

## Automatic Pipeline Welding System with Self-Diagnostic Function and Laser Vision Sensor

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**Abstract:** Automatic welding has been used frequently on pipeline projects. The productivity and reliability are most essential features of the automatic welding system. The mechanized GMAW process is the most widely used welding process and the carriage and band system is most effective welding system for pipeline laying.

This application-oriented paper introduces new automatic welding equipment for pipeline construction. It is based on cutting-edge design and practical welding physics to minimize downtime. This paper also describes the control system which was designed and implemented for new automatic welding equipment. The system has the self diagnostic function which facilitates maintenance and repairs, and also has the network function via which the welding task data can be transmitted and the welding process data can be monitored. The laser vision sensor was designed for narrow welding groove in order to implement higher accuracy of seam tracking and fully automatic operation.

**Keywords:** Automatic Pipeline Welding, Self-Diagnostic, Laser Vision Sensor, LonWorks

### 1. INTRODUCTION

There is strong trend for increases in natural gas consumption worldwide, which implies continued growth of pipeline installation [1]. Worldwide, it is reported that 20,000 km of pipelines were completed in 2003 at a cost of US\$15 billion.

There are two different pipeline laying, onshore pipe lines (land lines) and offshore lines (submarine lines). The lay of submarine lines is done from onboard huge semi-submersible barges, having high costs and working 24 hours a day, where the decrease or increase of times can mean the difference between profit or heavy losses.

Automatic welding has been used frequently on offshore pipeline projects. The productivity and reliability are most essential features of the automatic welding system. It has been proved that the carriage-and-band system is most effective on pipeline lay barges. Currently, many pipe laying contractors rely on automatic welding by using their own proprietary equipment or renting it at a high cost.

The aim of this development is to develop a new generation automatic pipeline welding system based on cutting-edge design and practical welding physics to minimize downtime caused by weld defects and machine faults on the barges. To achieve this, the self-diagnostic function has been developed so that the system can automatically detect faults status for each control board and cable connection.

The system consists of dual torches, a mechanized carriage with five axes (four for dual torch up/down and left/right motion, one for travel motion), a guide ring, a main control unit, a wire feeder box and two welding power sources.

The developed system has various features to make a weld effectively. In addition to the self-diagnostic function, the system offers through-the-arc weld seam tracking, a laser vision sensor, a remote pendant, a remote jog and remote monitoring function. Process monitoring and job data transfer are possible using delicate software running on a Windows system via LonWorks network.

The laser vision sensor was specially designed for narrow welding groove in order to implement higher accuracy of seam tracking and fully automatic operation. Front and rear torches can be controlled individually, and weaving frequency and width can be set separately on both torches. Arc amperage is maintained in each torch within a specified range through

either the arc sensor or laser vision sensor. We adopted the advanced motor control technology to move the carriage under a smooth speed profile around pipe circumference.

The mechanized carriage has been designed to have a slim, ergonomic design and less weight so that the operator can handle easily. Utilizing a CAD software, a unique, patented clamping handle design was obtained.

### 2. SYSTEM CONFIGURATION

For offshore pipeline installation, there are line-up, welding, NDT and coating stations on a lay barge. Fig. 1 shows layout of automatic welding production line on a lay barge. The number of welding stations depends on the thickness of a pipe. The welding station consists of typically two welding carriages traveling around the pipe on a guide ring. Each welding carriage is controlled by computerized system.

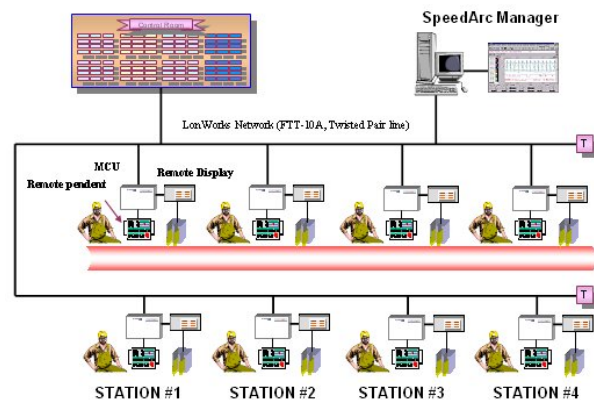


Fig. 1 Layout of automatic welding production line on a lay barge

Each welding system consists of a dual welding torch, mechanized carriage with five axes, a guide ring, a main control units, a wire feed box and two power sources. Fig. 2 shows components of each welding system.

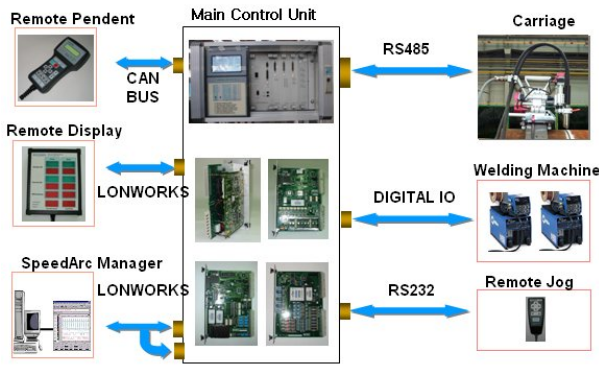


Fig. 2 Block diagram of system configuration

**3. AUTOMATIC WELDING SYSTEM**

The automatic welding system for pipeline welding consists of a welding carriage, a main control unit, a remote pendant, a remote display and other welding peripheral device.

The feature of the developed automatic welding system is outlined in Table 1.

Table 1 The feature of the automatic welding system.

Pipe size	Above 8 inch
Travel speed	0 ~ 4500mm/min
Torch distance	55 mm (adjustable)
Oscillation speed	5 Hz at 2mm oscillation width
Oscillation width	0 to 50 mm
Torch dwell time	unlimited
Torch up/down stroke	50mm
Welding position degree	1 degree
Torch type	Water cooled or air cooled
Carriage weight	15Kg

**3.1 Welding carriage**

Offshore pipe laying is achieved consecutively during 24 hours a day if the weather is good. So durability, reliability and easy maintenance were considered in design of carriage. Fig. 3 shows the schematic diagram of developed welding carriage.

The carriage consists of total 5 axes, four axes for dual torch up/down and left/right motion and one for travel motion. The dual torch independently control up/down height and oscillation width.

The weight of carriage is crucial point because welding helper places the carriage on guide ring more than 400times in a day. So the weight of carriage was designed under 15kg.

Fig. 4 shows the picture of automatic welding carriage developed.

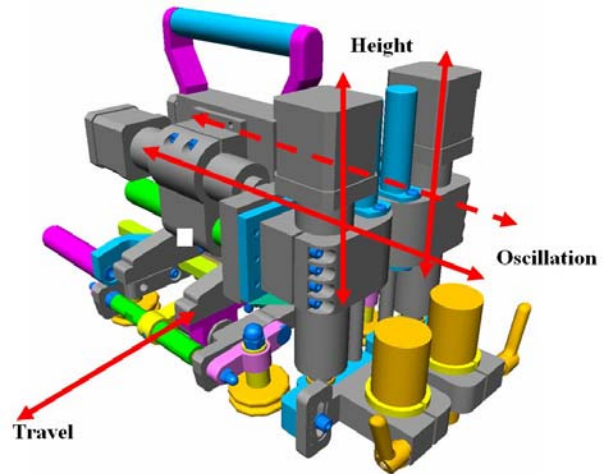


Fig. 3 Schematic diagram of welding carriage developed

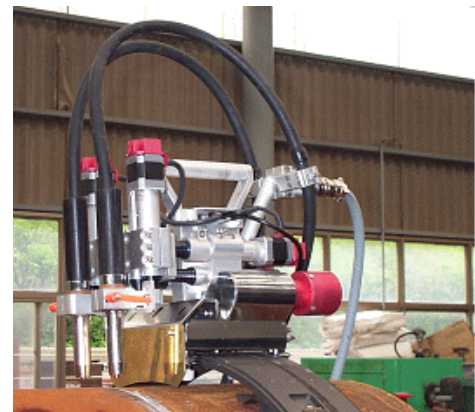


Fig. 4 Picture of automatic welding carriage developed

**3.2 Main control unit**

The main control unit consists of a MPC850 board(MPC), a bus control board(BCB), a travel control board(TCB), a motion control board(MCB), a welding control board(WCB) and a welding analog board(WAB) as shown in Fig. 5.

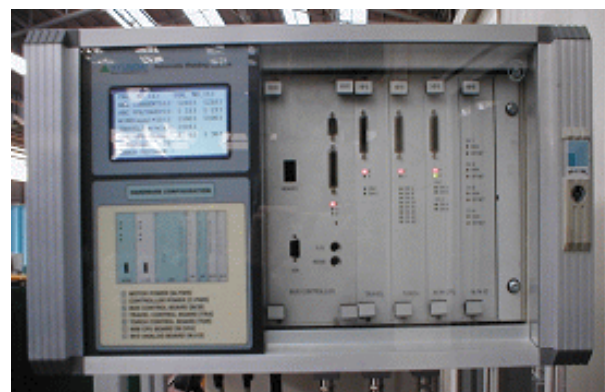


Fig. 5 Main control unit

The MPC stores welding process data by real time via USB flash memory.

The BCB manages welding database received from a welding condition management software via LON (Local Operation network). The welding database in BCB is passed to each control board through VME bus. The BCB collects

operating state of each control board and welding process data through VME bus also.

The TCB controls DC motor so that carriage can follow a pre-defined welding speed on a guide ring.

The MCB controls vertical and horizontal motion of front and rear welding torches.

The WCB controls welding current and arc voltage of welding machines by using through-the-arc sensor.

The self-diagnosis function of the system monitors faults of hardware operation. The fault diagnosis should guarantees the normal operation of the system. So the self-diagnosis function can judge faults of hardware and operation. Each control board has its own fault diagnosis function. The BCB collects various faults from each control board and displays the alarm message.

Fig. 6 shows multi processor system for automatic welding control system.

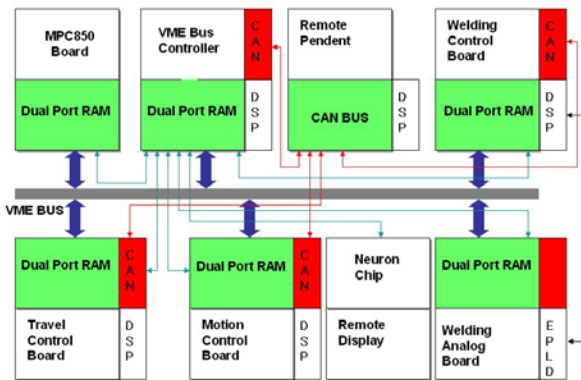


Fig. 6 Multi Processor system for automatic welding carriage control system

The features of main control unit can be summarized as follows:

- Fully micro-processor control
- Multi processor system
- Process monitoring, logging and saving function
- Accurate arc control
- Through-the-arc tracking
- Self-diagnosis function
- Automatic torch alignment

**3.3 Remote pendant and display**

The welding operator handles a remote pendant most frequently for welding database selection and carriage operation. Therefore, the remote pendant should be designed so that the operator can use very easily. Fig. 7 shows the developed remote pendant.



Fig. 7 Remote pendant

Remote display is the device that can display welding process variables on real time. So, welding inspector and quality management expert can monitor welding variables such as welding current, voltage, wire feed rate and welding speed. Fig. 8 shows the developed remote display.



Fig. 8 Remote display

**3.4 Network monitoring and welding database**

There are at least eight main control units and each MCU uses different welding parameters. All MCU are connected to Local Operating Network(LON). Remote monitoring software (SpeedArc Manager) has functions such as welding database management, remote weld monitoring and remote fault diagnosis function. The SpeedArc is a user-friendly application applying a graphical user interface. It allows fast development of welding procedure. It manages welding database and allows easy management of weld passes and conditions according to carriage angle.

Fig. 9 and Fig. 10 show some sample screenshot of SpeedArc software.

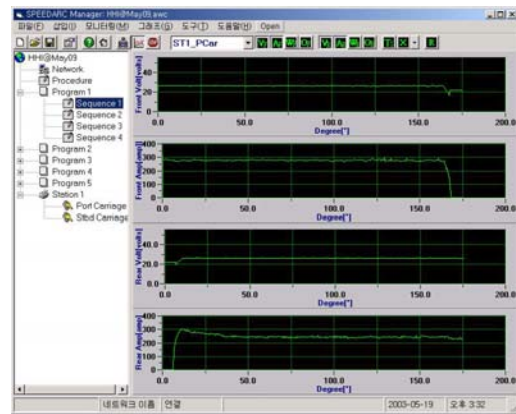


Fig. 9 Remote weld monitoring

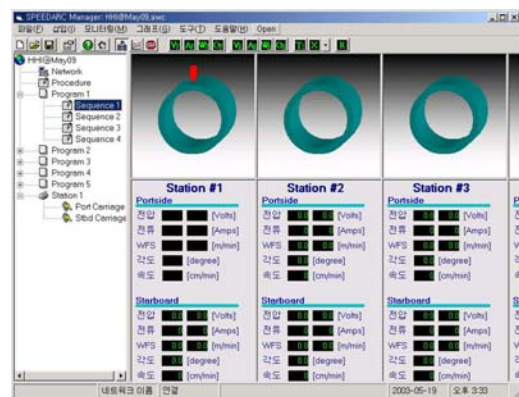


Fig. 10 Production monitoring



3.5 Laser vision sensor

The term “Automatic welding” has been used to describe GMAW pipeline welding for over thirty years but none of the systems are actually automatic. The carriage in use is actually mechanized and requires a high degree of welder skills. The daily productivity depends on welder skills. The welder continually monitors the position of the weld tip and makes corrections to keep the weld tip centered on the welding bead. The travel speed of welding carriage is higher than normal GMAW welding carriage and highly skilled welder can operate it without any welding defect.

The laser vision sensor can track correctly weld seam center with high travel speed and reduce welding defects as results.

The laser vision sensor was specially designed for narrow welding groove in order to implement higher accuracy of seam tracking and fully automatic operation.

The laser vision sensor consists of a vision sensor head and a controller. Vision sensor head is equipped with a CCD camera, a camera lens and a diode laser. Vision sensor controller is a computer based control system. It is connected with the MCU via RS232.

Front and rear torches can be controlled individually, and weaving frequency and width can be set separately in both torches. Arc amperage is maintained in each torch within a specified range through either the arc sensor or laser vision sensor.

Fig. 11 shows laser vision sensor developed.



Fig. 11 Laser vision sensor developed

Welding seam tracking results is shown in Fig. 12. It shows center points of front and rear torch.

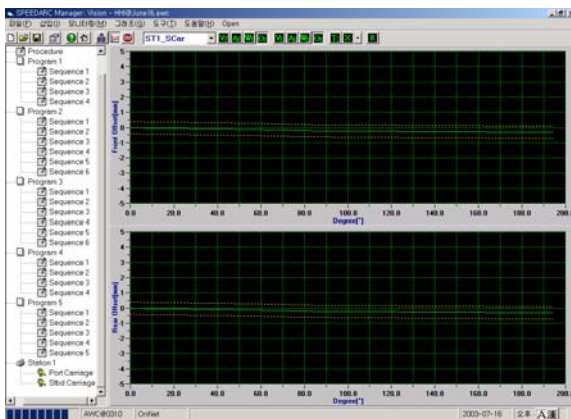


Fig. 11 Welding seam tracking results

4. CONCLUSIONS

The automatic welding system for pipeline construction has been developed and applied for Chunxio pipeline project in 2004.

The developed automatic welding system was designed to minimize downtime caused by weld defects and machine faults during production. To do this, the main control unit has self-diagnostic function and can automatically detect faults status of each control board and cable connections.

The mechanized carriage has been designed to have a slim, ergonomic design and less weight so that the welder can handle it more easily.

The laser vision sensor has been used for welding seam tracking. The GUI software for welding database management and welding state monitoring was successfully applied to actual project.

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