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Overview of Recent Welding Technology Relating to Pipeline Construction[†]

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Abstract

The welding technologies for pipeline construction of the high strength steel pipe are summarized mainly for the overseas pipeline systems in this paper. Considering the energy issue of Japan, the imperative problem is to realize the steady output of the natural gas. It is quite important to ensure the security of high pressure pipelines with increasing demand for natural gas. Since large scale high strength steel pipe fabricated by UOE or ERW process is used to build the pipeline, the welding technologies are essential.

KEY WORDS: (Pipeline) (High Strength Steel) (Laser) (GMAW) (MIAB) (EBW) (FRIEX)

1. Introduction

The long-distance pipeline for transportation of the natural gas, one of the green energy resources, is now under construction in the worldwide range, due mainly to the expansive requirement of the energy resources. One of the major difficulties is that, usually, the production area is far from the usage area, resulting in higher transport costs of the natural gas, although this has been known for many years. The optimum way of transport depends on the traffic volume and the transport distance. The transport by using pipelines in a major way, is shown schematically in Fig. 1¹⁾, and is more economic than the liquefied natural gas (LNG) transport system, especially on the land for short-distance transport.

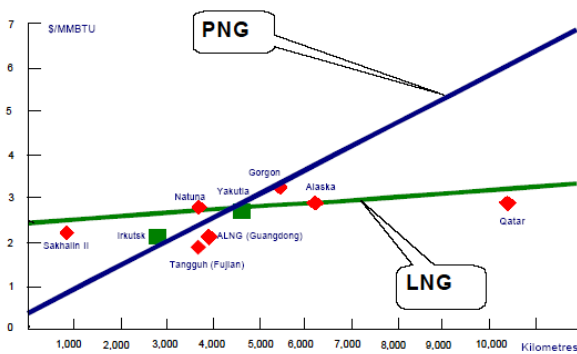


Fig.1 Transportation Costs by Types of Natural Gas Trade (APERC, 2005)¹⁾

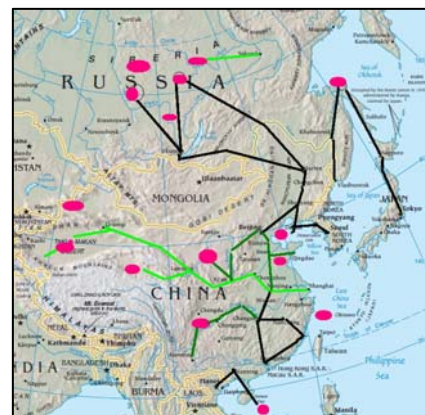


Fig.2 Large-scale pipeline projects in Asia³⁾

The pipeline for gas transport has been promoted in recent years in the US and Europe, compared with the well developed pipe network for oil transport. Especially in recent years, the higher grade pipeline has been highlighted to seek the low cost transport. The API 5LX-80 grade material was used twenty years ago. In addition, in the last decade, the X-100 grade material was first used in Canada to build a pipeline²⁾. Figure 2 shows the layout of the large-scale project in Asia, where the development of a pipe network was later than in Europe. A 4000 km West-East gas transmission pipeline to transport natural gas from the Tarim basin in Xinjiang and the Ordus basin in Shaanxi in western China to the Yangtze river delta in the east coastal regions, including Shanghai, has finished its first phase construction³⁾. The Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

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X-70 and X-80 grade pipe steels were used in this project.

In the future, under investigation of the long-distance pipeline, the transport costs of the X-100 grade material is likely to decrease through high pressure and thin wall thickness of the pipeline. Welding technology is one of the tasks of the related higher grade materials. Since large-scale high-strength steel pipe fabricated by UOE process is used to build the pipeline, the welding technology for pipeline construction of the high-strength steel pipe is summarized in this paper.

2. Welding Technology

The majority of welded steel pipe is produced from coil or plate. To produce pipe, the coil is cut to length and the edges are mechanically slit. Then a subsequent forming process is applied. The choice of welding process is largely dependent on the steel grades to be welded. Pipes are manufactured at the pipe mills by different welding techniques, such as submerged arc welding (SAW) process and electric resistance welding (ERW) process. Both have been widely used in the manufacturing of linepipes for many years. Although the welding speed and productivity are lower than ERW, in recent years, SAW is frequently used to produce the X-100 and X-120 high-grade pipelines, taking into consideration the toughness and tensile properties⁴⁾. Here, not only the thick steel plate, but also the SAW welding material with higher toughness and tensile properties are now under development⁵⁾. The strength of the seam weld metal of the UO pipe depends on the microstructure, which is determined by the alloy composition. The microstructure transformed from acicular ferrite to bainite with increasing strength, and furthermore transformed to martensite with increasing alloy composition. **Figure 3(a) and (b)** show the microstructure of weld metals for the X-70 grade, acicular ferrite, and X-120 grade, mainly bainite, respectively⁶⁾.

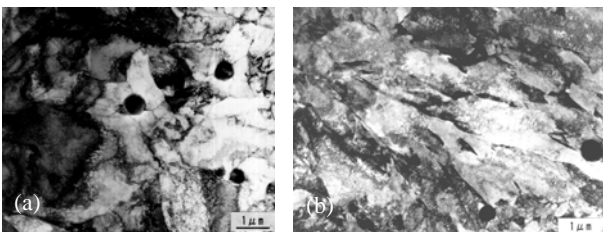


Fig.3 Microstructures of weld metal for (a) X-70, and (b) X-120⁶⁾.

The requirement for the properties of a weld joint increases as the grade of the linepipe increases, thus the applicability of the new welding method was investigated. The laser welding technique has been developed in Japan for the pipes up to 24 inch in diameter and wall thickness up to 10 mm with a production rate of approximately 10 m/minute^{7,8)}. The LAWPIPET consortium in the EU consists of companies including the steel producer, pipe manufacturer, pipe laying contractor and the universities.

The overall objective of the LAWPIPET project is to produce high grade steel linepipe with high toughness properties based on the induction assisted laser welding process. The high property and high effectiveness welding is successfully realized, by using the combination of high frequency pre-heating and keyhole welding. The relationship of laser beam penetration versus welding speed for various laser beam power up to 45 kW is shown in **Fig.4** for low carbon steel up to 38 mm thick. The welding joint with better mechanical properties was obtained and the microstructure of the fabricated the X-80 grade steel pipe is shown in **Fig. 5**.

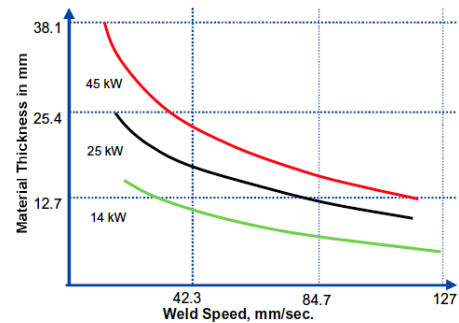


Fig.4 The relationship of laser beam penetration versus welding speed for various laser beam power up to 45 kW⁷⁾.

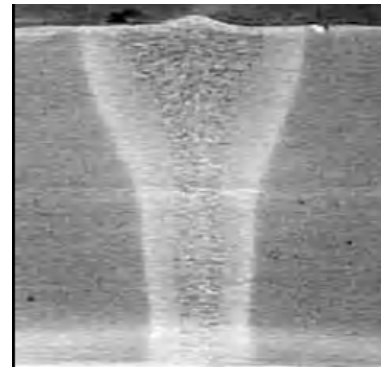


Fig.5 Laser induction welded 12.7- mm thick X 80⁹⁾.

3. On-Site Welding

The pipeline can be prepared in tens of meters everyday in Japan, whereas in foreign countries, it can reach 2 to 3 kilometers. The famous spread welding method, includes the edge preparation, axis alignment, root-pass, filler pass and cap pass welding, simultaneously. This inner-outer welding system was typically realized in 1969 by CRC-EVANS Company, and is used continuously until now.

Since more than 300, 0000 welding joints are involved along the 3500 km Alaska pipeline, the main factor to cut the cost is to improve the speed of on-site circumferential girth welding. Several pipeline contractors now offer

dual-torch welding equipment although single-torch systems still remain the most widely used. Tandem GMAW differ from conventional GMAW as two welding wires are passed through the same welding torch. A single torch with two contact tips is used to feed both wires into a single weld pool. CAPS may be used with a single torch or dual-torch arrangement. Dual-tandem involves two torches each with two wires. The dual-tandem GMAW provides the greatest productivity with four welding arcs operating simultaneously on each welding carriage(see Fig.6). Figure 7 shows the macrosection from the weld in 14.9 mm wall X-100 linepipe.

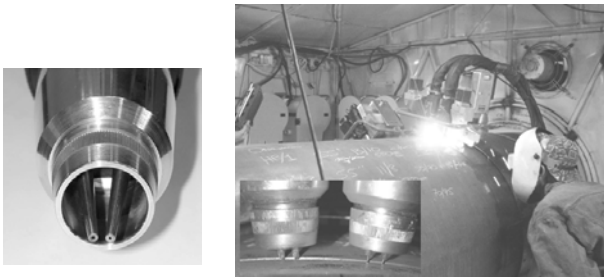


Fig.6 CAPS dual-tandem GMAW welding ¹⁰⁾.

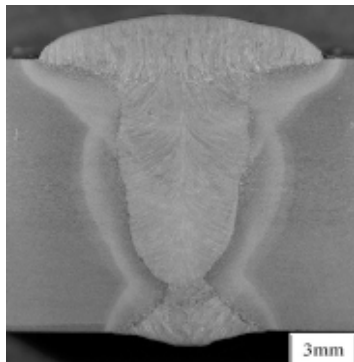


Fig.7 Macro section from weld in 14.9 mm wall X100 linepipe by CAPS dual-tandem GMAW welding ¹⁰⁾.

New welding consumables for X-120 grade linepipe was developed as a microstructure of acicular ferrite combined with martensite in circumferential girth welds¹¹⁾.

Under the condition of offshore pipe laying, the welding is carried out on the barge ship, and then the pipeline is laid on the seabed. It is important to improve the effectiveness of circumferential girth welding, because the rental fee of a barge is quite high. Thus, various measures are taken to establish the high-power CO₂ laser welding system on the barge ¹²⁾. Recently work has been carried out to investigate the use of hybrid laser/arc processing for improving the performance of laser welding applications.

The on-site adaptability is better, because the YAG laser can be transmitted by fiber. Figure 8 shows the developed YAG laser/MAG hybrid laser-arc welding,

which combines high-speed depth welding and arc welding ¹³⁾. An example of this type of joint through 16 mm thick pipe is shown in Fig.9 as internal GMAW root run, laser fill and GMAW capping pass.

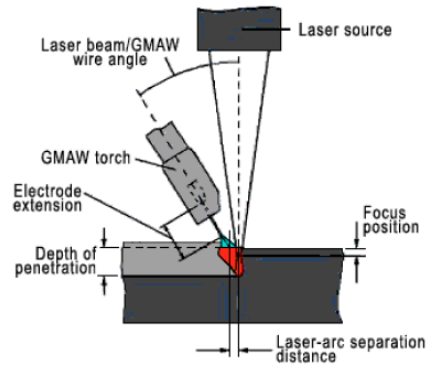


Fig.8 Hybrid laser-arc welding ¹³⁾.

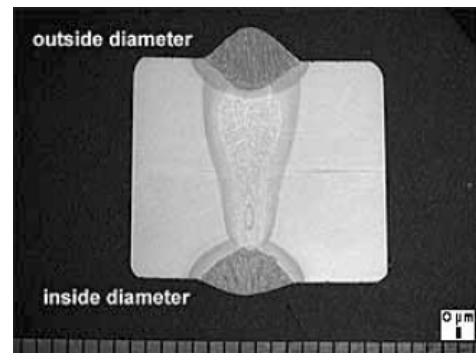


Fig.9 Section through 16mm thick pipe wall, showing internal GMAW root run, laser fill and GMAW capping pass ¹³⁾.

The reduced pressure electron beam welding has been developed, in which the gun can rotate along the horizontal direction, schematically shown in Fig. 10 ¹⁴⁾. Many of the potential thick section, industrial applications in the 1990s required in excess of 50mm penetration and it was felt that these could best be undertaken in an intermediate pressure regime. Of course, it was relatively easy to fire a NVEB beam into a chamber in which the pressure and gas species could be readily controlled. Studies were made of the beam profiles at pressures of between 1000mbar and less than 0.1mbar and it was discovered that with suitable electron optics, a near parallel electron beam could be sustained over a long working distance range even at pressures of the order 1mbar.

In 1994, Japan began the national project to develop the electronic beam welding, in which the fixing pipe was horizontally deposited as shown in Fig.11 ¹⁵⁾. During the welding process, the gun can be moved inside. This low-heat welding method without filler metal makes it appropriate for the electron beam welding. All position continuous EBW sequence for API 5L-X65 steel pipe of

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15.1 mm in thickness and 609 mm in outer diameter was established by using the new welding system.

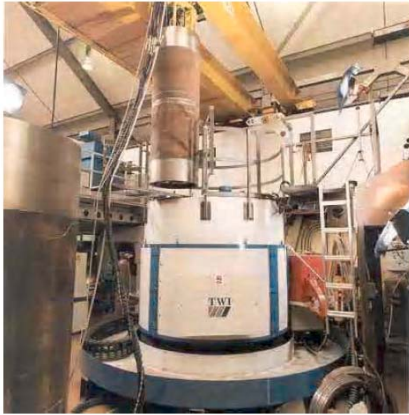


Fig.10 Laboratory Prototype Reduced Pressure EB welding system developed by TWI/Saipem for offshore pipelay¹⁴⁾.

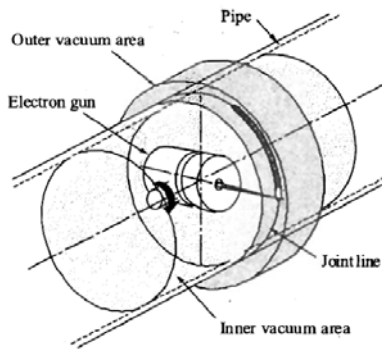


Fig.11 Basic concept of EBW system layout for pipeline joints¹⁵⁾.

Magnetically Impelled Arc Butt Welding (MIAB), one of the single shot methods, is now developing in Australia, in which the magnetic coil is rotated around the arc. The MIAB welding process is a forge-welding process similar to other processes such as electric resistance welding, and flash butt welding, except that a different method of heating is employed prior to the forging cycle. The square edged pipe ends to be welded are separated by a small gap, and a welding arc is established in the gap. A radial magnetic field is then superimposed upon the gap and this causes the arc to rotate. A schematic view of the process is shown in **Fig.12**¹⁶⁾. By using this method, a pipeline with a thickness of 15 mm can be welded in little more than 15 s. Furthermore, in the freezing area of Russia, flash butt welding is frequently used as a substitute for arc welding, as shown in **Fig.13**, because another pre-heating process is not needed. The pipelines can be joined due to friction heat, when the sander ring is rotated between the pipes.

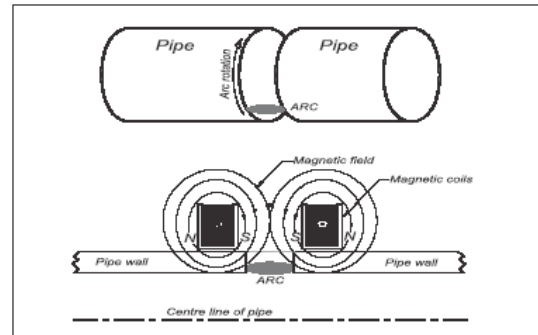
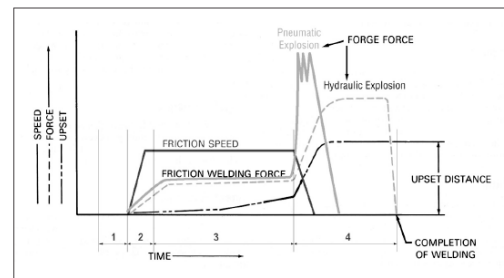
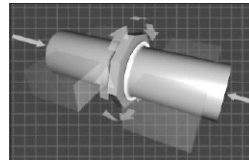


Fig.12 Magnetically Impelled Arc Butt (MIAB) welding¹⁶⁾.



Fig.13 Flash Butt welding in Siberia.



The Friex welding process consists of four distinct phases.

Fig.14 FRIEX: friction welding of pipeline girth welds¹⁷⁾. This is called the friction and explosion (FRIEX) welding process, one of the friction welding methods¹⁷⁾. The major difference of this variant with the classic friction welding process is that a filler material in the form of a solid ring is used. This welding ring is placed between the pipes, and rotating the ring under an axial pressure generates the required friction and associated heat. A principle drawing of the process can be seen in **Figure 14**. The friction welding process is

controlled by the rotation speed, upset force and upset distance. **Figure 15** shows the macrograph of the weldment of X42 pipes. In addition, in the friction stir welding (FSW), typically used in the field of aluminium alloys, we are developing the FSW rotation tool used for carbon steel.

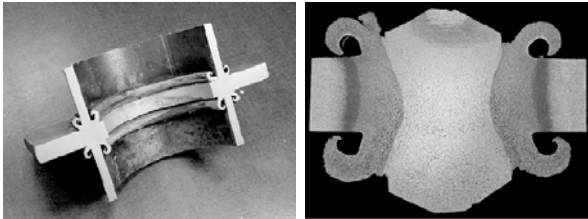


Fig.15 Macrograph of the weldment of X42 pipes by FRIEX ¹⁷⁾.

4. Prospect

The welding technology of the high-grade pipeline is discussed, mainly for the overseas pipeline systems. The number of receiving bases for LNG in Japan is the highest in the world, but the length of pipeline is only 1% of the US. Considering the energy issue of Japan, the imperative problem is to realize the steady output of the natural gas. It is quite important to ensure the security of high pressure pipelines with increasing demand for natural gas.

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