Phased Array UT Applied to Boiler Tube Inspection in Lieu of RT

Viwek VAIDYA 1, Charles THIBAULT 1, Stephan LAURIAULT 2, Dave GOLANI 3, Guy COUSINEAU 4

1 Mistras-Métaltec, Montréal, Qc, Canada 514 712 2801 e-mail: viwek.vaidya@mistrasgroup.com, charles.thibault@mistrasgroup.com,  
2 Kamtech Services Inc, Montreal, Qc, Canada e-mail: stephan.lauriault@kamtechservices.com  
3 Induscan Quality Inc, Mississauga, Ont, Canada e-mail: induscan@sympatico.ca  
4 Fortress Speciality Cellulose Inc, Thurso, Qc Canada, e-mail: guy.cousineau@fortresscell.com

Abstract

Recovery boilers need to be inspected on a regular basis to ensure boiler tubing used to make the components has not undergone premature wall thinning. Since the preventive maintenance must occur during a short planned shutdown of several days, any interference to work progression cannot be tolerated. Recently developed, advanced UT inspection techniques are now being solicited in lieu of radiography. These techniques use multi-element probes, reducing considerably the inspection time while providing computer generated image of the inspected area. This paper presents a case study of comparative data between conventional radiography and advanced ultrasonic testing applied to 0.165” wall, 2” diameter tubing, in SA210 Gr C material. This calibrated technology was recently used to inspect 420 economizer tubes during a fall shutdown in a paper mill in Quebec, Canada.

Keywords: Boiler tube inspection, Phased array UT

1. Introduction

Utility and recovery boilers need to be inspected on a regular basis to ensure boiler tubing used to make the components has not undergone premature wall thinning. The wall thinning can occur due to corrosion, thermal fatigue, corrosion fatigue, fly ash abrasion etc. Since the preventive maintenance must occur during a short planned shutdown of several days, any interference to work progression cannot be tolerated. For this reason, conventional industrial radiography is reluctantly used.

Recently developed, advanced UT inspection techniques are now being solicited. The techniques are so new, that most codes need properly documented experimental comparative data between RT and Advanced UT demonstrated to be equivalent needing documented acceptance by the customer and the ASME authorized inspection agency in the province.

These techniques use multiple micro-transducers in the make-up of the probes, reducing considerably the inspection time while providing computer generated image of the inspected area. This paper presents a case study of comparative data between conventional radiography and advanced ultrasonic testing applied to 0.165” wall, 2” diameter tubing, in SA210 Gr C material. This calibrated technology was recently used to inspect 420 economizer tubes during a fall shutdown in a paper mill in Quebec, Canada.
2. Scope of the work

Kamtech Services Inc was retained by Fortress Specialty Cellulose Inc. to refurbish the boiler components needing replacement and upgrade. This was to occur during a fall shut down at the Thurso mill in Quebec, Canada in 2011. Since the amount of work to be performed required 100% radiography, there was a possibility that the work stoppages during the radiographic inspection could negatively impact a tight shut down timeline of 18 days.

Three bottom economiser headers were to be replaced. There were several portions of the water walls that were also going to be replaced including some other piping work. All the tubes and pipe butt welds were to be inspected 100% by RT. The only time radiography could be conducted, was before and after shifts and break periods within the shifts.

Fortress engineers working with Dave Golani of Induscan Quality Inc and Stephan Lauriault, of Kamtech Services Inc were looking at ways to save inspection time in the boiler. Phased array UT inspection in lieu of RT inspection of the economizer tubes was proposed to Fortress Management. Fortress maintenance engineers were aware of this technology and knew about its use in Western Canada but they had never tried this new technology in the eastern part of Canada. Collectively, the group made a decision to use 100% Phased array inspection on the economiser boiler tubes in the boiler cavity to save time. They also decided to re-verify 5% of the tube welds with RT. Mistras Metaltec Inc was retained to work with Kamtech Services Inc. to provide the required inspection.

3. Welding Engineering

Welding of Economizer Tubes

Induscan Quality Inc selected GTAW process for economizer tube welding to ensure the steady arc performances and weld quality. This process is specifically applied for root pass welds for proper fusion and elimination of potential rework. The tube size (2” dia, 0.165 wall thickness) was in the range (0.250”) to have GTAW cover pass. This combination was beneficial in maintaining the same welding process particularly in a very tight workspace at the welds location of tubes and the related economizer header.

Procedure and welders were qualified for tube welds using GTAW/SMAW processes to ASME Section IX. Each qualified welder also welded actual size of tube using GTAW process only prior to the welding of economizer tube. Based on the initial results of Phased Array (PA) and Radiographic Examination (RT), we selected a team of welders that work together to achieve consistent results. PA process of Inspection permitted us to weld and inspect the joint without delays, and stoppage in the shutdown work period.

4. Economiser Header welds

The economizer headers were welded in a fabrication shop close to the site in Papineauville, Quebec. Since the 2 inch tubing was only 0.165” thick, it was decided to do the butt welding of the tubes using uniquely one welding process namely GTAW. There were three headers, each designed with five rows of tubes, with 30 tubes per row. The three headers were positioned off the ground and the technique of two welders welding up one tube was tested.
The key was for first welder to start the arc around the tube, while the second welder helped the first welder at around 160° with the wire feeding and then took control of the weld puddle from the other side of the tube once the first 180° of the circumference was welded, without breaking the arc. 'The welding duo' would constantly communicate with each other for switching between feeding the wire and the GTAW to carry the weld puddle uninterrupted all around the 360° circumference of the tube.

![Figure 1 Economizer header in the fab shop](image1)

![Figure 2 Economizer Header welded with 100% GTAW 'welding duo'](image2)

5. Radiographic results of the economizer welds - 'welding duo'

As can be seen in the figures 1 and 2, due to spacing of the tube rows it was important to clear the welds progressively row by row. Mistras Metaltec inspectors worked hand in hand with the welding supervision to provide results of the inspection, so that non conforming welds could be repaired and re inspected before installing the subsequent rows of the pipes.

Welder teams, who worked well together were chosen to perform the 'welding duo' and confirm compatibility through RT. The results were outstandingly good. Out of the first 296 welds inspected, there were only 7 tubes rejected. The rejection rate was recorded at 2.36%. Often the rejection rate for such work is close to 7-10%!
6. Phased array inspection technique

As the work in the fabrication shop was coming to an end, Mistras Metaltec Inc set up the phased array inspection procedure. It was decided to use the exact same tube diameter and wall thickness of the economizer tube for setting up the calibration tube sample. Two circumferential slots 1" long, by 0.017" deep, by 0.062" wide were machined on the outside and inside surface, at diametrically opposite locations.

Philip Ducharm, CGSB/ISO 9712 UT Level III and Patrick Déry EN473 LEVEL II PA/TOFD set up the UT Procedure #: IPP-PA-7701-11029 for this job. Calibration tube samples per T-434.1 in ASME Sec V Art 4 was made up and a scan plan calculated to determine the spacing between the probes.

The procedure contained all the needed information and more: Scope, Referenced Documents, Personnel Qualification Requirements, Safety Requirements, Equipment, Examination Area, Equipment Calibration, Pre-Inspeetion miscellaneous, Inspection Procedure, Recording, Acceptance Criteria, Disposition Instructions and finally Reporting Criteria.

The procedure covered the following scope:

- Thickness Range $\rightarrow$ 3.0 mm to 30.0 mm
- Diameter Range $\rightarrow$ 19 mm minimum, no maximum
- Material $\rightarrow$ Carbon Steel, Low Alloy Steel, and Stainless Steel

The angle beam sensitivity calibration procedure covered the following and in actual practice took quite some time to establish the TCG. Some of the details appear below:

Angle Beam Sensitivity Calibration

- A TCG (Time Corrected Gain) shall be performed on the OmniScan. The TCG function on the OmniScan automatically calibrates the reference reflectors to produce an equal amplitude response, regardless of angle or sound path distance
- The TCG shall be built to a screen height of 80%; this is the primary reference sensitivity (PRS)
- The first point shall be the ID notch on the first leg, the second point shall be the OD notch on the second leg, as shown below in figure 3.

![Figure 3 TCG Calibration Points](image)

- When complete, the TCG must encompass the entire area of interest within the S-scan
- Refer to the OmniScan Users Manual for steps on building a TCG
- The completed calibration may be saved to an electronic setup file; however, the calibration must be verified whenever the setup file is opened.
Encoder Calibration

- The encoder shall be calibrated as per the OmniScan users manual
- The encoder shall be calibrated to within 10 mm of the complete scan length

The scan plan and other details appear below:

**General information:**

- Material: Carbon Steel, Low Alloy Steel, and Stainless Steel
- Thickness: 3.0 mm to 30.0 mm
- Diameter Range: 19 mm minimum, no maximum
- Omniscan setup name: __________________________
- Maximum inspection speed: 50 mm/s
- Scanner type: Cobra
- Instrument: Omni Scan MX with module 16/128 (minimum requirement)
- Wedge number: SA15-N60S-1H
- Phased Array probe:

<table>
<thead>
<tr>
<th>Part number</th>
<th>Frequency</th>
<th>Number of elements</th>
<th>Pitch</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5CCEV35-A15-P-2.5-CM</td>
<td>7.5</td>
<td>16</td>
<td>0.5</td>
<td>10</td>
</tr>
</tbody>
</table>

- The scanner movement will be parallel to the weld.
- Free surface on each side of the center line of weld should be at least 65 mm.

**Skew 90° and Skew 270°**

- Wave type: Shear wave
- Start Element: 1
- Element qty: 16
- Last element: 16
- Minimum angle: 47°
- Maximum angle: 75°
- Element step: 0.5mm
- Probes distance with weld centerline: -9mm (-0.354”)
- Range: 10 @ 39mm true depth (Start: 10mm Range: 29mm)
- Focus: 30 mm half path
- Calibration blocks #:
- Calibration techniques: Refer to IPP-PA-7701-11029-R00.
7. The Cobra scanner from Mistras - Q-Pro

Phased Array generates an ultrasonic beam with the capability of setting beam parameters such as angle, focal distance, and focal point size through computer controlled excitation of the beam. It can be multiplexed covering large areas and the operator can vary the angle of the beam without moving the probe. Applications include weld inspection, complex geometries, defect detection and location, and sizing. The ability to record weld scans and to visualize the reflectors and their position within the weld makes it a qualified technology and an excellent choice for projects constructed to ASME Code.

Ultraview™ is an integrated phased array UT inspection process used in lieu of code compliant radiography to ensure savings, limit safety hazards and increase productivity. Ultraview™ is based on providing the systematic and disciplined approach the code requires in order to utilize this technological advancement. Mistras approach integrates specific training requirements, unique internal qualification and certification standards, specialized equipment kits, calibration standards, examination procedures and procedure qualifications that are vital to the success of this program.

Q-Pro is part of the Mistras Group and is based in Texas. Mistras Q-Pro group has designed and built many systems for PA-TOFD pipe and tube inspection systems. For this contract, a compact Cobra scanner from Mistras Group was used. The scanner is moved manually and incorporates an encoder for PA UT evaluations of boiler tubes. It is a robust device and can be used on water wall weld inspection around tubes up to 4 inches in diameter.

In their work, they recommend various weld cap widths of tube and pipe welds to be compatible to the Cobra system. Since welders may not be advised of the size of the weld crowns and weld widths, the partial table provides a guideline during welder qualification. Since the scan plans require the beam to enter into the tube at a certain distance away from the weld cap width, this information should be shared with the welders before commencement!
Maximum Cap Width Guideline

<table>
<thead>
<tr>
<th>Material Thickness (in)</th>
<th>Maximum Cap Width (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.125</td>
<td>0.160</td>
</tr>
<tr>
<td>0.150</td>
<td>0.300</td>
</tr>
<tr>
<td>0.175</td>
<td>0.436</td>
</tr>
<tr>
<td>0.200</td>
<td>0.566</td>
</tr>
<tr>
<td>0.225</td>
<td>0.700</td>
</tr>
<tr>
<td>0.250</td>
<td>0.842</td>
</tr>
</tbody>
</table>

Figure 5: Maximum Cap width guide for PAUT from Mistras- Q-Pro

Figure 6: Mistras Q-Pro compact Cobra Scanner
8. Training requirements

The Level III, Mr. Phillip Ducharm trained Mr. Charles Thibault between October 3rd 2011 to November 8th 2011. The training content was in line with internationally recognized CSWIP/TWI certification, fully compliant with EN 473 and ISO 9712 certification schemes and took 91.5 hours.

9. Results and scans from the boiler tube inspection

PAUT inspection was carried out over 9 days in tandem with the progress of welding. Approximately 50 welds were examined in 12 hours of working shift during this process. Welders worked in a duo, with excellent quality performance.

Four hundred and eleven (411) welds were inspected with the Phased Array Cobra system from Mistras while 9 tubes were removed due to damage. Originally 420 welds were to be inspected with PAUT. Twelve (12) welds were rejected with the PAUT, some examples of the traces appear below in figures 7-10.

Due to the excellent communication between welders on the job, while working as welding duo's, the quality of workmanship was excellent. A rejection rate of 2.9% was recorded. This is much lower than what is usually experienced in the field with a GTAW+SMAW combination procedure.

![Figure 7: Weld MK1-3-14-B, Lack of side wall fusion. Depth: 0.040"](image)
Figure 8: Weld MK1-1-21-B. Porosity or tungsten inclusion: 0.125" from top surface.

Figure 9: Weld MK1-5-11-B. Porosity at a depth of 0.100" from top surface.
10. Acknowledgements

The authors wish to thank Mr. Philip Ducharm from Absolute NDE. For any further technical questions he can be contacted at philip.ducharm@absolutende.com. All the help received from the Mistras Q-Pro group was much appreciated. The authors would also like to thank Fortress Specialty Cellulose management for their vision to embrace new technologies like PAUT for boiler tube inspection and for their permission to publish this work.