VITCEA Workshop

Oil and Gas Inspection: NDT in Non-Metallic Materials

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14:55 – 15:15 CET
13:55 – 14:15 GMT

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VITCEA Workshop

Non-metallic materials in oil & gas Inspection & NDT/NDE Information Sources Codes & Standards Summary Q & A

(20 minutes)
Non-metallic Materials in Oil & Gas

- Composites are used in increasing range of applications
- NDT usually done at Manufacture
- NDT in Service is more difficult and less widely done
- Traditionally conservatively designed to allow for in-service damage or degradation
- Perception of difficulty to inspect in service and limitations of defect assessment methods have limited uptake of composites
- They are increasingly being used in large structural applications
- With recent developments there are a range of NDT methods that can be used in-service
Non-metallic Materials in Oil & Gas

Definition

Non-metallic materials include ceramics, polymers, elastomers as well as composite materials. We will restrict it to materials comprising polymeric resins reinforced with fibres. The resin may be one of a class of thermosets (epoxy, polyester, vinyl ester, phenolic, etc.) or thermoplastic (PA, PEEK, PPS, PVDF, etc.).

The fibre reinforcement may be glass, carbon or aramid and can be present in continuous or chopped lengths.

Sandwich structures comprising two layers of composite bonded to either side of a foam or honeycomb core may also be classified as a composite material.

They do not corrode in the conventional sense but degrade in-service due to chemical, physical and thermal ageing.
Terms commonly used in the Oil and Gas industry for composite materials include:

**GRP**  Glass reinforced polyester (where the fibre is glass and the resin is polyester)

**GRE**  Glass reinforced epoxy (where the fibre is glass and the resin is an epoxy)

**GRV**  Glass reinforced vinyl ester (where the fibre is glass and the resin is a vinyl ester)

**FRP**  Fibre reinforced plastic (where the fibre may be any of those listed above and the resin is any of the polymer resins)

**RTR**  Reinforced Thermoset Resin (where the fibre is glass and the resin is any of the polymer resins)

**CFRP**  Carbon fibre reinforced plastic (where the fibre is carbon (conductive) and the resin is any of the polymer resins)
Non-metallic Materials in Oil & Gas

Non Metallic applications is increasing...

- Piping
- Tubing Casing
- Valves
- Liner
- Composite Repair
- Tanks & Vessel
- Secondary Structures
- Cooling Towers

Saudi Aramco
Non-metallic Materials in Oil & Gas

4 m GRP pipe installation in UAE

Future Pipe Industries
Non-metallic Materials in Oil & Gas

2.5 & 3.5 m pipe installation in Qatar

GRP Cooling water pipeline – 2.5 m dia. installed in 12m sections extending over 75 km in desert environment

Pipe joint (adhesively bonded)

Large Industrial Complex in North East Qatar
Gas Processing Plants (LPG and GTL)
Qatar Petroleum
Qatar Gas
Ras Gas
Q-Power
Shell
Sasol

Up to 100,000 people on site
Over 6,000 Dodsal Contractors
Non-metallic Materials in Oil & Gas

Application examples – composite repairs

Materials: Glass/Epoxy
Diameter: 16 inch
Temperature: 25°C
Pressure: 30 bar
Ease of installation
No hot work permit needed
Corrosion resistant
Non-metallic Materials in Oil & Gas
On Site Spool Manufacture
CFRP Pipe Repairs

Furmanite International
Non-metallic Materials in Oil & Gas

Materials formed to shape on site with no pre-fabrication

Flexible materials conform to difficult shapes

Epoxy bond to steel provides leak sealing capability, chemical & environmental resistance

Lightweight repair kits are easy to transport & handle

Repairs are close fitting & can be applied in confined spaces

Furmanite International
What to inspect

- **Components**
  - Tanks (above or below ground)
  - Pressure Vessels
  - Pipes & Joints

- **Structures**
  - Civil
  - Offshore

- **Systems**
  - Pressure
  - Actuators
  - Rotating equipment
  - Safety equipment, etc.
Challenges - In-Service NDT

- Thickness
- Accessibility
- Coupling & surface condition
- Positive Materials Identification
- Signal attenuation and scattering
- Inhomogeneous and anisotropic structure
- Lack of adequate standards
- Interpretation of inspection results (Probability of Detection)
- Unfamiliarity with nonmetallic structures
- Increased reliance on operator experience
Inspection Strategy – Large Structures

- Global inspection methods
- Monitoring (e.g. Acoustic Emission)
- Fast screening with detailed inspection of indications found
- Risk-Based Inspection – Locations and types of likely damage mechanisms known
Defect Types – In Service and Installation

Composites are damage tolerant.

Variety of *in-service* defects are possible

Most significant are

- Delaminations (debonding)
- Impact damage (localised)
- Matrix cracking (overstress)
- Weepage (leak)
- Environmental ingress (swelling)
- Thermal damage and lightning strike
- Disbonding – joints and repair applications
- Loss of thickness – due to erosion or severe chemical attack

Other failure mechanisms may also be present, e.g. UV degradation and possibly fibre failure but less of a concern.
Standards and Information

- ISO14692
- NORSOK
- Company and In-House specifications
- Generic NDT procedures
  - NPL/ QinetiQ ultrasonic C-Scan procedures
  - HOIS Guidance In-Service Inspection

www.MaterialsSolutions.info
www.HOIS.co.uk
Example  ISO 14692 (under revision)
Rapid C-Scanning

Wheel probes
Rapidscan™ or Phased Array
Air coupled UT probes
Example - NDT of Composites

- Mainly GRP
- Variable wall thickness (2-50mm) and section
- Connections, nozzles and flanges an issue
- Variable material properties and quality
- NDT may be affected by high porosity or poor surface finish
- NDT methods difficult to apply in thicker sections
- Access for NDT an issue. Piping often close packed e.g. water treatment plant
- Special issues in some applications – escape craft, firewater mains, lined vessels, etc.
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# Defect Assessment - Oil & Gas

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<th>Defect type</th>
<th>Defect assessment procedure</th>
<th>Comment</th>
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<td>Matrix cracking</td>
<td>Damage mechanics approach to estimate density</td>
<td>Procedure in development and under test</td>
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<td>Lack of adhesive</td>
<td>Simply area of de-bond (&lt; 30% of bond area OK)</td>
<td>Used in ISO 14692</td>
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<td>Loss of thickness</td>
<td>Simple 1-D assessment using estimated minimum wall</td>
<td>Very conservative for localised defects</td>
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<td>Delamination</td>
<td>Linked to damage mechanics plus also fracture mechanics approached</td>
<td>Damage approach under development. For fracture approach difficult to quantify critical values</td>
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NDT Methods

- Visual VT
- Ultrasonics UT
- Radiography RT
- Thermography TT
- Laser Shearography LS
- Microwave MW
- Acoustic Emission AE
- Other, e.g. coin and tap testing AI
UT Thickness Meter
The 35HP gages are excellent tools to measure fiberglass or composite parts, from aerospace structures to boat hulls and storage tanks that require thickness control.

Operator can view thickness and waveform with the optional A-scan mode.
Data Presentation

- Digital Image
- A-Scan *Signal v arrival time*
- B-Scan *Through thickness slice*
- C-Scan *Map from above surface*
- D-Scan Orthogonal view
- Depth scan or Time-of-Flight TOFD
- Digital data set
- Similar presentations used irrespective of NDT method used

Courtesy NPL, QinetiQ
Laser Shearography
Laser Shearography

Collar Joint Pipe

Vacuum Loading of Collar Joints
Thermography
Ultrasonic B-Scan and TOFD

Pipe wall loss through severe chemical attack

Erosion and wall loss, liner damage
Clock Spring microwave scans (before and after hydrotest showing changes).
Impact damage

Through-wall defects in pipe underneath carbon composite repair
We want to avoid this...

Example of an adhesive bond failure of GRE pipework in service
Applicable Standards

INTERNATIONAL STANDARD
ISO 14692-4

First edition
2002-12-15

Petroleum and natural gas industries — Glass reinforced plastics (GRP) piping — Part 4: Fabrication, Installation and operation

NORSOK STANDARD
M-622
Rev. 1, April 2015

Fabrication and installation of GRP piping systems
UT inspection of GRP pipe joint
Future Developments

- Improvements in rapid screening methods and monitoring techniques
- Improved defect assessment methods
- Application of risk-based methods. Identify critical areas
- Reliability and performance of composite NDT Methods POD
- Use of simulation and NDT reliability models
- Improved standards for in-service composite NDT
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