NDE of Non-metallic Repairs

Non-Metallic Components and Repairs

- Potential use cases for non-metallic materials are increasing and these are seen as attractive alternatives for aging management programs
  - High density polyethylene (HDPE)
  - Cure-in-place piping (CIPP)
    - Ultraviolet cure, heat cure, etc
  - Fiberglass
  - ***Carbon fiber reinforced polymer (CFRP)***
- Non-metallics can offer high performance, low cost, and potentially fewer known failure mechanisms
  - Conversely, non-metallic materials may be less understood long-term
    - In-service degradation mechanisms
  - May offer inspection challenges for conventional NDE tools

Observed Research Gaps - NDE

- Gap #1: (Previous effort) NDE through CFRP
  - What volumetric techniques are capable of measuring remaining substrate thickness beneath a CFRP laminate?
- Gap #2: (Current project) NDE of CFRP laminate
  - A) What are the capabilities of existing acoustic tap examination method?
  - B) What other NDE techniques can detect/size delaminations in CFRP repairs?

Background work: NDE of Metallic Substrate Through CFRP Materials (Gap #1)

Objective

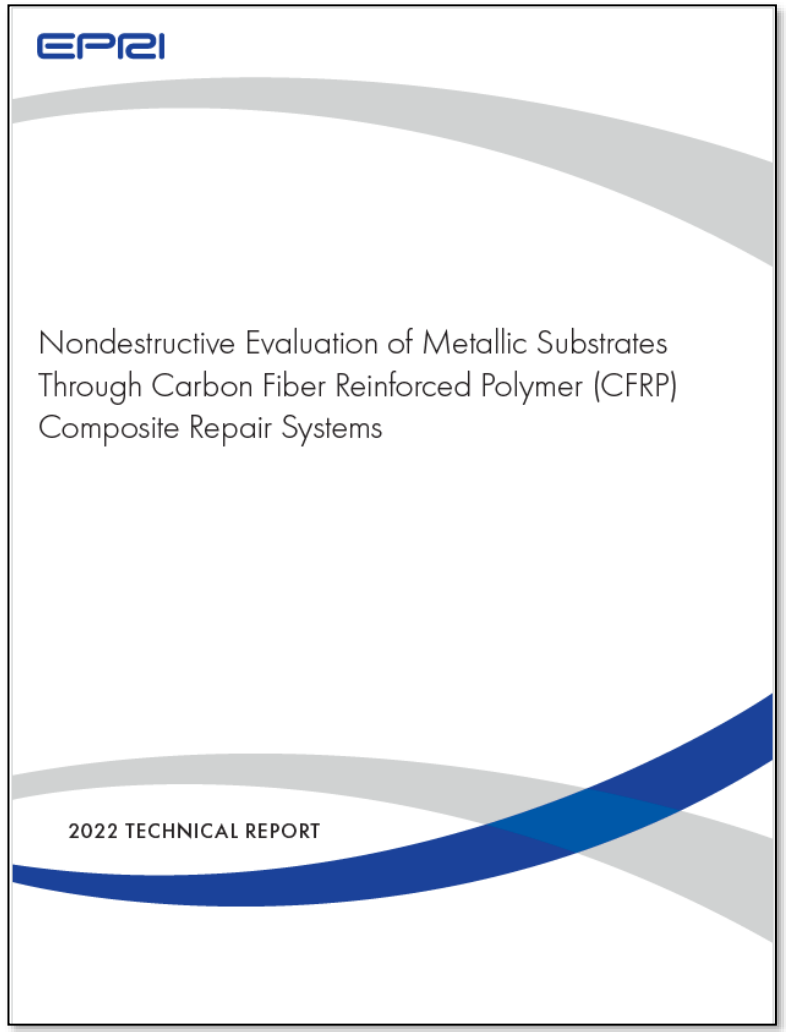
- Identify & evaluate NDE technologies capable of measuring remaining wall thickness of metal substrates beneath carbon fiber composite systems

Project Approach and Scope

- Fabricated variety of plate and pipe mock-ups
- Pipe mock-ups created with field removed piping samples with real corrosion (pitting & localized general corrosion)
- Evaluated various ultrasonic and electromagnetic techniques

Summary Results

- Identified two successful techniques:
  - **Dynamic Response Spectroscopy**
  - **Pulsed Eddy Current**
- Other electromagnetic techniques may also be applicable, depending on lift-off distance capabilities between sensors and substrate
- Report documents the sample configurations and examination results of each technique against baseline ultrasonic data



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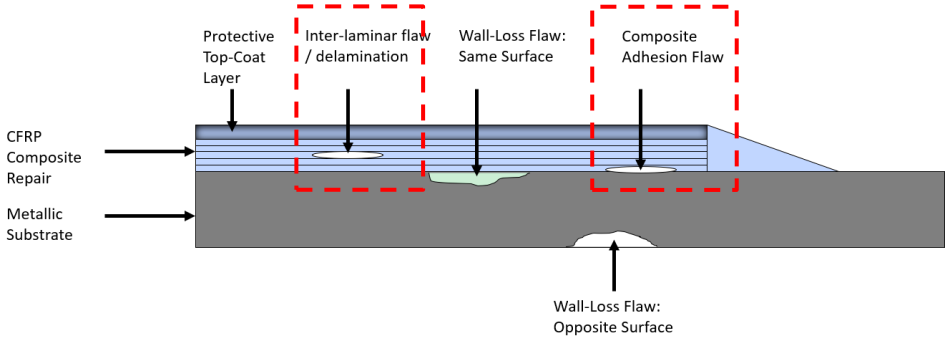
Gap # 2: Condition Assessment of CFRP Integrity

Research Questions

- What size flaws can be detected using acoustic tap testing method?
- At what depth within the CFRP laminate can a given flaw size be detected (in-service exam)?
- What alternative NDE techniques can be used to assess the CFRP condition to improve detection and sizing capabilities?

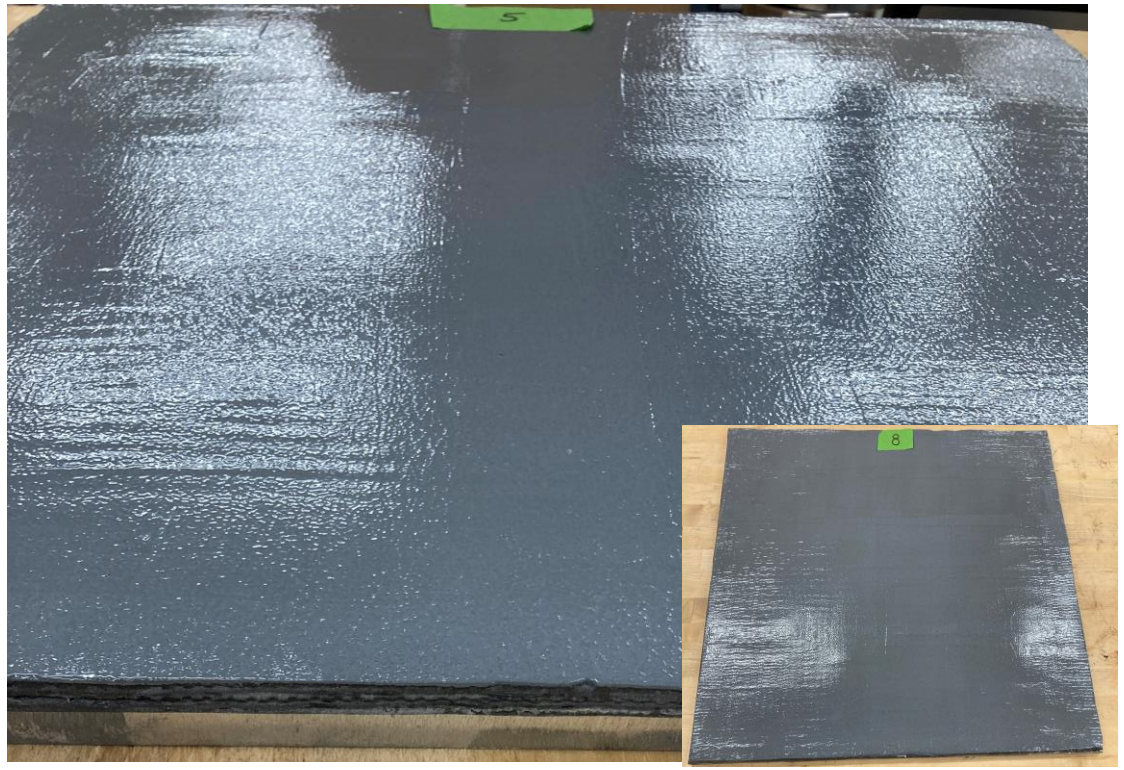


Project Objectives

- Evaluate flaw detection and sizing capabilities of existing acoustic tap examination methods
- Identify opportunities for enhancement to existing methods
- Evaluate needs for enhanced flaw detection / sizing capabilities by alternative existing techniques or development of new techniques
- Assess capabilities of new techniques
- Identify opportunities for enhancement to flaw documentation processes

First Mockups

- An initial set of mockups has been delivered (late 2023)
  - 8x plates 2’x2’x 0.5” steel
  - 20 oz/yd carbon fiber from 1 to 5 layers per plate
  - Most have 1 layer of fiberglass
  - Delamination/bubble flaws planted at various depths and total flaw sizes
  - Air bubble/delamination flaw inserts
  - Very thin layer of gray topcoat on each mockup
  - Each plate divided into quadrants via imaginary line to constitute 4x 1’x1’ individual mockups that can be sectioned out if warranted



Mockup Observations

- Edge and corner effects are substantial
  - Placing mockups in soil/sand to test may reduce edge effects
  - Round mockups, pipes, thin plates may be different
  - Excessive pitting on substrate might affect audio signatures?
- Large flaws are easily detectable
- Bulges offer visual cues for bubble flaws but are less apparent for small flaws under many CF layers
- Bubbles may constitute most readily detectable flaw type
- Mockups may be sectioned to confirm as-built characteristics
- Phased array and acoustic tap testing are promising based on first set of mockups, but resolution for small and deeper flaws is more challenging

Current Status and Next Steps

- Initiating fabrication of a second round of mockups (target completion Q4 2024)
  - One pipe mockup with ID side 5-layer and 3-layer CFRP layups
  - Multiple plate mockups with variable layers
    - New defects, including: undersaturation, repair areas, wrinkles, and flaws under overlap regions
    - Undersaturation is likely to be more difficult to detect and characterize than bubbles used in first set of mockups
- Acquire NDE results with these new mockups via tap testing, direct resonance spectroscopy (DRS)
  - Use Destructive examination as confirmatory or as otherwise needed

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