PRCI Project NDE 2-3 Phase 2
NDE & Inspection Techniques Applied to Composite Wrap Repairs

PRCI Project No. PR-398-133719

Richard Lee
ESR Technology Ltd, UK

Chris Alexander & Julian Bedoya
Stress Engineering Services, Inc., USA

3rd Annual Composite Repair Users Group
Conference & Exhibition Sept 26 2013, Houston,
Hilton Garden Inn NW America Plaza.
Outline of Talk

1. Introduction.
2. PRCI NDE 2-3 Phase 2 Project Overview.
4. NDE and Inspection.
5. Summary & Conclusions.
6. Q&A.

(20 minutes)
Project Overview
State Of The Art - Composite Wrap Repairs

Project Team

PRCI     Max Toch (mtoch@prci.org)

Co-Project Leaders

John O’Brien, Chevron jobrien@chevron.com
Mario Pezzi, Petrobras pezzi@petrobras.com.br

Consultants

Richard Lee, ESR Technology richard.lee@esrtechnology.com
Steve Burch, ESR Technology steve.burch@esrtechnology.com
Martin Wall, ESR Technology martin.wall@esrtechnology.com
Chris Alexander, Stress Engineering chris.alexander@stress.com
Julian Bedoya, Stress Engineering julian.bedoya@stress.com
ESR Scope of Work

- Phase 2 work by ESR Technology was contracted by PRCI in June 2013 to assess available NDE and inspection techniques for composite overwrap repairs for pipelines and other industries.

- Previous industry questionnaires and PRCI Research Roadmap identified inspection/NDE assessment of composite wrap repairs as a high priority for pipeline owners and operators.

- ESR has liaised with Stress Engineering Services, Inc. who prepared the 12” by 20 feet X42 pipeline samples and will pressure test them later. Results to be presented at PRCI Research Exchange Meeting in February 2014.

- Link with existing PRCI projects and other initiatives in this area, i.e. interactions with ISO TC67/SC6 committee responsible for the current ISO 24817 standard (under revision) on composite overwrap repairs.
What are the applicable standards?

- ISO/TS 24817

- ASME PCC-2
  - Article 4.1, Non-metallic composite repair systems for pipelines and pipework: low risk applications.
  - Article 4.2, Non-metallic composite repair systems for pipelines and pipework: high risk applications.

- Both standards are published (and under revision).
- No major differences in the technical details.
International Standard ISO/TS 24817

The content of ISO/TS 24817 includes details on:

**Qualification requirements**: tests that suppliers are required to comply to the standard.

**Design details**: how to design a repair.

**Installation guidance**: what are the critical issues, e.g. surface preparation and applicator training requirements.

**Monitoring guidance**: how to inspect the repair system.

No other reference standard or guideline is required to complete the composite repair application.

The standard should be used in conjunction with any in-house procedures or guidelines on composite repairs.
Inspection – what to inspect?

What to inspect for;

- Growth of internal pipe defects underneath the repair.
- Debonding of adhesive interface between the composite repair and the pipe surface.
- Delamination and degradation of the composite repair (less of an issue).

Where to inspect;

- Commonly all types of defects need to be inspected from above the repair, ‘in the ditch’ (access can be restricted). Detection of corrosion at end of repair.
How to inspect composite repairs?

**Internal defect growth in steel substrate:**
- Electromagnetic techniques, e.g. low frequency or pulsed eddy current for general wall loss.
- Gamma- and X-rays (using conventional film, CR or DR equipment).
- Guided Wave Testing (GWT).

**Interfacial delamination:**
- Microwave inspection (24GHz).
- Mechanical impedance (electronic coin tappers).
- Digital X-rays (further assessment of these techniques required).
- Laser shearography (technique uses small pressure or temperature changes).
- Ultrasonics (some practical limitations).

**Composite repair:**
- Visual inspection (gross surface defects).
- Monitor strain (conventional embedded and surface mounted strain gauges or fibre optic sensors).
- Hydrotesting (pressure test or leak test).
Four repair products:

- NRI Syntho-Glass repair (Glass/PU water activated, sub-sea system).
- WTR Technowrap 2K repair (Glass/epoxy).
- Furmanite FurmaWrap repair (Carbon/epoxy).
- Clock Spring repair (Pre-cured coiled glass/resin).

Repair #1 is an open trial (calibration) section containing simulated general corrosion and pitting.
Repair #2 is a blind trial example.
Repair #3 is a blind trial with additional flaws.

NDE before and after hydrotest to 90% SMYS (260 MPa) and 10k cycles at \( \Delta P \) 72% SMYS (208 MPa).
Repair samples at PRCI - Oceaneering
Repair samples – ‘Open trial’

Repair #1 is ‘open’ trial and Repair #2 and #3 are ‘blind’ trials.

Open trial is machined 75% wall loss area and partially drilled holes under repair (simulating ‘pitting’ defects).

Some interfacial and interlaminar (adhesion loss) defects.
Examples of inspection of composite repairs
Electromagnetic techniques (PEC, SLOFEC)

PEC (pulsed eddy current) trial on glycol drain system from North Sea platform.

Underlying remaining wall thickness of steel pipe readily detected.

Resolution limited – defects of diameter 10 mm or less cannot be detected.

SLOFEC will be trialled in current work, depending on availability.
Laser Shearography
Laser Shearography

Laser shearography trial
Interfacial delamination detected in some trials only
Strain Mapper
Film radiography (DWSI) using Iridium 192 isotope – Courtesy of Furmanite.
Radiography - RT

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Film radiography (DWSI) using Iridium 192 isotope – Courtesy of Furmanite.
Microwave Inspection

Evisive microwave trial on Clock Spring 6” pipe repair
Aquawrap® repair

Ch C MII NDT file - 07-06-2006 12:37:06
C:\Test Scans\AquaWrap\AquaWrap005.evd

$\frac{1}{2}$" disbond at surface
1" disbond at surface
1" disbond between layers 2 and 3
1" disbond between layers 6 and 7

Aquawrap repair materials supplied by Air Logistics, Franz Worth

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum/ air gap</td>
<td>1</td>
</tr>
<tr>
<td>Polymers</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Glass</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Elastomers, e.g. Neoprene</td>
<td>7</td>
</tr>
<tr>
<td>Water</td>
<td>80</td>
</tr>
</tbody>
</table>

Slide information courtesy of Donald McNicol
Thermography
Ultrasonics (B-Scan, M-Skip and TOFD)

Pipe wall loss through severe chemical attack.

Erosion and wall loss, liner damage.
Guided Wave Testing (GWT)

GUL Wavemaker G3 on Clock Spring

Courtesy of Dr Keith Vine, GUL
Guided Wave Testing (GWT)

Courtesy of Dr Keith Vine, GUL

Pipe end
Weld
Hole defects

12% change in cross section
8 inches

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Case Study – Piping repair

WTR Technowrap system.

Multi-axial glass/epoxy panel bonded to steel plate.

3 panels tested.

- Hand prep.
- No Primer.
- With primer.
Case Study – Piping repair

Tested at NPL in UK

Connected to hand pressure pump (Hi-Force) using pressure adapter.

Digital Image Correlation (DIC) equipment used LAVision DAVIS 7.4 software.

www.lavision.de

Panel #2

Blister formed at 100 bar before weeping at 150 bar.
AE Monitoring

Figure 2: Sample 1 Amplitude results from CH1 (on steel)
Pipe repair - Digital Image Correlation

Selected DIC images for $\varepsilon_{xx}$, $\varepsilon_{yy}$ and $\varepsilon_{zz}$
PRCI baseline document on inspection/NDE of composite repairs.

Publication/ release date – October 2012.

- INTRODUCTION
- SCOPE
- REQUIREMENTS
- INSPECTION APPROACH
- ALLOWABLE DEFECTS
- REPAIR OF DEFECTS
- MAINTENANCE AND REPLACEMENT STRATEGY
- INSPECTION METHODS
- RECOMMENDED NDT FOR OVERWRAP REPAIRS
- INSPECTION TECHNIQUE ASSESSMENT
- CONCLUSIONS AND RECOMMENDATIONS
- BIBLIOGRAPHY
- APPENDICES
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  - Appendix 2 - Thermographic methods
  - Appendix 3 - Radiographic methods
  - Appendix 4 - Acoustic methods
  - Appendix 5 - Magnetic methods
  - Appendix 6 - Ultrasound methods
  - Appendix 7 - Eddy current methods
  - Appendix 8 - Visual methods
  - Appendix 9 - Penetrant methods
Status of Composite Repairs

- Standard documentation is now in place for composite repairs.
- Composite repairs are an engineered solution – some experience sub-sea.
- The qualified repair consists of the repair material, surface preparation procedure and substrate.
- Inspection of substrate underneath the repair can be achieved – interfacial delaminations are still problematic.
- Current best practice is continually being developed.
- Advances with in-service inspection and condition monitoring continue.
Acknowledgements
Max Toch, PRCI, Programme Manager.
Steven Trevino & Donald McNicol, Oceaneering International, Inc.
Steve Burch & Martin Wall, ESR Technology Ltd., UK.

Composite Repair Suppliers:
Simon Frost, Walker Technical (ISO 24817 Chairman). Belzona, Furmanite, IMG, Clock Spring, Neptune Research Inc. and others.

Inspection service/ NDE vendor companies:
(includes several HOIS Cat 2 members).
Thank You
Questions?
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