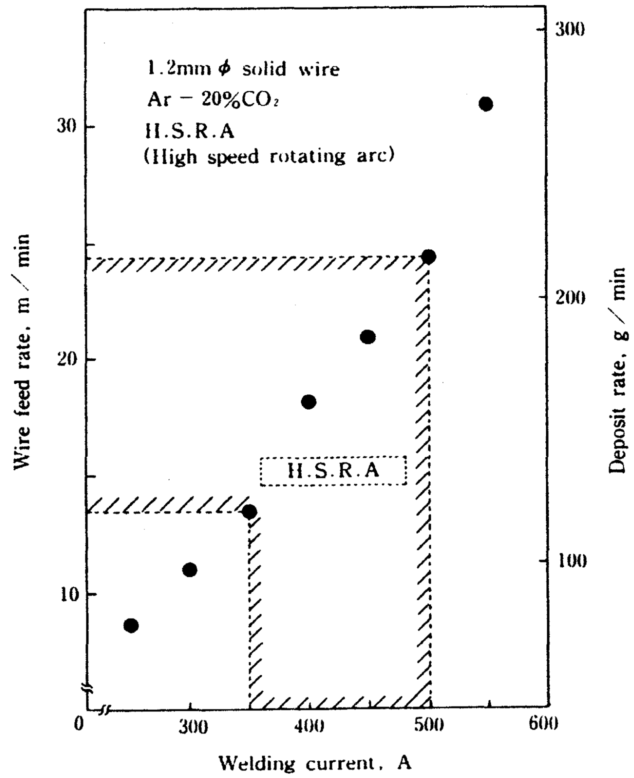

Fig. 3 Applied range of welding current and deposition rate in H.S.R.A.

current and 1.4 mm diameter wire, and resistance to cracking, compared with conventional CO_2-FCW process (300 A, 1.2 mm dia.). Metal cored wire is also useful for thin sheet welding without burn through [5-6].

2.3 High speed rotating arc

In the high speed rotating arc process, decentralization of physical effects (arc pressure, arc heat) and deflection of the welding arc, both provide pan shape penetration and flattened bead surface shape, see **Figs.1** and **2**. So higher welding currents with high deposition rates can be utilized in MAG and CO_2 welding, see **Fig.3.** The process, with its accurate arc sensing, has been applied in narrow gap welding, fillet welding, etc. in various fields [7-8].

The above 3 processes have common characteristics of welding arc phenomena. That is,a decentralized welding arc, weakened arc force, and stable arc phenomena, even at high welding currents (400-500 A),with small wire diameters (1.2 - 1.6 mm). As a result, high deposition welding can be achieved in wide range of thickness.

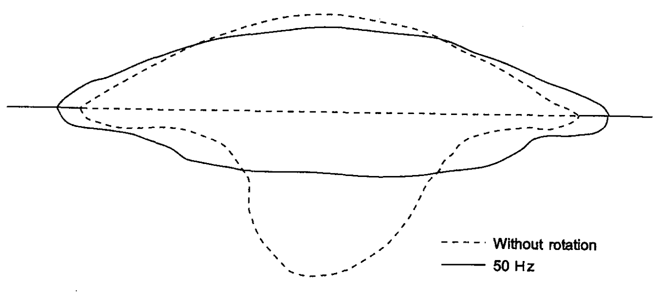

Fig. 2 Bead and penetration shape improved by high speed rotating arc.

3. Tandem SAW

3.1 High speed one side SAW

3-Tandem electrodes one side SAW with flux copper backing was accomplished over twenty years ago in shipyards. Recently a 4 electrodes process has been developed and applied for the purpose of doubling welding speed (1.5 m/min. at 16 mm thick). The leading two electrodes form a back bead and the trailing two electrodes form a surface bead and prevent hot cracks [9].

3.2 Large heat input tandem SAW

Another development of tandem SAW was applied for deep penetration processes with one pass welding such as the corner joint of a heavy building box column . Iron powder is added at 30 wt. % to increase deposition rates, to increase penetration with the concentrated arc, and to stabilize arc phenomena [10]. **Figure 4** shows box corner welding equipment with parallel 3-tandem SAW, and **Figure 5** shows an example of the weld bead section for 90mm plate thickness obtained with a leading welding current of 3100 A with 6.4 mm wire and heat input by over 700 kJ/cm [11].

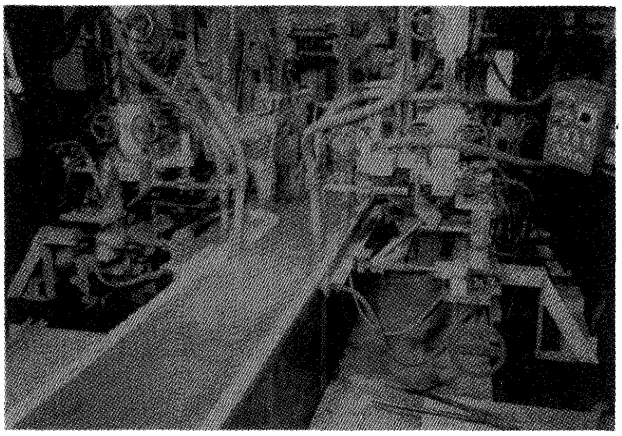

Fig. 4 Box corner welding equipment with parallel 3 tandem SAW.

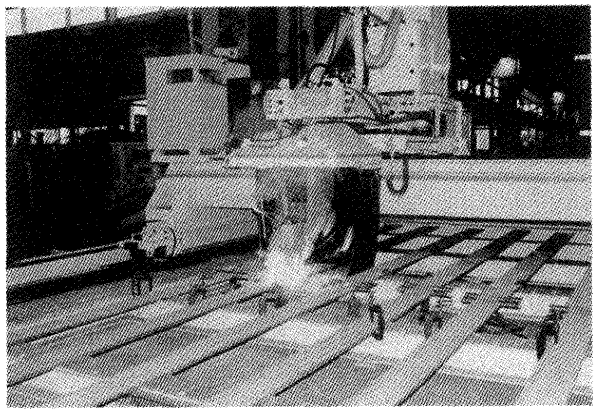

Fig. 6 One side GMAW robot in bridge factory.

4. One Side GMAW

4.1 Portable multi-pass welding robots

Various kinds of portable carriage type multi pass GMA welding robots have been applied to one side and multi pass welding in various industries, e.g. steel frame work, bridge fabrication, shipbuilding, etc. Their main functions are : light weight, torch weaving, easy teaching operation, multi pass welding software installed, etc. [12].

4.2 Efficient one side GMA welding process

In the above, one side GMAW, root gaps over about 4mm and welding currents below 300 Amps. are applied to get a good back bead without hot cracking. Recently more efficient one side welding processes with higher welding current have been being put into practical use. **Figure 6** shows one example of a one side multi pass CO_2 welding robot with single wire for short butt joints in bridge fabrication. The high speed rotating arc with

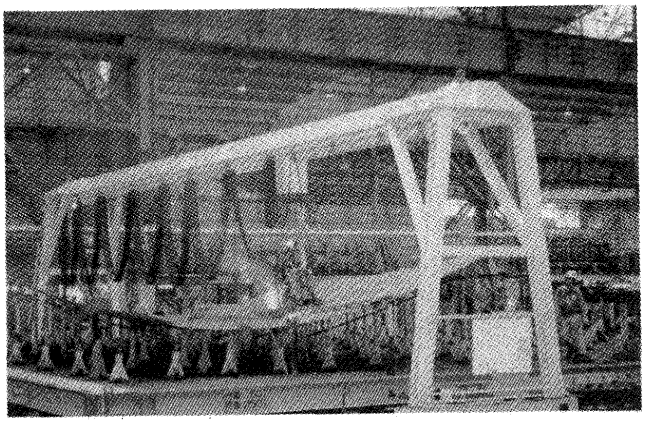

Fig. 7 Tandem one side GMAW robot for curved shell.

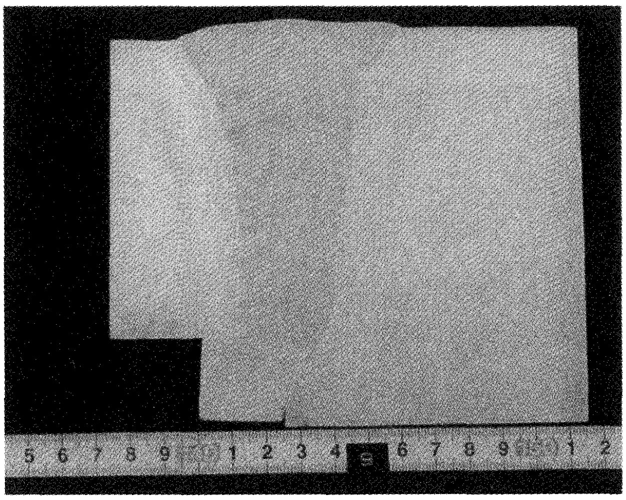

Fig. 5 Weld bead section for 90mm plate thickness.

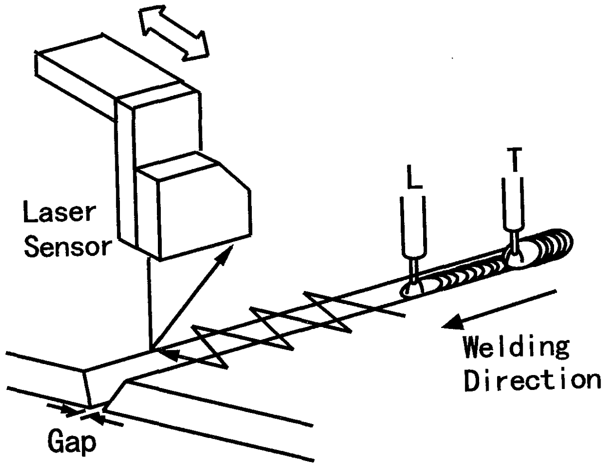

Fig. 8 Adaptive laser sensing.

metal cored wire and with a welding current of 500 A has been applied without root opening [13].

The latest development has been carried out for a 2-tandem CO_2 welding robot for a curved shell assembly shop in shipbuilding, see in **Fig.7**. The leading wire uses HSRA with 1.4 mm diameter solid wire having good anti-cracking properties, and trailing is a 1.2 mm flux cored wire. A carriage travels on a bendable rail, while various welding cables are hung by a movable gantry. An adaptive laser sensor, attached in front of the leading torch, detects joint position and groove shape, see in **Fig.8**, and a couple of slope sensors detect inclination of the joint during welding. Seam tracking and adaptive welding parameter control is carried out up to 20 degree slope and 5 mm root gap. A four times increase in efficiency can be obtained compared with conventional semiautomatic welding [14].

5. High Speed Tandem Fillet GMAW on Primer Coated Steel

The automatic welding process for flat horizontal fillet joints in panel assembly in shipbuilding and bridge construction was firstly carried out by 2 or 3 in electrodes in tandem SAW, and then around 10 years ago, more automated tandem MAG welding with sensing and programmable control was put into a shipyard [8]. But there remained a serious problem for " pit " which is opened by blow holes appearing at bead surface caused by gas blown out from the primer coating, see **Fig.9**. Recently, investigations have established that increase of molten pool length by the one pool tandem method is effective[15-17]. This method has been applied in shipyards. Decrease of pitting has been achieved at high welding speeds of 1.5 m/min and with 1.6 mm flux cored wire CO_2 welding [16-17]

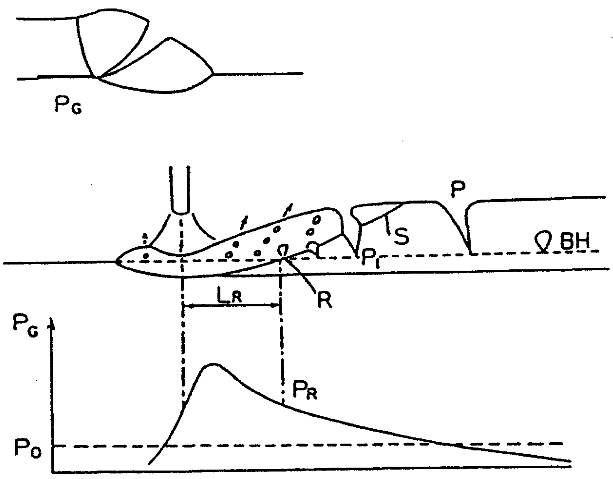

Fig. 9 Estimation on pit and blow hole.

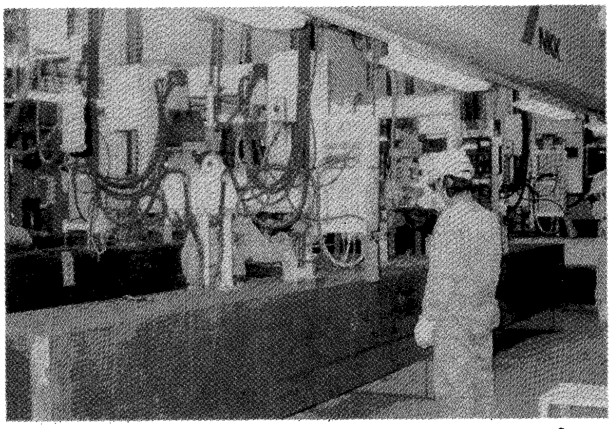

Fig. 10 12 heads eletroslag welding apparatus for diaphragm.

6. Electroslag and Electrogas Welding

6.1 Non-consumable nozzle electroslag welding

In place of conventional simplified electroslag welding with a consumable nozzle, the non-consumable nozzle electroslag welding process was developed. In the process, the wire guiding copper nozzle is as in GMAW, and its surface is isolated and the interior is water cooled. DC constant potential power is supplied to a contact tip. The nozzle is oscillated and raised upward so as to keep a constant welding current [18]. This welding apparatus has been applied to the joints between diaphragm and skin plate in building box columns, see **Fig.10**

6.2 Simplified electrogas welding

Simplified elecrogas welding apparatus characterized by portability was developed over 20 years ago, and since then applied in shipyards, bridges, and etc. Recently this process has been applied in building frame work in order to increase efficiency and to stabilize quality in place of conventional multi pass horizontal GMA welding [19].

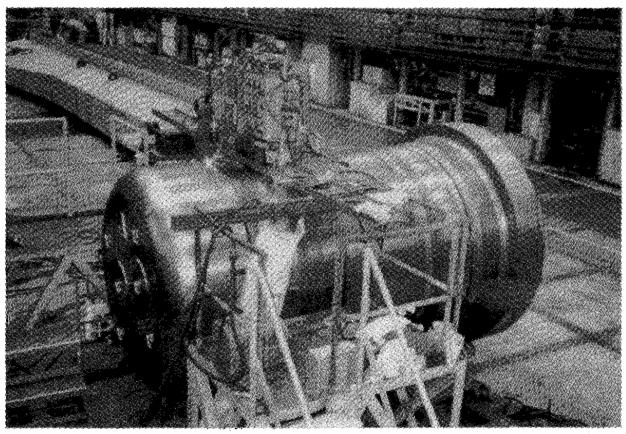

Fig. 11 Narrow gap welding for piston cylinder (276mm t.).

7. Narrow Gap Welding

Various narrow gap welding processes (GMAW, SAW, TIG) were developed before about 1985 in Japan. GMAW and SAW have mostly been applied in flat positioned heavy material, e.g. vessels, machineries, etc. **Figure.11** shows application examples of the high speed rotating arc (GMA) for cylindrical butt welding with 276 mm thickness. TIG processes have been applied in all position welding with several welding heads and with hot wire processes, e.g. nuclear vessel (SUS 304, 50 mm t.), penstocks (HT80, 50 mm t.), etc. [20].

8. Multi-torch, Multi-robot in Welding Systemization

Multi-torch, multi-head, multi-robot, etc. are the most effective adaptations to raise the efficiency of welding processes. These have been carried out during the systemization of automatic and robotized welding fabrication. In case of multi-robot systems, the systemization comprises subsystems as: CAD/CAM(or off-line teaching), CAPM-computer aided production

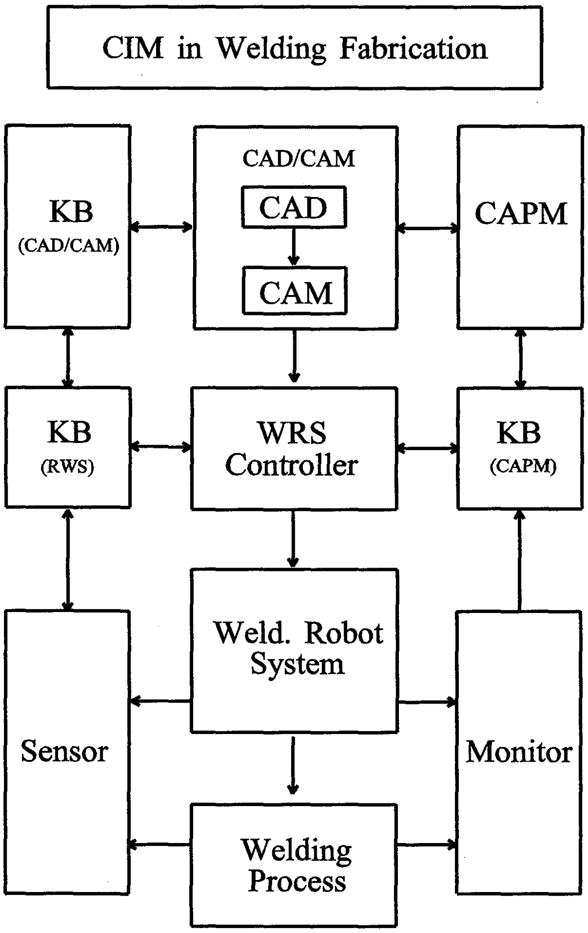

Fig. 12 Concept of CIM in welding Fabrication.

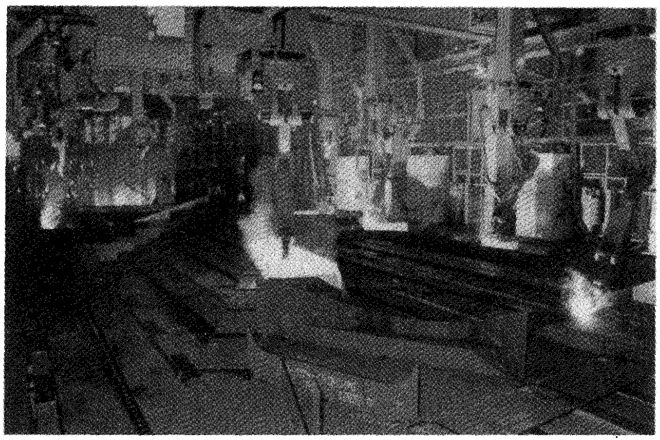

Fig. 13 Multi-robot system in subassembly in shipbuilding.

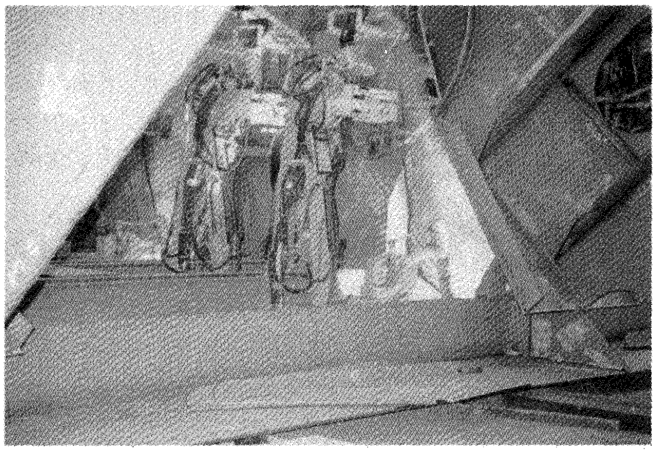

Fig. 14 Multi-robot system in assembly in shipbuilding.

Fig. 15 Multi-robot system in bridge panel.

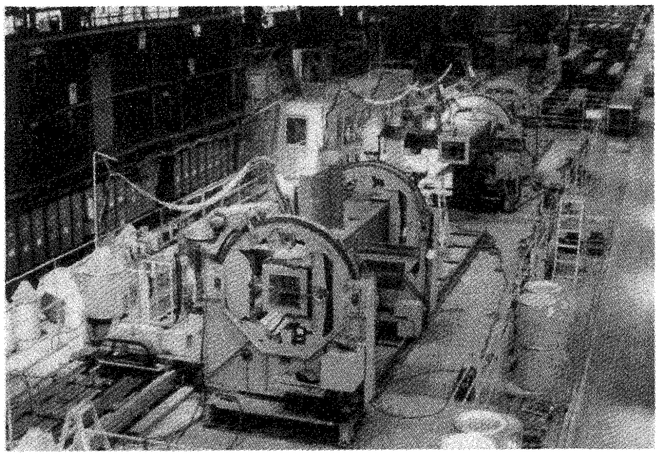

Fig. 16 Multi-robot system in column assembly.

management-, multi- robots, and sensor-based robot system controllers. Welding CIM as a goal of systemization will be achieved by better contribution of human abilities, termed " knowledge base (KB)", e.g. intelligence, sense, expertise, skill, etc., to the above subsystems, as shown in **Fig.12** [21-22]. Examples of recent application of multi-robot welding system in shipbuilding, bridge and steel column are shown in **Figs. 13-16** [23-25].

9. Conclusion

Increase in the efficiency of GMAW processes has progressed remarkably in such areas as single or 2-tandem one side welding, multi pass welding, high speed 2-tandem fillet welding, thin sheet welding, narrow gap welding, etc. in various fields. Application of flux cored wire for CO_2 welding with high current and high deposition rate is noteworthy

3 or 4-tandem SAW processes have been implemented for high speed one side welding in shipbuilding and large-heat-input deep-penetration welding in building frames. Electroslag welding and electrogas welding processes have also been implemented for specific applications.

Application of automatic or robotized welding systemization with multi-torches or multi-robots is being developed with GMA, SA and TIG welding processes.

References

1) J.Church, H.Imaizumi : Welding Characteristics of a new welding process, T.I.M.E. Process, IIW Doc. XII-1190-90
2) R.Lahnsteiner : The T.I.M.E. process-an innovative MAG welding process, Welding Review International 1992(2), 17-20
3) H.Yamamoto, S.Harada, Y.Yamamoto : Arc characteristics and metal transfer in high current MAG welding (Report 1), National Meeting of JWS 1989 45 118-119 (in Japanese)
4) M.Ushio, K.Ikeuchi, M.Tanaka, T.Seto : Effects of shielding gas composition on metal transfer phenomena in high current GMA welding, trans. JWRI, 1993, 22 1 7-12
5) Y.Sakai, T.Suga : Recent tendency of MAG/MIG welding wires, Welding Technique, 1993, 41(2) 62-71 (in Japanese)
6) K.Suda : High efficiency and low cost welding process, Joining Assembling automation, 1991, 12 60-65 (in Japanese)
7) H.Nomura, Y.Sugitani : Narrow Gap MIG Welding Process with High Speed Rotating Arc, IIW Doc. SG-212-527-82, XII-C-033-82
8) Y. Sugitani, Y.Kobayashi, M.Murayama : Development and application of automatic high speed rotation arc, Welding International, 1991, 5(7)-selected from Welding Technique 1990 38(2)-
9) N.Ohhama, S.Ohyama, T.Suzuki, K.Shinada, T.Miyazaki : High speed one-side submerged arc welding process " NH-HISAW ", ATAW 1996-77-82
10) S.Sakaguchi, T.Yamaguchi, C.Shiga : One pass submerged arc welding with flux containing iron powder for thick plate, IIW Doc. XII-1156-89
11) M.Mizobuchi, Y.Nishi : 3 electrode SAW equipment for corner welding of box column, ATAW 1996-162-166
12) ex. K.Uota et al : Development of portable carriage type multipass welding robot, Technical Commission on Welding Processes, 1986 SW-1733-86(in Japanese)
13) Y.Sugitani, M.Murayama, D.Ozamoto, Y.Kojima : Development and application of arc welding robot systems with highly efficient one side GMAW process, National Meeting of JWS, 1995 57 390-391(in Japanese)
14) Y.Sugitani, M.Murayama, D.Ozamoto, H.Murayama et al : Development and application of one side welding robot for curved shell, Technical Commission on Welding Processes, 1997 SW-2531-97(in Japanese)
15) Y.Sugitani, Y.Sato, N.Goto : Investigation on blow hole formation in rust prevented steel welding, Technical Commission on Welding Processes, 1992 SW-1301-92(in Japanese)
16) M.Kamada, T.Suzuki, N.Okui :High Speed Horizontal Fillet Gas Shielded Arc Welding Process, ATAW -83-88
17) T.Suga, S.Nagaoka, T.Nakano, K.Suenaga : An investigation into resistance to porosity generation in high speed horizontal CO2 fillet welding, IIW Doc. XII-1456-96
18) H.Fujiyama : Characteristics and application of SESNET welding process, The Structural Technology, 1992(7) 69-73(in Japanese)
19) S. Fujihira etal: Development of Automatic Electrogas Arc Welding Apparatus for Beam-Column Connection, ATAW 1995 -208-212(in Japanese)
20) Narrow gap welding-The state of the art in Japan-, 1986, Technical Commission on Welding Processes, JWS
21) Y.Sugitani, Y.Kanjo : CIM in Welding Fabrication (1st report), IIW Doc. XII-1497-97
22) Y.Sugitani, Y.Kanjo, M.Ushio : Welding systemization in Japanese heavy industries, Advances in welding & related technologies, 8-9 Sept. 1997, TWI, Cambridge, UK
23) Y.Sugitani etal : CAD/CAM Welding Robot System in Steel Bridge Panel Fabrication, IIW Doc. XII-1335-93
24) Y.Sugitani etal : Multi-robot welding system for sub-assembly in shipbuilding, IIW Doc. XII-1454-96
25) Y.Nishi : Introduction of the Large Assembly Welding Robot System for Box Columns Fabrication, The Structural Technology, 1996(5) 66-68(in Japanese)