Using Epoxy Adhesives in place of Hot Metal Welding

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What's the Problem?

Pipework, pipelines, tanks and other metal structures

- Thin-wall and pitting
- Through-wall defects
- Large assets
- Localised damage
- Pipe support erosion/corrosion
Issues – Existing assets
Three main factors cause deterioration on structures

- Environmental - Corrosion
- Process – Acidic/alkali
- External – Abrasion, impact and erosion

- Wear and through-wall defects take place

- Stress concentration nodes
  - A combination of these factors are often found working together e.g. stress corrosion cracking
Issues – New build

Traditional joining methods during fabrication are not always achievable

• Changing the substrate microstructure as a result of hot work
• Creation of cavities behind welded patches or brackets
**Advantages**
- Can restore metalwork to almost original condition
- Alloys can be added for additional strength
- Can be tested/inspected after
- A proven solution

**Disadvantages**
- Dissimilar metals can be difficult to weld
- Distortion & Stress due to heat introduction
- Safety risks associated with the heat
- Heat Affected Zone
- Internal linings can be affected by the heat
  
  • **Requires Trained Personnel**
Welding

Example: welding deck, tank external, separator internal fittings

Not full contact

Risk of gas or fluid ingress via defective weld

Hot Works
Additional Control Measures
HAZ
Corrosion
What is the Alternative?

**Cold Bonding**

This method offers numerous advantages:
- No external heating
- Inert once cured
- Relatively high strength
- Will adhere to an extensive range of substrates
- Some varieties suitable up to 200°C service temperature
Think of it as a “composite sandwich”

Cold bonded parts demonstrate better compressive strength, adhesion levels, dissipation of stress, forces and loads.

No need for bolts or welding

Example: bonding deck, tank external, separator internal fittings.
How do we test these materials and prove that they work?

Two methods, and two types of repair
Method 1: Hand Calculation

Unlike steel, the failure mode of these materials is notoriously difficult to predict. Failure happens on a small scale.

With that in mind, let’s take the example on the left. This is based on a similar, real life application – bonding a plate onto the external of a corroded tank.

The key to this is simplicity.
The bonded area is 1600mm$^2$. Let’s take a force of 3000N (pressure) to act from inside the tank across the plates surface. This gives:

<table>
<thead>
<tr>
<th>Force:</th>
<th>3000 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area:</td>
<td>1600 mm$^2$</td>
</tr>
</tbody>
</table>

Stress: 1.875 N/mm$^2$

Safety Factor: 12

**Inputs:**

**Steel Plate**
- Profile: 1000mm (L) x 100mm (W) x 4mm (T)
- Yield: 235 N/mm$^2$

**Adhesive**
- Type: 2-part Epoxy Bonding Agent
- Adhesive Strength (20$^\circ$C): 22.3 N/mm$^2$
Method 2: Finite Element Analysis (FEA)

FEA can be used to predict stresses in certain applications involving epoxy materials.

After inputting all relevant data, we can build a simple design.
When welding or bonding steel plates, a major issue is stress concentrations.

- Exacerbated stresses on “Peaks”
- Can lead to crack propagation

To obtain an effective analysis, an epoxy bonding material was processed through an FEA system.

An example of FEA

- 0.01 m² (1 ft²) plate by ¼” thick (6.35 mm)
- A36 (structural steel)
- 25 mm (1”) hole in center of plate
- Distributed loading 1587 Kg (3500 lb)
Testing
Finite Element Analysis

- Stress concentration nodes are avoided
- Stress dissipation element (epoxy material)
- Top metallic plate used for further reinforcing
- Provides protection to epoxy material
Testing
Finite Element Analysis
Application Techniques

Hand/Tools

Injection
Laydown area was badly corroded and weakened through daily operation

- North Sea
- Aberdeen
- 2004
Application: How it works

Injection Bonding Using Fluid Grade Systems

Demonstration with Perspex to show material distribution
Protecting Offshore Platform Legs at the Waterline

**Equipment**

Platform legs damaged by corrosion and impact from service/crew boats at the waterline.

**Problem**

Due to corrosion and impact damage platform legs were at risk of losing structural integrity. Client wanted to terminate damage to avoid further deterioration. Customer had welded top and sides of half wrap without welding bottom, due to water/wave action. Corrosion had accelerated between the leg and half wrap.

**Application Details**

Epoxy filler was used to seal the bottom of split shells, and an epoxy coating was then injected to fill cavity between platform leg and steel wrap.

Products used were Belzona 1161 (Super UW-Metal) & Belzona 5831 (ST-Barrier)
This type of bonding uses mostly indicative design methodology.

We know –

• Compressive strength
• Tensile strength
• Adhesive Strength etc.

However, not all applications are this straightforward, and will require more design input.
Composite Repairs

Repair system fabricated of a thermoset resin used in conjunction with fiber reinforcement sheet.

- No heat involved
- No shutdown required
- Cost-effective when compared to other alternatives

This is designed in accordance with two standards:

ISO 24817 & ASME PCC-2
Wrap
When a full circumferential wrap can be achieved.

Patch
When a full circumferential wrap is not practical.
Sample Design:

**Inputs:**
- Design Temperature: 20°C
- Design Pressure: 5 bar
- Process Fluid: Cooling water
- External Loads: None
  etc.

**Outputs:**
- Thickness: 6 mm
- Axial Extent: 400 mm
Application of a composite wrap system

Problem
Corroded flange and fasteners on the high-pressure fuel gas heater inlet and outlet. The client could not afford for the flange or bolts to leak and be shutdown as this would become very costly. Protection of the system was required for 9 months until the next shutdown, where the entire unit would be replaced.

Application Details
The application was carried out by validated Installers as per the method statement provided on the design. Following thorough surface preparation to the live system, an epoxy filler was applied to the flanges, bolts and pipe to create a smooth transition prior to application of the composite system.
How does this apply to patch repairs?

Patch repairs follow a similar methodology, although they lack the hoop strength provided by a full circumferential wrap.

How do we compensate for this lesser strength?

**Increase the thickness**

Advantages this repair type offers:

- Versatility as it can be applied on large diameter tanks/pipes
- Less material used than a wrap
- Can potentially provide the same strength as a wrap
Drinking Water Plant, France

Corroded pipe requires reinforcement

Background

- 2 vertical pipes (diameter: 1.1m)
- On ~ 70m inside a concrete pit (3.2m diameter)
- Bad ventilation system inside the pit → condensation in the bottom section → Corrosion
Drinking Water Plant, France

Corroded pipe requires reinforcement
Drinking Water Plant, France

Corroded pipe requires reinforcement

• Tests
  • Visual inspection
  • Ultrasonic tests
  • Laser profilometry on a few damaged sections

• Results
  • Visual inspection: Advanced deterioration of the external coating (only protection against corrosion), especially on the bottom section
  • Water flow alongside the outside of the pipes accelerates the corrosion rate of the steel where the coating is gone
  • Maximum thickness loss between 20.94% and 48.55%.
  • Surface prep. from previous coating was not conducted properly
Drinking Water Plant, France

Corroded pipe requires reinforcement

A composite patch was to be bonded in place on the external of the pipe.

This was to be completed using a pre-fabricated patch (500 x 500 mm), bonded with an epoxy.
Drinking Water Plant, France

Corroded pipe requires reinforcement

Workshop tests were completed:
Advantages of Cold Bonding

- Quick, safe-to-use, **cold-applied and cold-curing** solutions.
- **Simple application** procedures without specialist tools.
- Suitable for equipment operating at **elevated temperatures**.
- **Fast curing grades** for minimal downtime.

- **Excellent adhesion** to a variety of common substrates.
- Excellent **corrosion protection** in harsh environments.
- Outstanding **chemical resistance** to a wide range of chemicals.
- Can be **designed for compliance** with engineering standards.
- Proven **long-lasting** solutions which can **increase an asset’s lifespan**.