Non-intrusive, Non-destructive FRP Inspection

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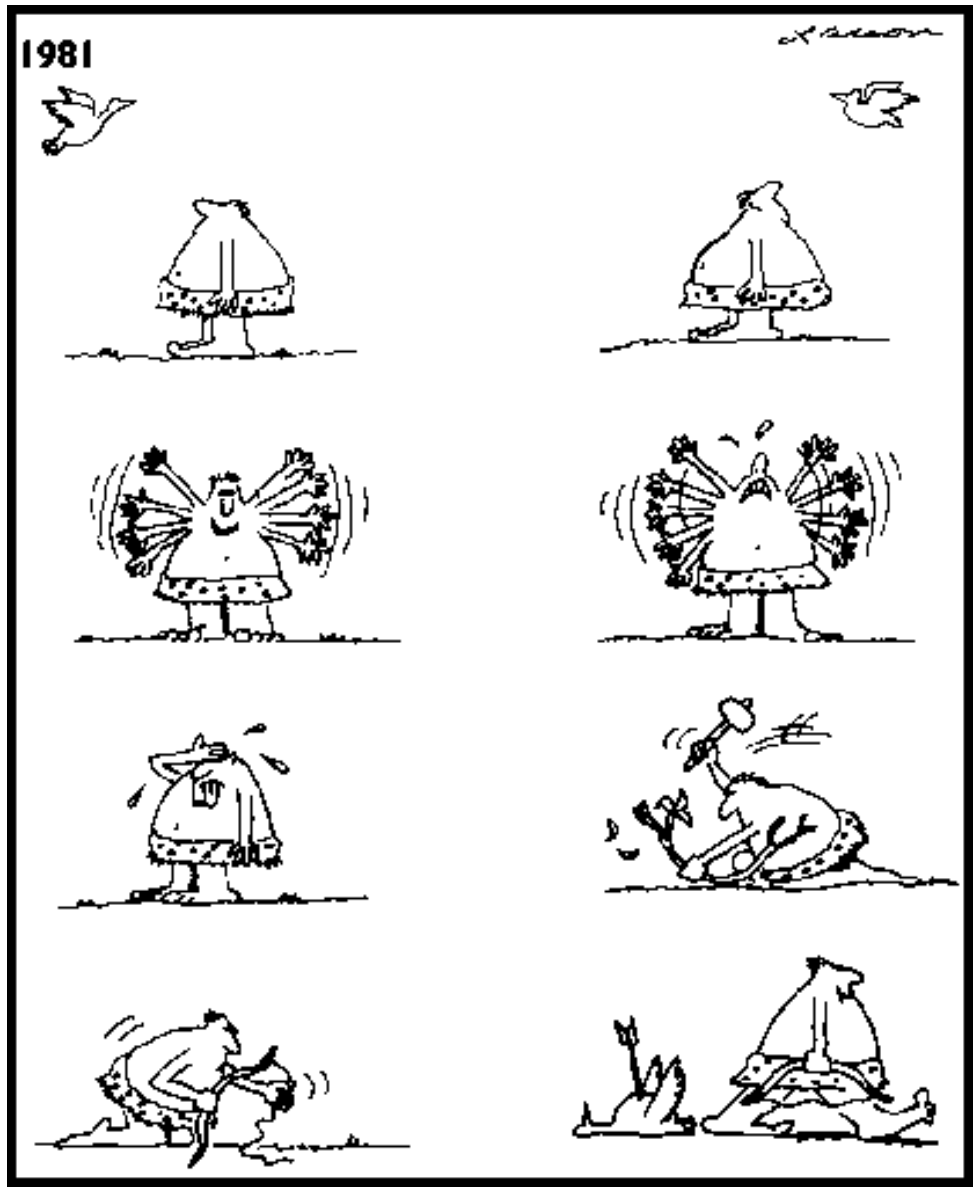
How to effectively inspect FRP for mechanical integrity (MI) and Fitness for Service (FFS)?

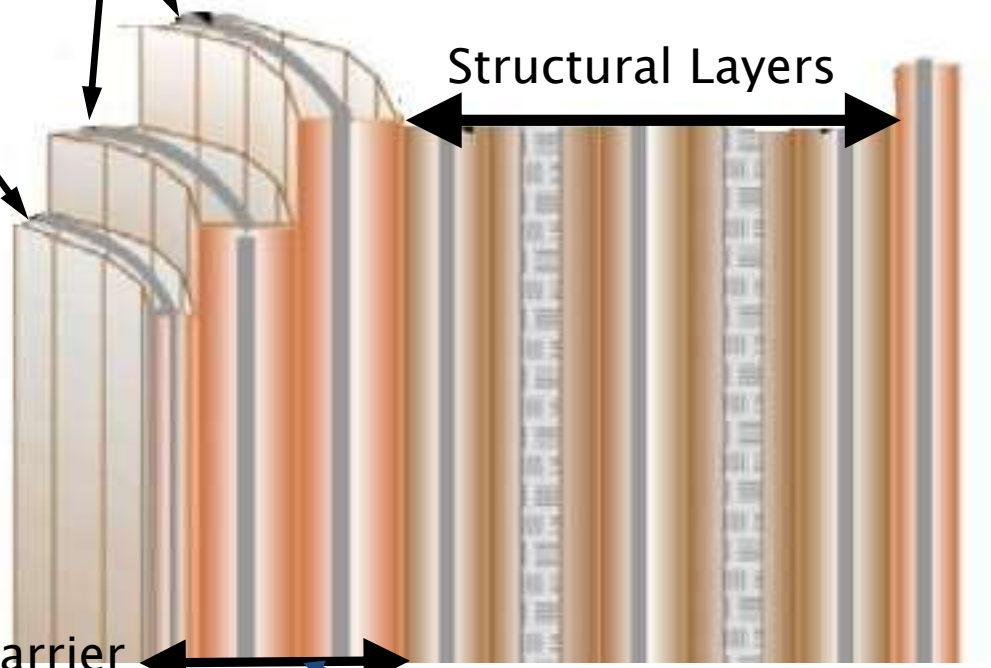


Definitions:

- Non-destructive: Measurements are made without causing any damage to the material inspected.

- Non-intrusive: Measurements are made while the pressure boundary is intact.
  - NO confined space entry
  - Possibly in operation

FRP Construction



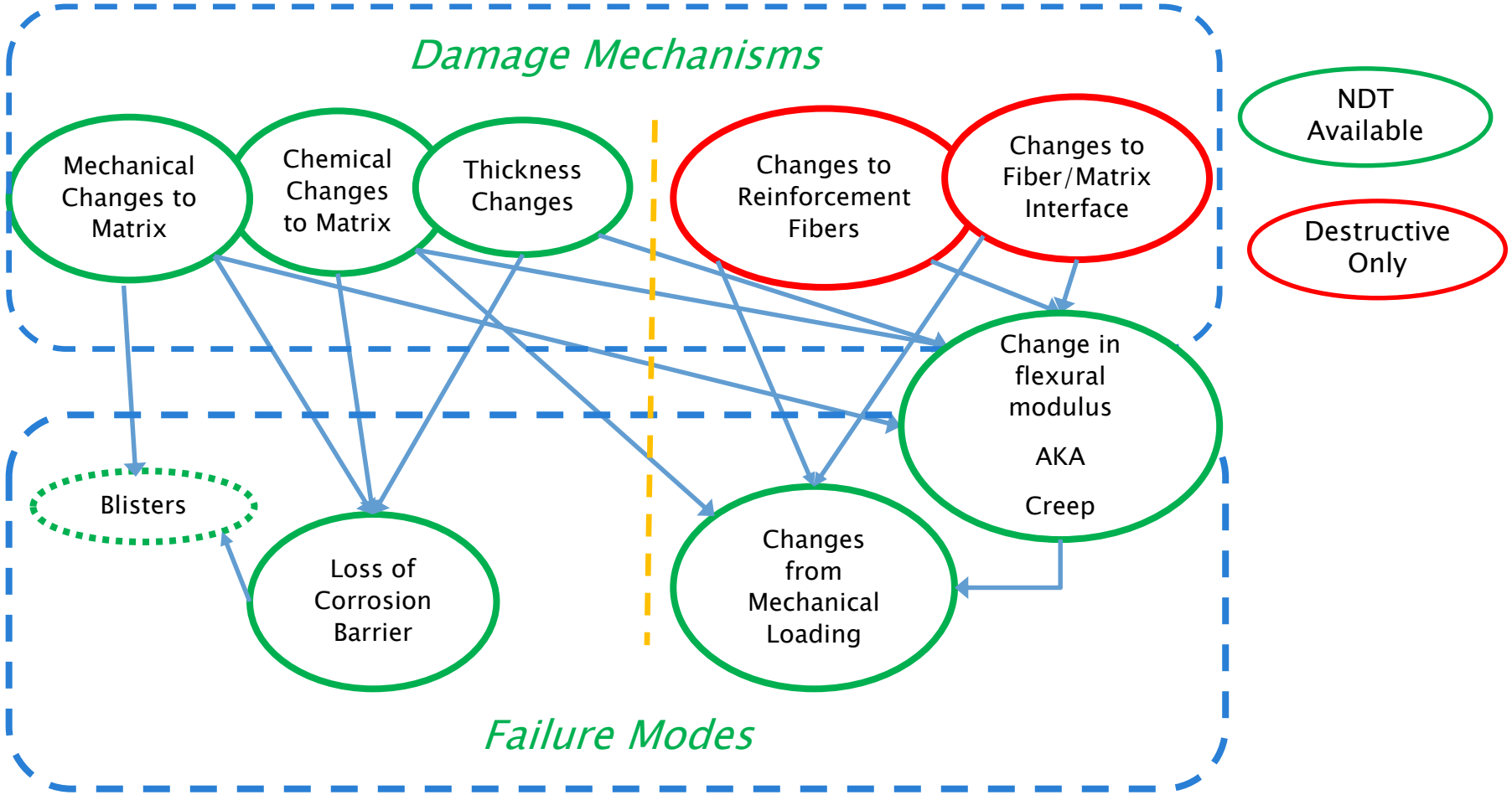
Owner Preferences

- Fitness for Service can be defined by:
  - Corrosion Barrier condition
  - Structural Capacity
- Mechanical Integrity:
  - Certification of Fitness for Service

FRP Construction & Quality Control

- Resin
  - Validation of chemical resistance using ASTM C581to the following:
    - Hardness changes
    - Weight loss
    - Flexural modulus change
- Corrosion Barrier
  - Detection and repair of visible defects
  - Resin Cure
- Structural Layers
  - Detection and repair of visible defects
  - Destructive testing and resin cure

FRP Damage & Failure



Guidance from Codes and Standards

- Piping Inspection
  - API Refers to FRP.
    - Some damage mechanisms discussed.
    - Few recommendations for detection and measurement.
    - No discussion of Condition Monitoring
  - Extensive detail for Condition Monitoring of metal piping.
- Vessel Inspection
  - No reference to FRP in API, ASME, ASTM.
  - New document available for Swedish Flue Gas Equipment.
  - TAPPI TIP 0402-28 – includes some destructive methods
  - Intrusive Inspection is the *NORM*

In-service Inspection Challenges

- Relationship of design and construction details to in-service inspection requirements.
  - What is the “Corrosion Allowance”? How determined? Where provided?
  - Where does Inspector obtain criteria for acceptance or repair?
  - Acceptable depth of damage to Corrosion Barrier?
- Risk of failure with damaged corrosion barrier?
- What measurements can be taken to show extent of damage and calculate Remaining Service Life?
- Same results with different inspectors?

Inspection of In-service FRP Equipment

- Detect and measure damage development as part of Mechanical Integrity or Fitness for Service (FFS).
  - Allow proactive repair or replacement decisions.
  - Provide information so that the rate of change can be calculated.

Possible Non-Intrusive Techniques

- Advanced Ultrasound
- Infra-Red Thermography
- Visual External
- Acousto-Ultrasonic Testing
- Acoustic Emission
- Micro-wave

- This presentation will focus on Advanced Ultrasound.

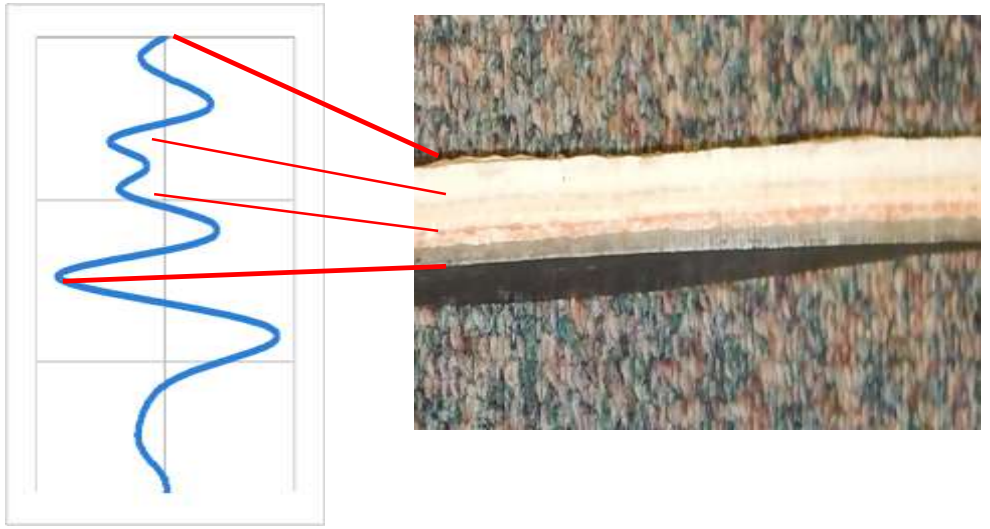
Advanced Ultrasound

- Uses conventional ultrasonic flaw detector and transducer.
- Required Post-Processing of Data
- Results provide:
  - Thickness Range,
  - Current Flexural Modulus,
  - Damage Depth to Corrosion Barrier

Advanced Ultrasonic Method

1. Samples provided by users.
2. Visual information from corrosion barrier to simulate intrusive inspection.
   a. Include surface hardness
3. Evaluation of cut edge for depth of damage.
4. Ultrasonic readings from outer surface to simulate non-intrusive inspection.
5. Destructive testing of flexural modulus to confirm value from ultrasound.

Case Study 1



- SO_2 service
- Discolouration
- Cracks in surface
- No blistering evident
- Hardness: 41

- From outer surface
- Damage depth from N-I: 0mm
- Damage depth from section 0mm
- Intermediate detected
- Flexural Modulus: 41% of theor.

Intrusive

Non-Intrusive

Case Study 2

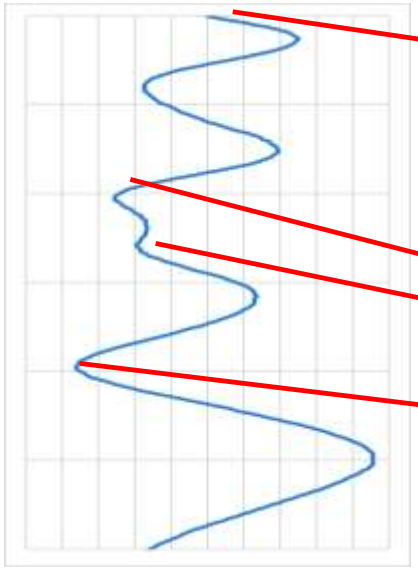
- Weak HCl
- Temp ~100°C
- External Pressure
- Cracking and separation
- Hardness: 35

- Damage depth: 3.4mm
- Flexural Modulus: 44%

Intrusive	Non-Intrusive

Case Study 3

- SO_2 and solids
- Temp ~100°C
- External Pressure
- Heavy scale
- Hardness: 13



- Damage depth: 1.7mm
- Blisters at 4mm
- Flexural Modulus: 41%

Intrusive

Non-Intrusive

Case Study 4

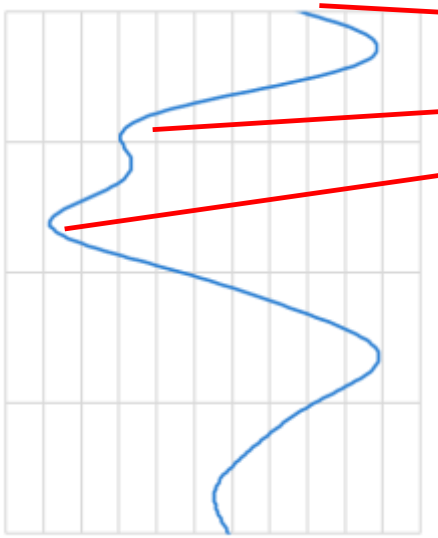
- CO & CO_2
- Temp ~75°C
- External Pressure
- No Scale
- Hardness: 25

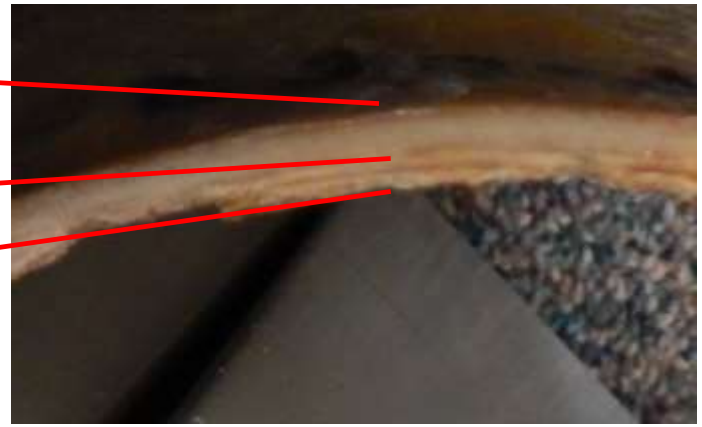
- Damage depth: 1.5mm
- Flexural Modulus: 96%

Intrusive

Non-Intrusive

Case Study 5





- Chlorine dioxide and pulp
- Temp ~75°C
- Hardness: 6

- Damage depth: 1mm
- Flexural Modulus: 44%

Intrusive	Non-Intrusive

Sometimes Intrusion is Required

- Flat bottoms of tanks
- Nozzle seal bonds
- Process reactors

In many cases, damage detected by non-intrusive methods can guide when intrusion is required.

Summary

- Advanced Ultrasonic methods can provide non-intrusive assessment of both corrosion barrier condition and structural capacity.
- Final assessment and/or internal structures may require intrusive inspection.
- Inconsistent relationship of hardness with corrosion barrier condition.
- Change in flexural modulus can be used to guide when remediation should be considered.

Questions?

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The good thing about science is that it is true whether you believe it or not.

Neil deGrasse Tyson