Ultrasonic Production Monitoring of Small Diameter ERW Pipes

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Abstract
Electro Resistance Welded (ERW) pipes are attractive for their reliability and cost effectiveness. However a 100% final ultrasonic inspection is required to avoid any weld defects. While the large diameter pipes (6-24”) are inspected with contact or gap probes, smaller diameter (less than 4.5” or 10-12cm) are inspected with ultrasonic rotary heads. The first method is not easily adaptable to small diameter pipes. The second method is capital-intense and involves high maintenance efforts. A new method for small diameter pipes is described here. A combination of local immersion with high focusing of ultrasonic beams yields high sensitivity and high inspection speeds at affordable costs. Weld and full-body inspections are undertaken simultaneously. The method, as well as comparison with other techniques, will be described and analyzed.

Keywords: ultrasonic testing (UT), ERW pipes, ultrasonic production monitoring small diameter pipes.

1. Introduction

Electro resistance welded (ERW) pipes are advantageous and becoming more common. The manufacturing process starts with a metal strip, which is bent into the pipe shape. The two ends are heated by high frequency (250 KHz) induction heating and pressed together to form a metallurgical bond. The process is simple, reliable and cost effective.

Up to four NDT UT steps are sometimes used to analyze defects: inspection of the metal strips, an on-line UT test as a control tool, (transverse defects only), deburring /scarfing check to monitor internal wall and a final UT test as a quality tool, carried out after hydrostatic pressure tests.

In this presentation we are detailing the final UT system for mill production of small diameter ERW pipes.

2. Problem Definition

The ultrasonic testing of ERW pipes uses two main methods. Water gap testing with shear wave probes with internal or external wedges is common for larger pipe size 5-24” (125-600mm) (TSI, Carl Deutsch[1,2]).

For smaller pipes, 2-8” (50-200mm), rotary head ultrasonic is used. This method uses immersion probes set to generate 45° refracted angle, rotating around the pipe at high speed (600-3000 rpm) (GE Rota, MAC Echomac [3,4]).

The first method is simpler, economical, and easy for size change over, but the inspection speeds are usually in the 20-30m/min range.

The second method is faster more than 60m/min, reliable but very demanding on maintenance (seals) and change over times.

As detailed below, we used a combination of the above methods; immersion technique in local immersion mode with the pipe stationary for weld inspection and rotating pipe for full body inspection.
3. System Description
The system has the ability to inspect ERW welds as per API 5L to check longitudinal flaws, transversal flaws and laminations. Detected defects are marked, flaws with two colors and lamination with another color.
The system automatically tracks the seam and pipe bending, and performs a full-body pipe inspection. It works off-line.

The application calls for two systems with direct approach: for ERW weld inspection the pipe is stationary, while for full body, the pipe rotates. The two concepts were combined in one combo unit.

4. Transducers
The system consists of 6 transducers to test longitudinal flaws and HAZ, and another four probes by four channels each to test the full body for laminations. Each transducer has manual horizontal, height and angle adjustment.
The coupling liquid, water with additives, is contained in a stainless steel vessel ‘fishpond’ and the water level is monitored by sensor with electronic valves.
5. Seam tracking
The 100% coverage of weld inspection is complicated the fact by that the weld seam does not run in straight line down the tube. It can spiral along the tube.

A paint line is applied shortly after welding usually at 3 o’clock position to denote the weld. An LED source light and CCD camera with polarizing filter reads the line position to the tracking computer and if needed, sends a corrective signal to the servo motors to move the transducer head to be within ±0.5mm of the weld seam set up.

This seam tracking is the first step in inspection cycle after the pipe is loaded from the loading ramp. This brings the weld to 12 o’clock position.

During inspection the weld/probes setting is maintained by the seam tracker.

Figure 3: Paint line as seen by seam tracker cameras
6. **Dynamic Gates**
The A-scan signal on the weld side usually does not have the front wall; therefore we cannot use a Gate following technique to synchronize the gates. We use Main pulse synchronization (static gates) which requires constant distance between probe and pipe. This distance is not always constant along the pipe, because small diameter pipe bends when it is pushed down by the fishpond with probe. This causes signal change - the defect echo moves out of the gate. We developed a Dynamic Gate Synchronization to compensate the variation of pipe distance from the probe. We use the HAZ signal for the synchronization. HAZ probe is normal to the pipe and has reliable front wall. The gate is still synchronized by Main pulse, but its sync time is dynamically modified according HAZ front wall time change.

![Figure 4: A-scan image screen with UT parameters](image)

7. **Computers & Software**
The testing system has six industrial computers: a Control Computer, four Ultrasonic Computers and a Vision & Tracking Computer. The control computer controls the system, stores all collected data and generates testing reports. UT computers control the UT boards, collect and process the data and send information about defects to the PLC for marking the defect area. All computers are equipped with custom software developed for this application. The software is written in C++ under Windows 7.

The user interface allows for easy set up of all UT parameters for inspection. Each channel has its own parameters setting. This setting is stored on the control computer hard drive in a look up table.

The system is equipped with a tablet showing the screen of selected computer. It can be used as a remote control (figure 5). It is useful for the system setting and calibration. The operator can see the A-scan signal and set the parameters straight from the probe head location.

![Figure 5: Weld head with adjustable probes and remote set-up tablet](image)
The Vision & Tracking computer automatically tracks the weld seam with vision system technology, which consists of a camera, light source, and vision system software. All calibration data and test results are stored in a database on a Control computer. A database backup is run daily and is stored on another computer through company LAN. All tests can be printed in a single report or as a batch report.

8. PLC
The PLC is used to automate the operation of the system. The operations are: loading the test pipe, start movement of test head, clamping the probes on the pipe when the start of pipe is reached, filling the fishpond with coupling water and signalling the control computer to start the UT test. As the end of pipe is reached the probes are released. Proximity sensors are used at both the ends of the base on which the head move. It signals to stop the motors and end test cycle in that direction. Laser sensors are used to precisely identify the start and end of the pipe. The positional data is captured in real time using an encoder attached to the servo motor. The marking system is also attached to the test head. The defect position is communicated to the PLC through the control computer and PLC actuates the marking system when the defect position is reached.

9. Mechanics
The system mechanics has the following components
   a) Ultrasonic Stand for ERW Testing / full body
   b) Pipe Mechanics
   c) Material Handling
   d) Marking station (standalone unit)
   e) Pneumatic system
   f) Water system

9.1. Ultrasonic Stand for ERW Testing
The ultrasonic stand is constructed of rigid welded steel onto which two aluminium extrusion columns are mounted. These columns support the cantilever arm, which is height adjustable through a servomotor. The entire stand moves in an axial direction to the pipe along the full length of the pipe on the floor mounted gantry. Fixtures for the probes ensure that the probes sit precisely on both sides of the seam. The concept of probe mounting on pneumatic cylinders is depicted in figure 6 & 7.

![Figure 6: Close-up of the column showing both weld and full body heads.](image)
A CCD video camera mounted on the probe fixture tracks the seam (via the white painted line) and notifies the roller drive electronic controller of any error or deviation. The controller then directs the roller drive servo valve to keep probes within 0.5mm of the set position on weld.

For the full body testing, the TR probes head is positioned on the centre of the pipe. Adjustable air cylinders maintain the transducer’s position constant. The head moves along the axis of the pipe while the pipe rotates. With 16 probes in parallel (but fired in sequence) it covers max 350 mm in one sweep (figure 8). The water is wiped and blown off to allow for paint marking of the pipe’s defects.
10. Electronics
The following special electronics are used in the system: Ultrasonic boards, UPAM multiplexer boards, motor drivers and controllers, water level controls. Each UT computer is equipped with two or three UT boards. Each UT board has a High Voltage Pulser, Receiver, A/D converter (100MHz), a peak detector with four independent programmable gates, gate following and DAC capabilities and other parameters. Each channel can be triggered with a repetition rate 1-10KHz, which is fast enough to detect 1 mm flaws. Only two UT boards are used for the full body system. Each board is connected to an UPAM multiplexer board 1:8, which switches the UT board to one of eight (8) channels. Therefore, the Full body system is capable of operating on 16 channels. The UPAM boards are inside of a UPAM enclosure placed close to the weld probes on the ultrasonic stand. The multiplexer unit can perform in either calibration or testing mode. The calibration mode is a static mode. Any single channel can be selected and individually examined for calibration and troubleshooting purposes. The testing mode provides operation for all 16 channels in a sequenced fashion to test the pipe.

![Figure 9: Computer & PLC cabinets in the cabin.](image)

11. System operations
The combo system is capable of conducting the weld as well as full body inspection in one scan. These two inspections are independent of each other. Each inspection has its own set of UT probes and the required accessories along with the feedback mechanism through field sensors. Each inspection system has an independent marking scheme. The system marks the defects as it inspects and it is capable of testing in forward as well as reverse run. This feature of testing in both directions doubles the throughput of the system. The inspection speed achieved was more than 40 meters per minute.
Treated water is delivered from an in ground tank and is collected, filtered and reused. The pipe is first loaded to the weld inspection side. After the weld inspection, the pipe is rolled over the swinging bridge to the body inspection side and a new pipe is loaded on the weld side. In the second run both weld and full body inspection are done simultaneously. After the completion of the full body inspection the pipe is unloaded from the system the pipe on weld side is transferred on to the full body side and new pipe is loaded on the weld side and the process repeats.
The arm holding the marking paint nozzles swings 180° after each run in to follow the stand.

12. **Calibration pipes**
For each size one calibration pipe is prepared. As per API5L it has eleven test defects. i.e. three (3) I.D. notches, three (3) O.D notches, three (3)1/16” through holes, two HAZ 50% lamination defects. These calibration pipes are run at least daily or as per client requested frequency. The graphic display of calibration defects is shown in figure 10.

![Figure 10: Graphic report with calibration pipe defects](image-url)
13. Discussion
The system concept fits the applications in the range of 2-8” (50-200mm) pipe diameter and wall thickness of 1/8-1/2” (3-12mm). The challenge of the system is in ensuring mechanical stability, but the robust design provides the required rigidity. The small pipe curvature causes the beam to defocus and this has to be considered during set-up.
For thinner wall it is important that the probe is set to produce refracted shear wave only (figure 11).

![Figure 11: A-Scan of real LOF defect](image)

This will separate the reflections from the front wall and notch or real defect. Figure 11 shows the signals of real lack of fusion on 3” (75mm) diameter, five (5) mm wall thickness pipe. The signal-to-noise ration is very high >20db, credit to immersion coupling.
The system water consumption is moderate and water is recycled to an in-ground tank.
Small diameter pipes, 2” (50mm), have a tendency to sag so additional support had to be incorporated. Changeover times are shorter than for a rotary head system, but slightly longer than for water gap testing systems. Maintenance is moderate for a system of this complexity, dealing primarily with seals on fishponds and lubrication of pipe pneumatic cylinders for probes and kickers.
The combo concept saves floor space and simplifies production material flow.
The simplified weld inspection version of this system can be applied on-line as a process control tool.

14. Conclusion
We built an ultrasonic small diameter ERW pipe inspection system, based on local immersion for pipe mill use. This system offers an attractive and cost effective alternative to rotary head ultrasonic pipe inspection systems.

15. References