Overview

- Application of composite repairs
- Product Selection
- International Standards
- Compliance testing and Adhesion
- Additional testing
- Design scenarios for pipework and pipelines
- Design life and temperature effects
- Some case studies
Composite repairs are not just a “bandage” or temporary repair, they can be engineered to give a lifetime of up to 20 years.
Why Choose a Composite Repair?

• Reinstate integrity (pipework, pipeline, structures, decks)
• Long design life (up to 20 years)
• No hot work required
• No shutdown required
  • Can be applied to live pipework
• Significant cost saving over shutdown and replacement
• Applied by fully trained technicians
## Product Selection - Resins

<table>
<thead>
<tr>
<th>Resin</th>
<th>Key Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULT</td>
<td>Cures at 10°C</td>
</tr>
<tr>
<td>LT</td>
<td>Quick curing at low ambient temperatures</td>
</tr>
<tr>
<td>HT</td>
<td>Suitable for service temperatures up to 220°C</td>
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<tr>
<td>HA</td>
<td>Longer working life at high ambient temperatures</td>
</tr>
<tr>
<td>UHA</td>
<td>Cures slower at high ambient temps</td>
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<tr>
<td>DRS</td>
<td>Rubber toughened to withstand impacts</td>
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<tr>
<td>Glycol</td>
<td>Compatible with 100% glycol at 90°C</td>
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<tr>
<td>Potable</td>
<td>Potable water approved Epoxy Resin</td>
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<tr>
<td></td>
<td>Potable water systems</td>
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<tr>
<td>Splashzone</td>
<td>Hydrophobic Epoxy Resin</td>
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<tr>
<td></td>
<td>Pipework in wet areas</td>
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<tr>
<td>Product</td>
<td>Application</td>
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<tr>
<td>-----------</td>
<td>--------------------------------------------------</td>
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<tr>
<td><strong>2K</strong></td>
<td>Tri axial Fibre Glass Cloth (0, ±45)</td>
</tr>
<tr>
<td><strong>PRS</strong></td>
<td>Uni directional Fibre Glass Cloth + Various Epoxy Resins</td>
</tr>
<tr>
<td><strong>HP PRS</strong></td>
<td>Uni directional carbon fibre, 99 Gpa (anisotropic)</td>
</tr>
<tr>
<td><strong>Structural</strong></td>
<td>Carbon Fibre, Quadraxial fibre, Quasi isotropic laminate, $E_{avg}$ 36 GPa</td>
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<tr>
<td><strong>E1</strong></td>
<td>1.5mm thick glass fibre cloth</td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td>Water activated Poly urethane resin and fibre glass</td>
</tr>
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<td></td>
<td>Emergency repairs to pipework</td>
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</tbody>
</table>
Properties of Composite and Steel

- Laminate can be orientated to give a quasi-isotropic structure
- Similar Strength
- Elastic modulus is much lower than steel (carbon around 40GPa, glass around 25GPa, Steel 200GPa)
- Therefore strain is significantly higher for composites
Applicable Standards

- Guidance on testing, design and installation
- Both standards are similar, but there are a few differences;
  - External loadings not considered in ASME ($P_{eq}$)
  - Temperature factor for through wall defects
  - Design life

- Result is the ISO standard gives a slightly more conservative value, given the same inputs
Compliance Testing

• Prescribed by both ISO and ASME standards

• Includes;
  • Mechanical Testing (modulus, poisson, shear, thermal expansion, Tg and lap shears)
  • Performance data (Impact test, long term strength, burst tests and Energy release rate)
Adhesion

• Adhesion is measured with the Energy Release Rate (ERR, J/m²)
• Calculated using data points as per relevant standard
• Repair performance is controlled through the adhesion of the repair to the substrate

• Various factors affect the level of adhesion achieved;
  • Surface preparation (cleanliness and profile)
  • Substrate material
  • Repair system used
# Surface Preparation Techniques

<table>
<thead>
<tr>
<th>Surface Preparation standard</th>
<th>Technique</th>
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<tbody>
<tr>
<td>Sa2.5 (60μm profile)</td>
<td>Grit blasting</td>
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<tr>
<td></td>
<td>Slurry blasting</td>
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<tr>
<td>ST3 (40μm profile)</td>
<td>Bristle blaster</td>
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<tr>
<td></td>
<td>Grinding disc</td>
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<tr>
<td>ST2</td>
<td>Emery paper</td>
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<td></td>
<td>File</td>
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<td></td>
<td>Needle gun</td>
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</table>
Effect of Repair Material and Surface Preparation

- Design pressure against repair thickness for a design lifetime of 20 years and a circular through wall defect of diameter 25 mm.
Effect of Leak Sealing Different Substrates

- Carbon steel / GRP
- Stainless steel
- Duplex
- Cunifer
- Cast iron
Additional Testing

- Large diameter pipework
Additional Testing

• Small diameter pipework
• 0.5”
• 0.5mm steel remaining
• 6mm composite applied
• 200 bar design pressure
• Failed at 1400 bar
Additional Testing

• Short term elevated temperature burst testing
  • In addition to 10,000 creep test at 140°C
  • Long term design strain of 0.65% (standard limits to 0.4%)

• Burst test carried out at 150°C
• 25mm hole
• Bust at around 150 bar
• Gave an ERR higher than ambient testing
Overview of Composite repair Design Engineering

Design of a composite repair answers the following questions:

- Is the repair strong enough in all loading directions? (stress/strain calculation)
- Will the repair remain bonded to the surface? (adhesion strength calculation ERR)
- Is the extent of repair sufficient to ensure load transfer between repair and substrate?

\[ l_{over} = 2\sqrt{Dt} \quad l_{over} = 4d \]

Design output:

- Thickness of composite repair
- Length of the repair \( l = 2l_{over} + l_{defect} + 2l_{taper} \)
Factors to consider when designing repairs

- Pressure (operating and design)
- Diameter/Geometry
- Temperature
  - Installation and design, $\Delta T$
  - $\varepsilon = F_{T1}\varepsilon_0 - |\Delta T(\alpha_s - \alpha_c)|$
  - Calculated in both circumferential and axial directions
  - Can become an issue where $\Delta T$ is over 150°C

- Also Tg of resin is important to determine upper temperature limits
  - Tg-20°C for Type A, Tg-30°C for Type B
Factors to consider when designing repairs

• Design Life of repair
  • Between 2 and 20 years (for ISO)
  • Used to determine the allowable strain of the repair
  • A lower design life will have a higher allowable strain
    • 0.4%
  • A higher design life will have a lower allowable strain
    • 0.25%

• This is due to creep in the composite
  • Usually occurs within the first 1000 hours
  • Safety factors keep allowable strain well below failure strain
Dynamic Response Spectroscopy (DRS)
Ultrasonic WT measurement through composite repairs

Conventional WT measurement
- Uses reflected signal timings to calculate WT
- Accuracy depends on high frequency ultrasound, which won’t penetrate composite repairs
- Conventional WT measurement is often not possible through composite repairs

New DRS WT measurement
- Excites steel with a broad range of low ultrasonic frequencies – pass easily through composite repairs
- Steel responds at natural frequencies related to the WTs
- DRS technique developed by Sonomatic Ltd
Microwave inspection - Interfacial delaminations underlying the repair
Caisson Repair

Successfully contained 40+ through wall defects

Reinstated the structural integrity

All challenges successfully overcome

Provided a cost-saving solution which did not require a shutdown

20 years lifetime repair guarantee

Client pleased with the execution and finished repair
Overview

• 14” gas vent line suffering severe external corrosion
• Up to 40 meters of pipework affected
• Design conditions, pressure 28 bar, temperature 30°C

Why a composite solution?

• Tailored repair for the pipework
• 4 layers required over most of the pipework but where extensive corrosion was present 14 layers were applied
• Applied live – no downtime, zero impact on production
• Integrity maintained through an engineered repair solution with a life of field guarantee
Summary

• Repair performance is controlled through the **adhesion** of the repair to the substrate

• Adhesion is a function of the repair material, surface preparation and substrate material

• Demonstration of long term integrity through long term qualification data

• Repairs must be applied by **trained installers**