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Development of Dual Torch Welding System for Pipeline and Its On-Site Application†

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Abstract:

Dual torch welding system was developed for girth welding to improve welding efficiency on the pipeline construction. This is the first application of girth welding to pipeline construction in Japan, reducing the welding time by half at field, and enabling high quality girth welding. The developed dual torch welding system is introduced and the effect of application is reported.

1. Introduction

On-site welding of pipelines has conventionally depended on experienced welders who possess a high level of skill, as it is outdoor work, groove accuracy is difficult to secure, and welding is performed by all-position one-side penetration welding. However, in recent years, shortages of skilled welders and the advanced age of available personnel have become serious problems. In response, automation of pipeline welding has been promoted. The main-force MAX-II automatic welding system for pipelines, which was developed by JFE Engineering, has been used to weld approximately 65 000 joints to date, and has earned a high evaluation from customers.

In recent pipeline construction work (high pressure pipelines) in Japan, the number of projects involving welding in non-open cut shielded tunnels and pipe casing welding has increased. Since welding efficiency determines total project efficiency to a greater extent than in the past, higher welding efficiency is now demanded. This paper presents an outline of the development of a dual torch welding technology for the purpose of achieving higher efficiency in automatic welding, and the results of its on-site application.

2. Transition of Automatic Welding Technologies for Pipelines

JFE Engineering began on-site introduction of automatic welding systems for pipelines in 1970, and has continued to develop automatic welding systems with the aim of improving weld quality and ending dependence on the competence of operators. **Table 1** shows the transition of the automation level. MAX, which was an automation level I technology, was an automatic welding system in which each of the operations was mechanized while retaining the feel of manual welding. This technology made an important contribution to easing resistance to automatic welding in the field. As a

Table 1 Transition of welding automation level

Category \ Level	I	II	III
(1) Mechanization of each operation	○	○	○
(2) Pre-set of welding conditions	×	○	○
(3) Sequence control	×	○	○
(4) Seam tracking control	×	×	○
(5) Adaptive control	×	×	○
Automatic welding system of the JFE Engineering Group	MAX From 1970	mini-MAX From 1987	MAX-II From 1987

○: Affained ×: Unaffained

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level II technology, mini-MAX is an automatic welding system for small-diameter pipes, and realizes presetting of welding conditions and automatic sequence control of the welding operation. The level III technology MAX-II achieves automation of vertical movement of the torch and seam tracking. MAX-II has been improved repeatedly to date and is now JFE Engineering's leading automatic welding system for pipelines.

3. Dual Torch Welding System

3.1 Outline

Because the conventional automatic welding system MAX-II for on-site girth welding of gas pipelines in Japan was based on a one welding head/one-torch design, as shown in **Fig. 1**, efficiency was limited. The high efficiency welding system developed in the present work is equipped with two torches in one welding head, as illustrated in **Fig. 2**, with the aim of reducing welding time by half. This technology is called the "dual torch welding system."

Following various tests, the dual torch welding system was applied to welding in shielded tunnels and pipe casing welding by a major gas company, and excellent results were obtained in both welding efficiency and weld quality.

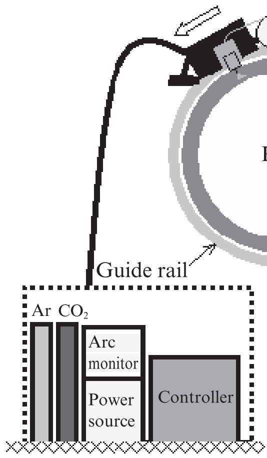


Fig. 1 Components of 1head welding system

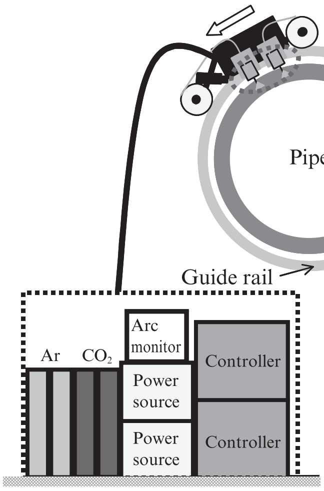


Fig. 2 Components of dual torch welding system

3.2 Composition of Equipment

The components of the dual torch welding system are shown in Fig. 2. The features of the system are as follows:

(1) The weight of the dedicated dual torch welding head in one unit is approximately 1.5 times that of the conventional type.

(2) The controller, welding power source, shield gas, and other equipment all comprise two sets of the conventional-type equipment and are interchangeable with the conventional type.

(3) The dedicated welding head uses a common travel axis; however, two sets each are provided for all other axes, including the torch lateral axis, torch vertical axis, wire feed axis, etc.

3.3 Key Points of Technology

3.3.1 Welding conditions

In other countries, pipeline welding is performed using a U-groove or a 2-step V-groove with a narrow groove angle of about 10° or less. On the other hand, because higher weld quality is required in on-site girth welds of gas pipelines in Japan, the country with frequent earthquakes in comparison with other countries, a V-groove with an angle of 30°–60° is normally used. Accordingly, in the build-up sequence in conventional automatic welding, the build-up thickness of each layer

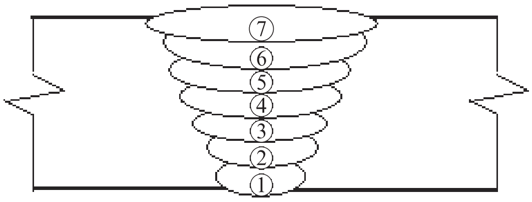
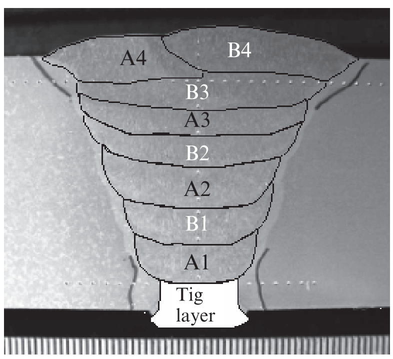


Fig. 3 Build-up sequence of conventional automatic welding



A: Leading torch, B: Tracing torch

Fig. 4 Build-up sequence of dual torch welding does not change greatly, as shown in in **Fig. 3** (wall thickness: 17.6 mm). The optimum welding speed is also different in each layer, and the order of the welding speed is generally ①>②>③>④>⑤>⑥>⑦.

With dual torches, it is necessary to perform welding of two passes at the same speed. Therefore, 2-pass simultaneous welding conditions were established by incorporating a wealth of data on welding conditions in a database, and innovations were also made in the build-up method. The build-up sequence in dual torch welding is shown in **Fig. 4** (in the case of wall thickness: 17.6 mm). In the case of conventional welding, as shown in Fig. 3, after the first pass, finishing is performed in 6 cycles (6 layers, 6 passes). In contrast, in dual torch welding, finishing is performed in 4 cycles (7 layers, 8 passes), and the arcing rate of the two torches is substantially 100%.

In all-layer automatic welding, the welding conditions in first pass welding differ greatly from those in the following passes. Therefore, first welding is performed by the leading torch alone, and 2-pass simultaneous welding is performed from the second layer.

3.3.2 Inter-torch distance

In dual torch welding, the two torches are set adjacently. This means the welding current is supplied to the arc of the tracing torch several seconds after welding by the leading torch. As a result, the interpass temperature is high in comparison with conventional one-torch welding, and decreased strength of the weld metal due to the delayed cooling rate was a concern.

Therefore, based on experiments, the inter-torch distance was selected so as to obtain the same weld metal strength as in one-torch welding. **Figure 5** shows the relationship between the inter-torch distance and the hardness of the weld metal. Four levels within an inter-torch distance of 200 mm are shown, and are set in the order of A<B<C<D. In comparison with one-torch welding, a drop of approximately Hv30 could be seen with inter-torch distances A and B, but the same weld metal hardness as in one-torch welding could be obtained with C and D, and the fact that the weld metal hardness satisfies the specification of major gas companies was confirmed. Based on these results, the inter-torch distance is set between C and D.

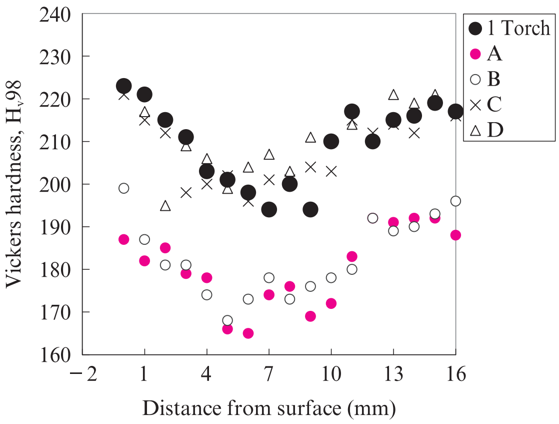


Fig. 5 Comparison of Vickers hardness

3.3.3 Possibility of welding by one operator

With conventional-type one-head (one-torch) welding system, the operator monitors images of the welding taken by a CCD camera, which is mounted on the welding head, from a TV monitor, and makes fine adjustments in the oscillation width, seam tracking, etc. corresponding to variations in the groove. With the dual torch welding system, it is necessary to respond to variations in the groove while monitoring two torches. Therefore, the following functions were added to the dual torch welding system:

(1) Tracing Torch Memory Reproduction Function

In case the operator performs seam tracking and fine adjustment operation of the oscillation width of the leading torch, a newly-added function reproduces the memory of the leading torch and automatically performs fine adjustment of the tracing torch at the welding position where the operator performed the adjustment operation of the leading torch. This func-

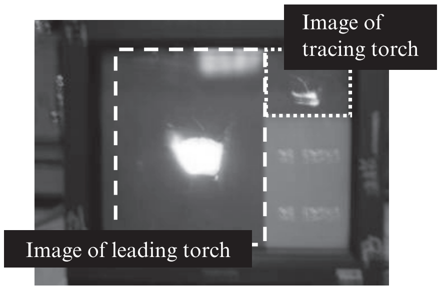


Photo 1 Arc monitor

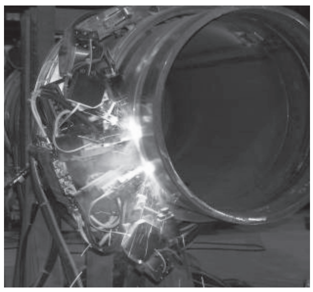


Photo 2 Welding scene of dual torch welding

Table 2 Result of mechanical property test

Tensile test (≧530 MPa)	604, 602 MPa
Impact test (Temp. 0°C≧40 J)	97−132 J (Ave. 117 J)
Hardness test (≦260) (Vickers)	3H: 188−233 (Ave. 209) 9H: 195−229 (Ave. 211)

tion makes it possible to obtain good weld quality, basically if the operator only performs fine adjustment operation of the leading torch for groove variations.

(2) Tracing Torch Monitoring Camera

A CCD camera which performs monitoring from behind was added for use in checking the initial position of the tracing torch. Operability is improved by simultaneous display of the two screens on the arc monitor (**Photo 1**) .

The condition of welding by the dual torch welding system is shown in **Photo 2**.

3.4 Weld Quality

The non-destructive inspection performance of the developed dual torch welding system is satisfactory in X-ray, AUT, and visual inspections. As shown in **Table 2**, the mechanical testing performance results also satisfied the general specifications of domestic gas companies.

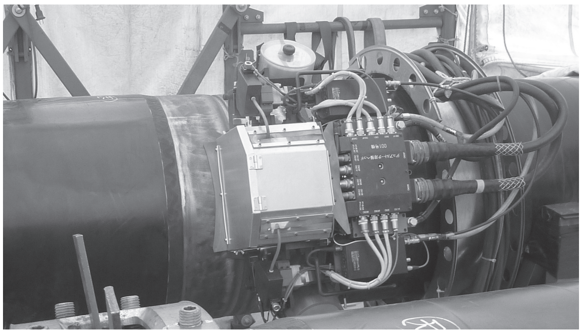


Photo 3 Appearance of welding on onshore pipeline construction

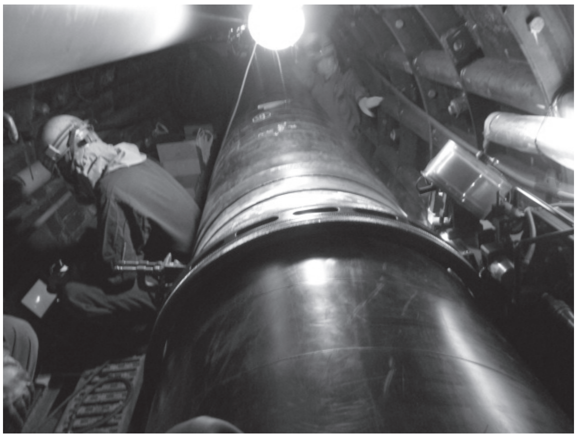


Photo 4 Appearance of welding in the shielded tunnel

Photo 5 Appearance of pipe casing welding

Table 3 Comparison of welding efficiency

Applicable sectors	O. D. × W. T. (mm)	Welding method	Welding time (min)		Cycle time (min) (Dual)
			1 Torch	Dual	
Onshore	610 × 18.6	T + S	104	53	70
Shielded tunnel	610 × 18.6	T + S	104	53	80
Pipe casing	610 × 15.6	S	90	51	210

O. D.: Outside diameter, W. T.: Wall thickness

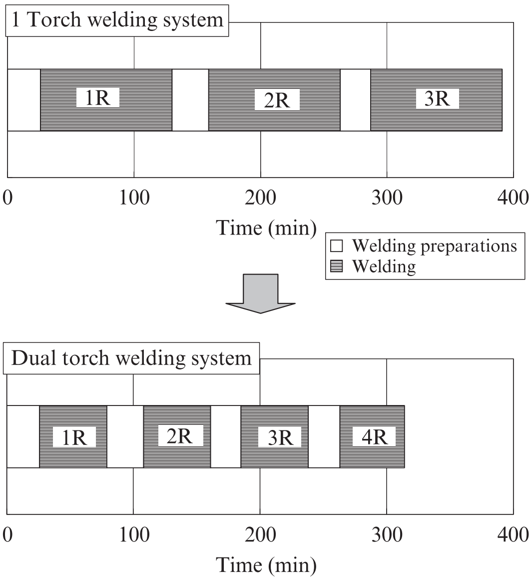


Fig. 6 Example of cycle time in the case of welding in the shielded tunnel

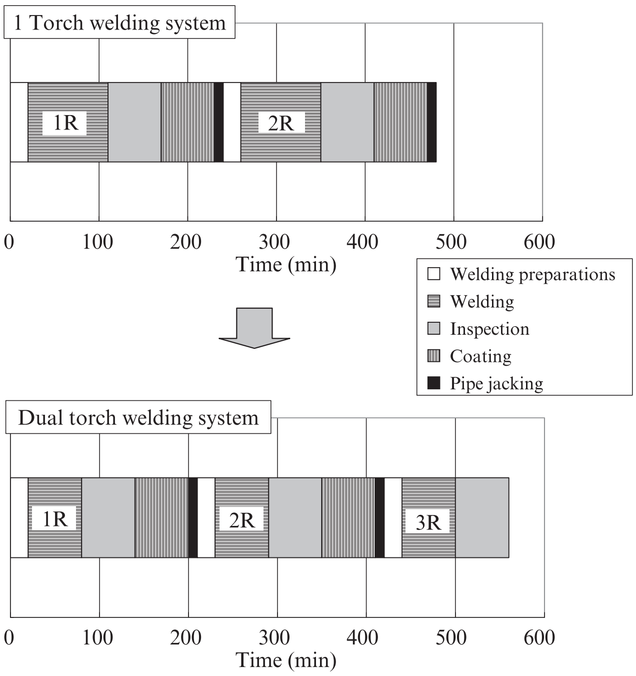


Fig. 7 Example of cycle time in the case of pipe casing welding

4. On-Site Application

The dual torch welding system was applied at an onshore pipeline construction site, shielded tunnel welding site, and pipe casing welding site of a major gas company. The conditions of application in each case are shown in **Photos 3**–**5**. In the onshore pipeline construction and welding in the shielded tunnel, first pass TIG welding + build-up dual torch welding was performed, and in the pipe casing welding, dual torch welding was performed from the first pass.

Weld quality was satisfactory, and was on the same level as that of the conventional one-torch welding.

A comparison of work efficiency is shown in **Table 3**. Welding time was greatly shortened when dual torch welding was applied, being reduced by 51% in comparison with conventional welding when the dual torch method was applied only to build-up welding and by 57% when applied from the first pass.

Figures 6 and **7** show efficiency in comparison with the conventional method. By using dual torch welding, it was possible to increase the number of joints welded per day from 3 joints by conventional welding to 4 joints in shielded tunnel welding, and from 2 joints to 2.5 joints in pipe casing welding, thereby confirming that welding efficiency is improved by dual torch welding.

5. Conclusion

The first dual torch welding technology for pipelines in Japan was developed and introduced in on-site welding. As a result, welding time was shortened to approximately 1/2 and improved welding efficiency was confirmed in all cases in onshore pipeline construction, welding in a shielded tunnel, and pipe casing welding.

In the future, successive introduction of the developed technology is planned at sites where welding efficiency affects work progress.

References

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