WELD PENETRATION MONITORING USING PAUT FOR ORTHOTROPIC DECKS & STRUCTURAL BOXES

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Presentation overview

- Introduction
- Standard/client specification
- PAUT description
- Inspection methodology
- Validation
- Encoding
- Reporting
- Conclusion
Weld penetration monitoring alternatives

- **Destructive testing (Macro etch testing):** Involves sectioning and/or breaking the welded section.

- **Conventional UT:** Several limitations (Poor beam coverage, unreasonable inspection time, subjective interpretation, etc.)

- **Phased Array UT:** Large beam coverage, recordable data, multiple views, repeatability, etc.
Introduction

Scope:

Canam Bridges requested Nucleom services for the determination of the weld penetration on PP in two different projects.

**Ribs to deck assembly**: The top part of the orthotropic steel deck.

**Structural boxes**: Components of BMO Field’s roof support beams (Toronto).

Ribs to deck assembly (Canam, Quebec)

Roof support beams (BMO Field, Toronto)
**Introduction**

### Joints description:

Ribs are connected to the deck with a PP welding prepared in half V (connexion angle within $60^\circ$-$80^\circ$). Rib’s wall thickness and its connection angle to the deck may vary depending on client and project specifications.
Joints description:

Boxes are fabricated using 4 panels with two different thickness. Panels are connected with half V PP L joints. Preparation is done on the thicker panel.
LRFDUS-6-E1: June 2012 Errata to LRFD Design

SECTION 9: DECKS AND DECK SYSTEMS

9.8.3.6.2—Closed Ribs

The one-sided weld between the web of a closed rib and the deck plate shall have a target penetration of 80 percent, with 70 percent minimum and no blow-through, and shall be placed with a tight fit of less than 0.02 in. gap prior to welding.

Historically, specified as a or minimum 80 percent. 80 percent penetration difficult and fabr...
Client specification:

For each type of boxes, the client welding engineering department required a specified penetration. For example: for preparation of 10mm, The effective throat should be 7mm at minimum.
Definition (PAUT = Phased Array Ultrasonic Testing)

- A mosaic of piezoelectric elements where the timing of each pulser/receiver excitation can be controlled electronically and independently
- The same physical principles than conventional UT apply

Beam Steering

Beam Focussing

Firing Sequence

Elements
PAUT technology

- A number of ultrasonic beams is fired at the same time at different angles (e.g. 45°-70°).

- Encoded inspection allows recording data along the scan for further analysis and verification. Different views are generated, A-Scan, S-Scan, C-Scan etc.
Main Views

(TomoView screenshot)
PAUT scan plan (weld coverage strategy)
Orthotropic Deck

Suggested Scan Plan (ES Beam, Civa, etc.)

Resulting Sectorial scan (S-Scan View)
PAUT technique

- The probe is positioned so as to be able to detect the opposite corner and the upper tip of the non-fused portion of the joint.

  - The height from the corner to the upper tip represents the non-fused section of the weldment.

  - The **percentage of non fused area** is this height divided by the thickness of the plate.
Equipment

- PAUT unit
- Scanner buggy
- Magnetic wheels
- PAUT probe/wedge
PAUT scan plan (weld coverage strategy)

Structural Boxes

Suggested Scan Plan (ES Beam, Civa, etc.)  Deck plate  Resulting Sectorial scan (S-Scan View)
Inspection methodology

Equipment

Scanner buggy

PAUT unit

Magnetic wheels

PAUT probe/wedge
Demonstration Block

4 notches machined at different depths
Demonstration Block configuration

Non fusion simulation: 4mm, 3mm, 2mm and 1mm
Resulting data

The 4 indications are clear along the C-Scan. S-Scan and A-Scan are used for a complete characterization.
Detailed results

- Accuracy of ±0.1mm for notch height measurements

(approximately ±1% for weld penetration for a 9.5mm thick plate)

<table>
<thead>
<tr>
<th>Notch</th>
<th>Notch corner (PA) (mm)</th>
<th>Notch end (PA) (mm)</th>
<th>Notch height (PA) (mm)</th>
<th>Simulation for percentage of penetration (%)</th>
<th>Height measured by metrology (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mm</td>
<td>9.5</td>
<td>8.6</td>
<td>0.9</td>
<td>91</td>
<td>0.8</td>
</tr>
<tr>
<td>2mm</td>
<td>9.5</td>
<td>8.0</td>
<td>1.5</td>
<td>84</td>
<td>1.5</td>
</tr>
<tr>
<td>3mm</td>
<td>9.5</td>
<td>7.4</td>
<td>2.1</td>
<td>78</td>
<td>2.2</td>
</tr>
<tr>
<td>4mm</td>
<td>9.5</td>
<td>6.4</td>
<td>3.1</td>
<td>67</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Validation with Macro Etch tests

Validation sample with 5 selected position
**Measurements validation**

Results show a maximum difference of 0.3 mm then ± 3% in accuracy.

<table>
<thead>
<tr>
<th>Section #</th>
<th>Scan position (mm)</th>
<th>PAUT Measurement</th>
<th>Macro Etch testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Non fused area mm</td>
<td>% of penetration</td>
</tr>
<tr>
<td>1</td>
<td>102</td>
<td>1.1</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>402</td>
<td>2.6</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>574</td>
<td>2.7</td>
<td>71</td>
</tr>
<tr>
<td>4</td>
<td>810</td>
<td>2.8</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>1043</td>
<td>2.3</td>
<td>75</td>
</tr>
</tbody>
</table>
Scanning pattern

→ Probe is moved with an encoded scanner
→ PAUT data is saved every 1 millimeter (0.040in)
  ➢ Percentage of weld penetration is available for each position on the weld
PAUT data acquisition

Important parameters to set
• Scan Resolution
• Scan Speed
• Data Size
Scanning pattern
PAUT data acquisition
PAUT data analysis
Orthotropic Deck
PAUT data analysis
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PAUT data analysis
Structural Boxes
PAUT data analysis
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PAUT data analysis
Structural Boxes
Inspection report example
Orthotropic Deck
Inspection report example
Orthotropic Deck

Weld penetration is showed by a color code

<table>
<thead>
<tr>
<th>Position (mm)</th>
<th>Length (mm)</th>
<th>Penetration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18</td>
<td>[60% à 70%]</td>
</tr>
<tr>
<td>18</td>
<td>192</td>
<td>[70% à 80%]</td>
</tr>
<tr>
<td>210</td>
<td>98</td>
<td>≥ 80%</td>
</tr>
<tr>
<td>308</td>
<td>66</td>
<td>[70% à 80%]</td>
</tr>
<tr>
<td>374</td>
<td>62</td>
<td>≥ 80%</td>
</tr>
<tr>
<td>436</td>
<td>92</td>
<td>[70% à 80%]</td>
</tr>
<tr>
<td>528</td>
<td>14</td>
<td>[60% à 70%]</td>
</tr>
<tr>
<td>542</td>
<td>16</td>
<td>≤ 60%</td>
</tr>
<tr>
<td>558</td>
<td>28</td>
<td>[70% à 80%]</td>
</tr>
<tr>
<td>586</td>
<td>160</td>
<td>[60% à 70%]</td>
</tr>
<tr>
<td>746</td>
<td>26</td>
<td>≤ 60%</td>
</tr>
<tr>
<td>772</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>rib length</th>
<th>Total Length</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 80%</td>
<td>160</td>
<td>20.7%</td>
</tr>
<tr>
<td>[70% à 80%]</td>
<td>378</td>
<td>49.0%</td>
</tr>
<tr>
<td>[60% à 70%]</td>
<td>192</td>
<td>24.9%</td>
</tr>
<tr>
<td>≤ 60%</td>
<td>42</td>
<td>5.4%</td>
</tr>
<tr>
<td>No Data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Inspection report example
Structural Boxes
Advantages

› Penetration percentage is measured at all positions in the weld
› Accuracy on the weld penetration percentage is ±5% (±1% in optimal conditions)
› Repeatability, less subjectivity in acquisition and analysis
› Track record
› Can be adapted for different joint configuration
› Fast acquisition
Limitation

- Weld flaws can affect the data interpretation (undercuts, LOF)
- Weld profile can affect the data acquisition
- Requires expertise in PAUT technology
- Non constant long weld could require many hours of analysis.
- Electronic limitations
PAUT (Phased Array Ultrasonic Testing) is an efficient technique to monitor weld penetration for orthotropic bridges over the entire length of the weldment.

The technique has been proven on 5 different projects (bridges and steel structures) in collaboration with CANAM BRIDGES.
The technique can include more than one probe in order to perform 2 or more simultaneous scans.

It’s possible to characterize flaws (Porosities, LOF, etc.) along the scan. A sensitivity calibration is needed in this case.
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Éric Levesque
Thank you, questions are welcome!