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Walker Technical Resources

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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

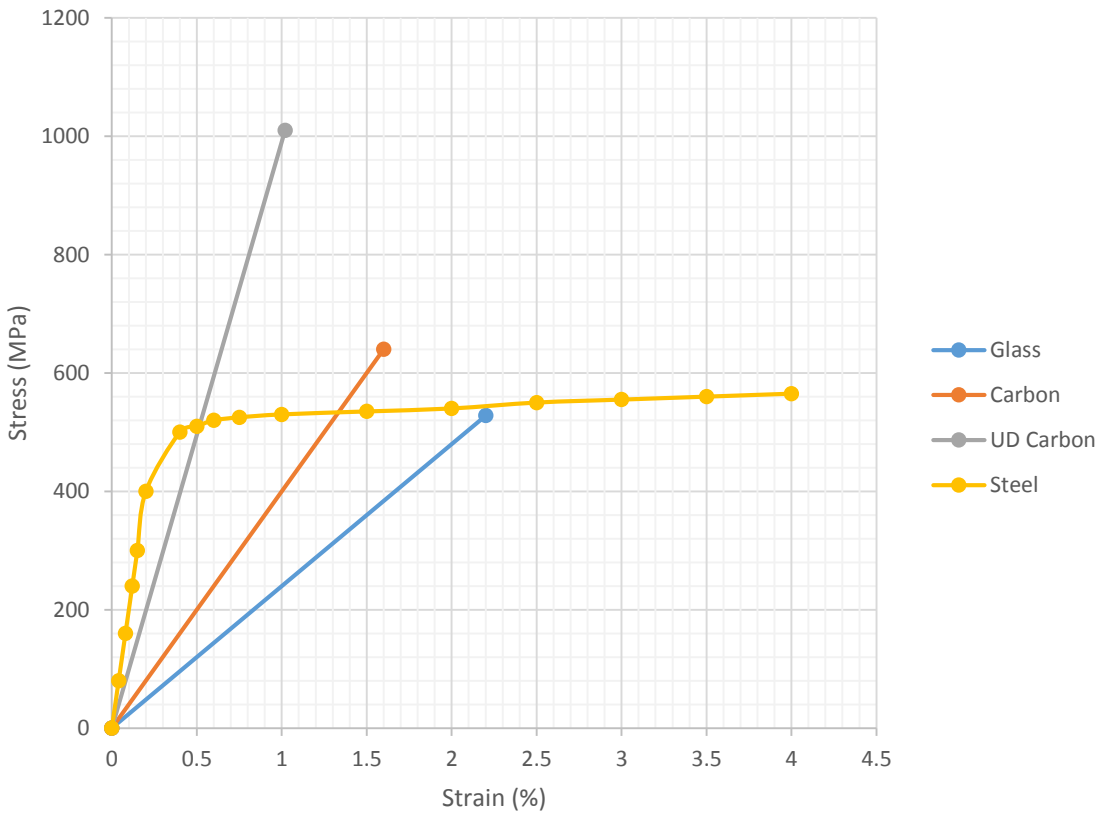
Resin		Key Properties
ULT		Cures at 10°C
LT		Quick curing at low ambient temperatures
HT		Suitable for service temperatures up to 220°C
HA		Longer working life at high ambient temperatures
UHA		Cures slower at high ambient temps
DRS		Rubber toughened to withstand impacts
Glycol		Compatible with 100% glycol at 90°C
Potable	Potable water approved Epoxy Resin	Potable water systems
Splashzone	Hydrophobic Epoxy Resin	Pipework in wet areas

Product Selection – Fabric/Fibres

Product		Application
2K	Tri axial Fibre Glass Cloth (0, ±45)	General Piping systems
PRS	Uni directional Fibre Glass Cloth + Various Epoxy Resins	Pipeline Repair System
HP PRS	Uni directional carbon fibre, 99 Gpa (anisotropic)	High pressure Pipeline Repair System, structural components
Structural	Carbon Fibre, Quadraxial fibre, Quasi isotropic laminate, E_{avg} 36 GPa	All structural components
E1	1.5mm thick glass fibre cloth	
Core	Water activated Poly urethane resin and fibre glass	Emergency repairs to pipework

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

- ISO 24817 (2015) and ASME PCC2 (2015)
- 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

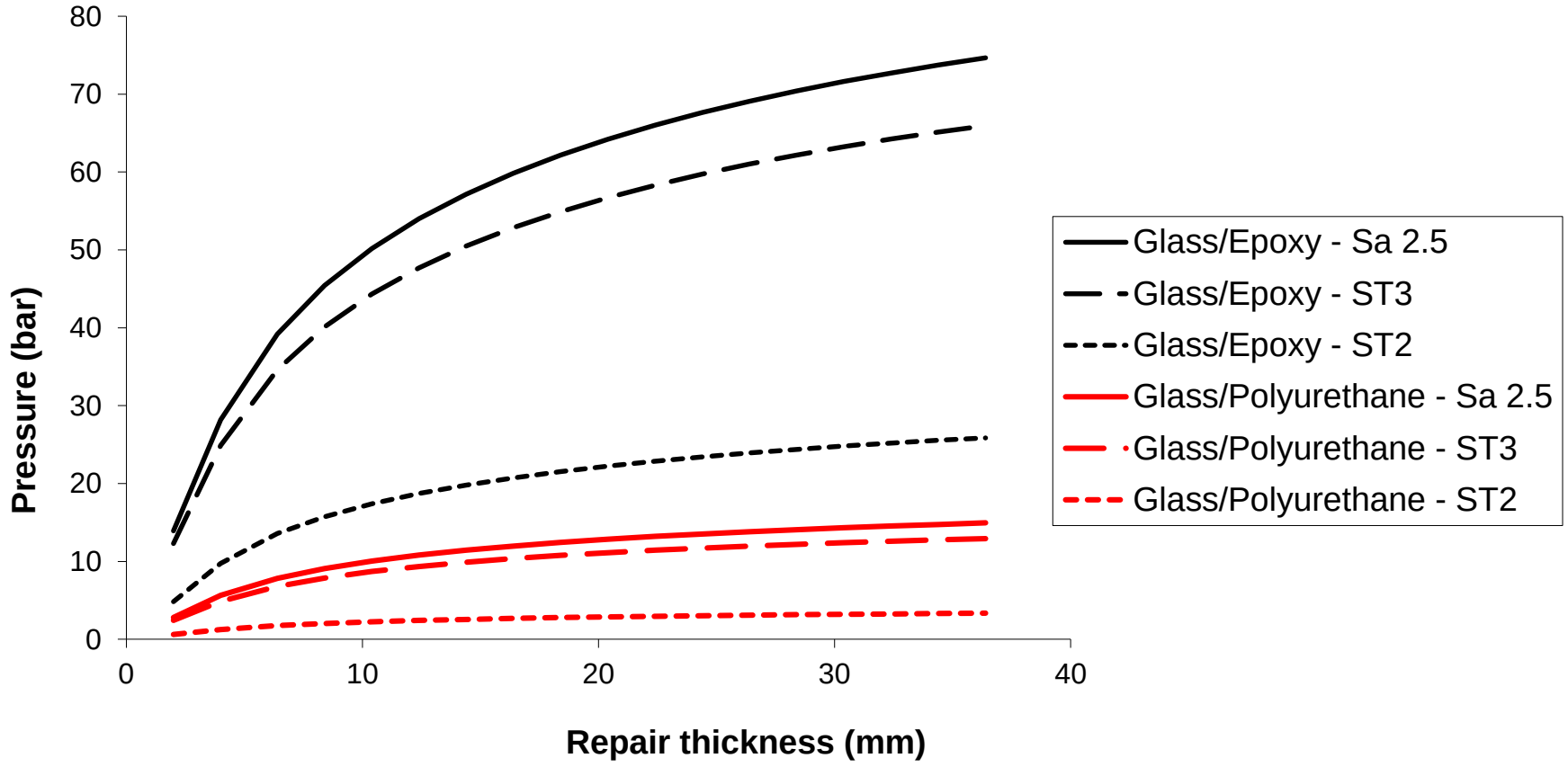
- Various factors affect the level of adhesion achieved;
  - Surface preparation (cleanliness and profile)
  - Substrate material
  - Repair system used

Surface Preparation Techniques

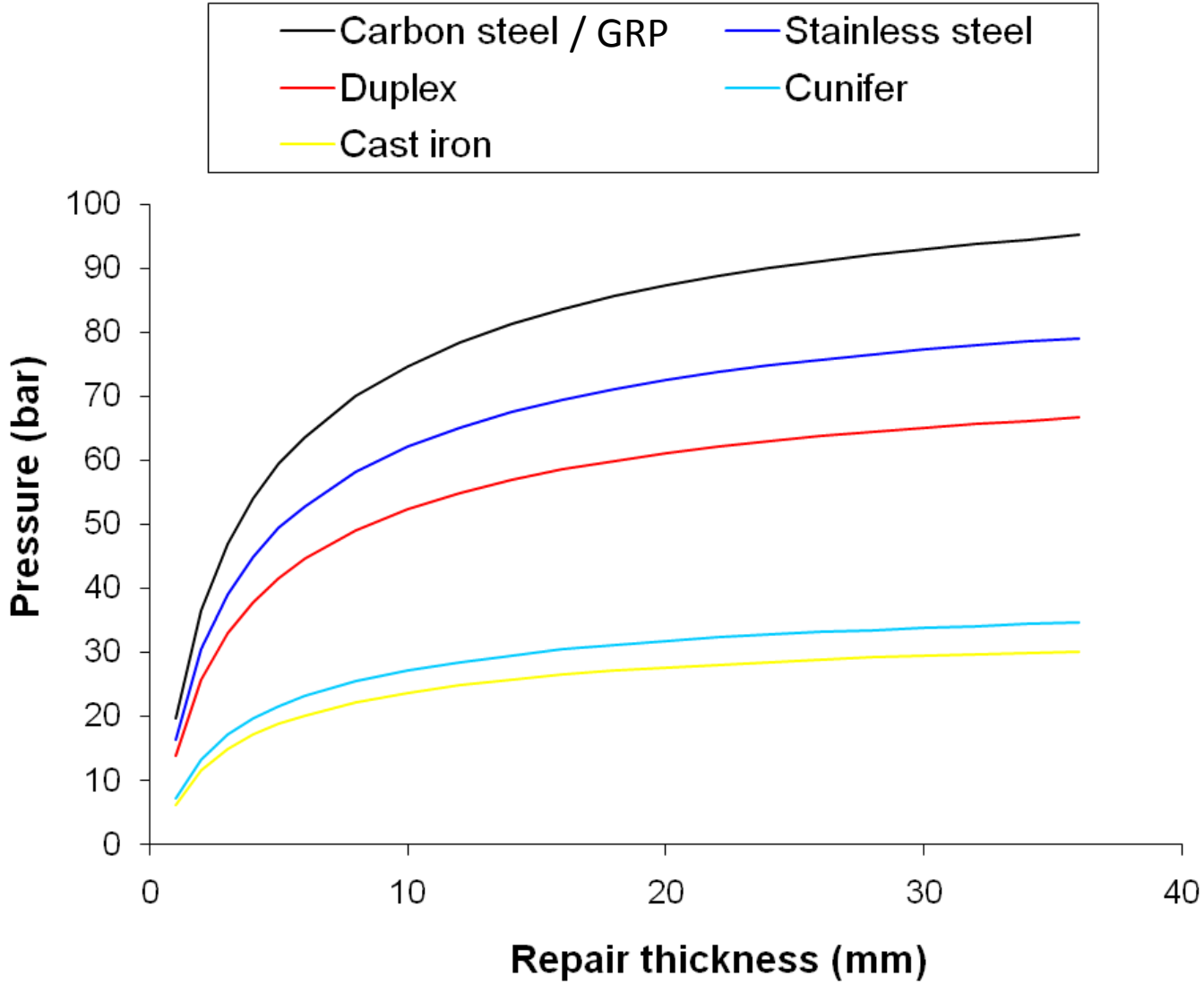
Surface Preparation standard	Technique
Sa2.5 (60µm profile)	Grit blasting Slurry blasting
ST3 (40µm profile)	Bristle blaster Grinding disc
ST2	Emery paper File Needle gun

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



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, ΔT
  - $\varepsilon = F_{T1}\varepsilon_0 - |\Delta T(\propto_s - \alpha_c)|$
  - Calculated in both circumferential and axial directions
  - Can become an issue where ΔT 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

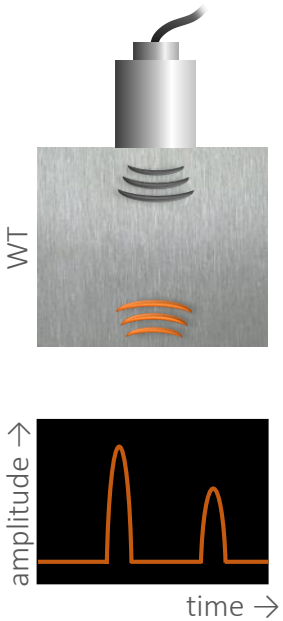
Factors to consider when designing repairs

- 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

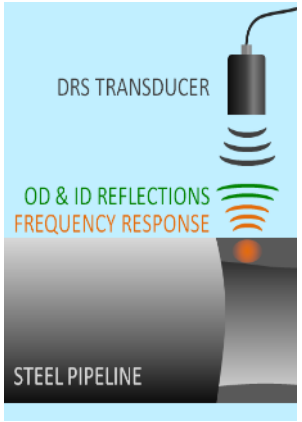
Dynamic Response Spectroscopy (DRS)
Ultrasonic WT measurement through composite repairs

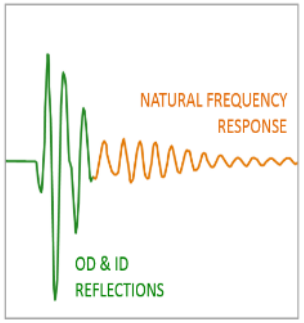
Conventional WT measurement



- 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

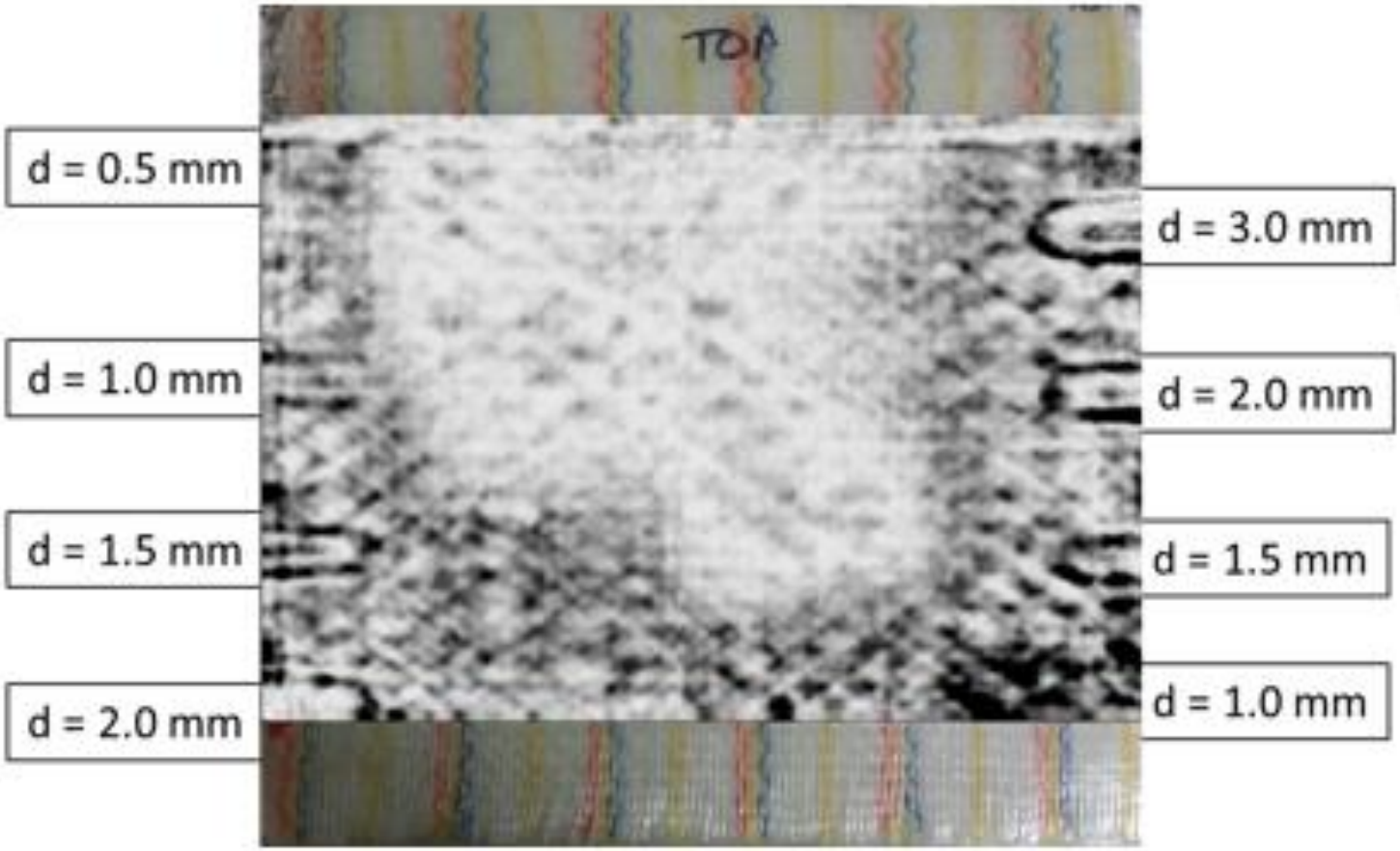




- Excites steel with a broad range of *low* ultrasonic frequencies – pass easily through composite repairs
- Steel responds at natural frequencies related to the WTs
- DRS technique developed by Sonomatic Ltd

sonomatic®
innovative inspection technologies

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

14” Gas line

Overview

- 14” gas vent line suffering severe external corrosion
- Up to 40 meters of pipework affected
- Design conditions, pressure 28 bar, temperature 30^0C

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**