Research Overview Of Composite Materials in Pipelines

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Taking on your toughest technical problems

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Composite Use Overview

- Composite Materials in Pipeline Applications (+25 years)
  - Corrosion
  - Mechanical Damage (Dents plus Gouge, Dent + Metal Loss)
  - Wrinkle Bends
  - Fittings
  - Girth Welds
  - Pipeline re-rate
  - Cracks
  - Development of Standards (ASME PCC-2; ISO 24817)
- Past, Current and Future Work
  - *Dent repair (Past)*
  - *Vintage Girth Weld Reinforcement (Past)*
  - Repair of pipe fittings (Past)
  - Long-term study (Current)
  - Subsea Repair (Current)
  - *Pipeline Re-rate (Current)*
  - *Crack Mitigation (Current)*
  - NDE of composites (Future)
  - Certification programs (Future)
  - Integration of different technologies (Future)

Variables to Consider When Using Composites

- Environment of pipeline
- Operating conditions
  - Loading, temperature,
  - Failure modes (static overload, fatigue, material degradation)
- Geometry of anomaly
- Geometry of repair
  - Stiffness of repair
- Total Disruption Time
- Reliability
- Ease of installation
- Inspectability
- Traceability
- Industry recognition, regulating entities

PRCI Research Programs

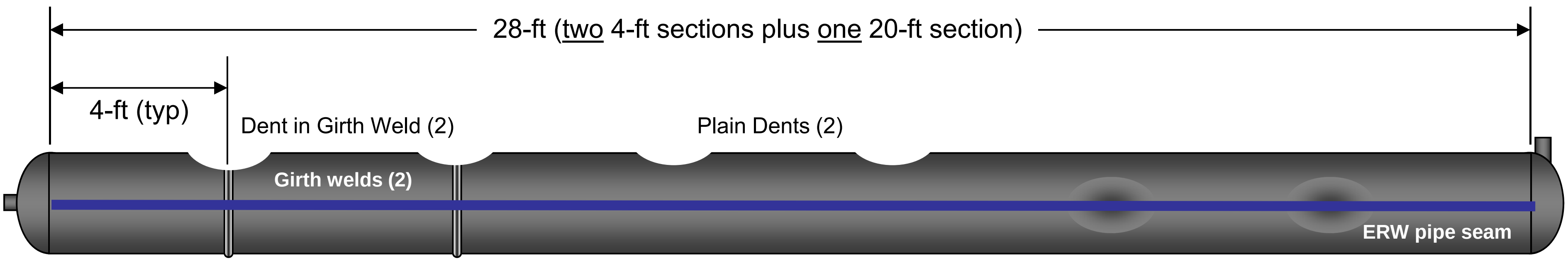
- MATR-3-4 Long-term performance (10-year study)
- *MATR-3-5 Repair of dents*
- MATR-3-6 Repair of subsea pipelines/risers
- *MATR-3-7 Girth weld reinforcement*
- MATV-1-2 Wrinkle bend reinforcement
- *MATR-3-9 Re-rating to establish MAOP*
- NDE 2-3 NDE & Inspection Techniques
- MATR-3-10 Composite Repair Guideline Document
- Composite Roadmap
- Future (potential) programs
  - Crack repair and reinforcement
  - Effects of pressure during installation
  - Elevated temperature testing

Case Study: Repair of Dents

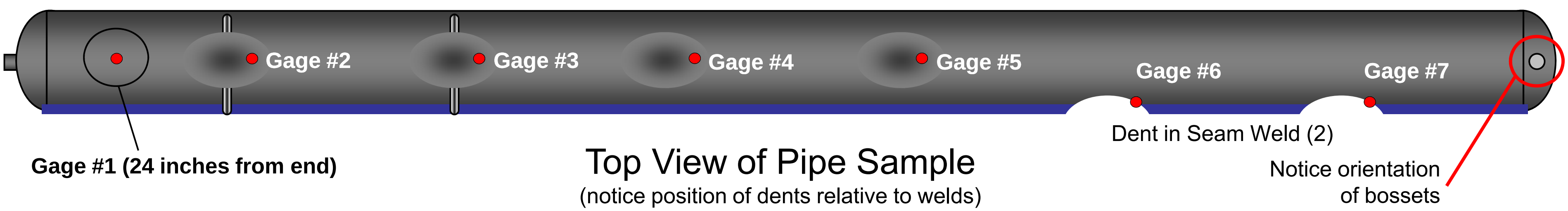
- PRCI-sponsored program (25%) along with co-funding from manufacturers (75%)
- Ten (10) repair systems participating in study
  - 2 rigid coil system (one E-glass & one steel)
  - 3 carbon systems
  - 4 E-glass systems
  - 1 Steel Sleeve
- One unrepaired test sample served as baseline
- 68 total dents in study
- Intent was to validate composite materials for repairing dents subject to cyclic service

Dented Pipeline Samples – Strain Gage Locations

Samples fabricated using 12.75-inch x 0.188-inch, Grade X42 pipe material, ΔP = 72%SMYS

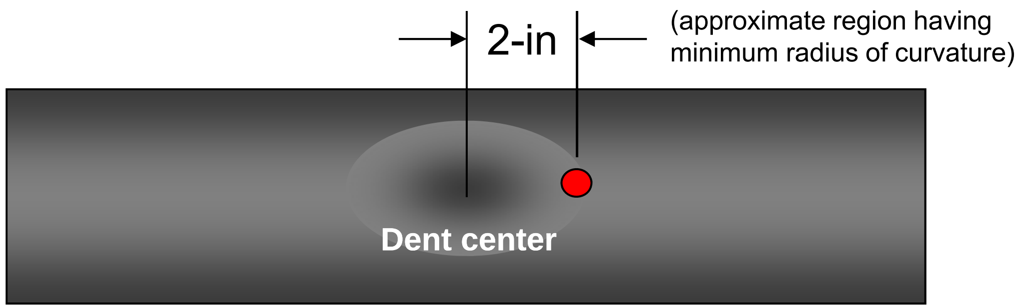


Side View of Pipe Sample (6 defects total)



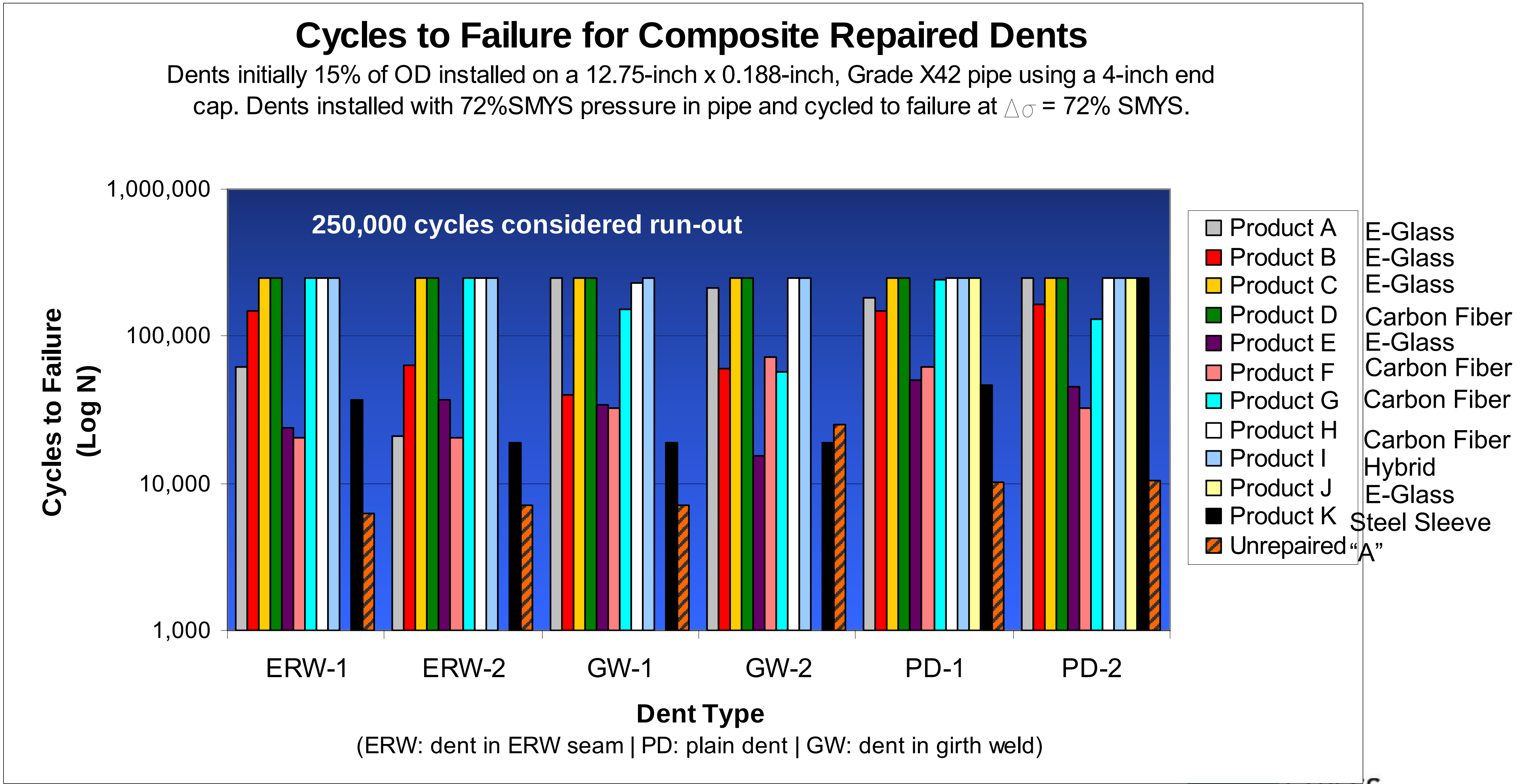
Top View of Pipe Sample

(notice position of dents relative to welds)



Close-up View of Dented Region

Cycles to Failure – Not all Systems Created Equal!

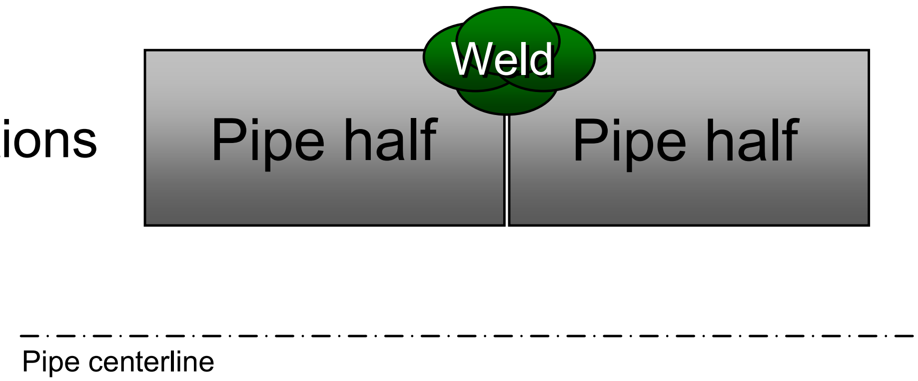


Case Study – Girth Weld Reinforcement

- Focus is to evaluate the ability of composite materials to reinforce girth welds subject to axial and bending loads
- Full scale test program involving:
  - **Vintage welds (intentional defects)**
  - **Repair using composite materials (PCC-2 as guide)**
  - **Test loads: Pressure (36% SMYS, constant), axial tension and bending.**
- Five (5) composite systems participated

MATR-3-7 Test Plan

1. Purchase pipe material (12.75-inch x 0.188-inch, Gr. X42)
2. Perform material characterization (Chemistry, tensile, and Charpy including properties in exemplar weld)
3. Weld samples with intentional girth weld deficiencies (weld cap only) and threaded end caps
4. Sandblast
5. Install strain gages at select locations
6. Install composite repairs
7. Set-up test fixtures
8. Conduct test and record data
    1. Pressure cycles from 8% to 80% SMYS, 18,000 cycles.
    2. Pressurize sample to 36% SMYS
    3. Apply tension (or bending) loading with holds at specific load levels
    4. Apply tension (or bending) loads to failure
9. Inspect failures including photo documentation region of failure



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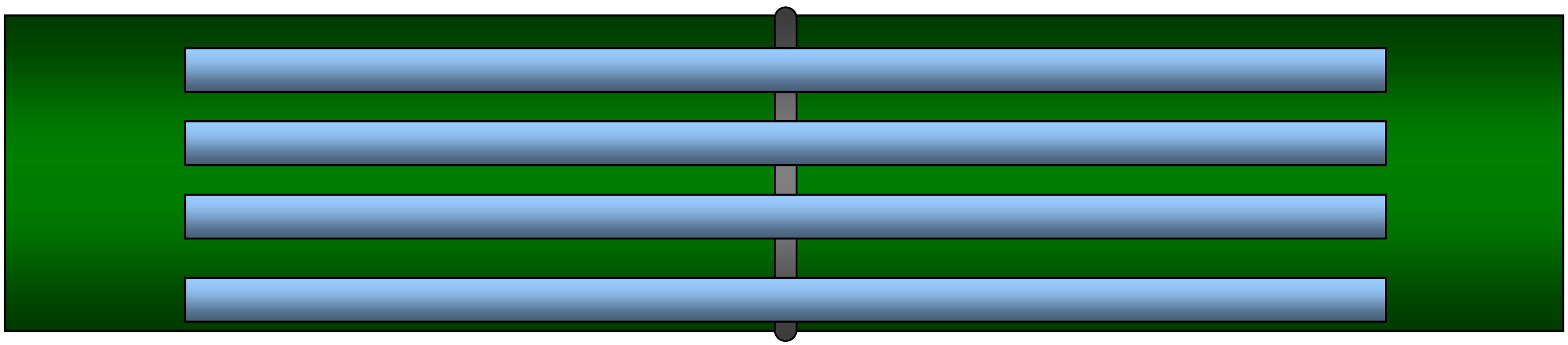
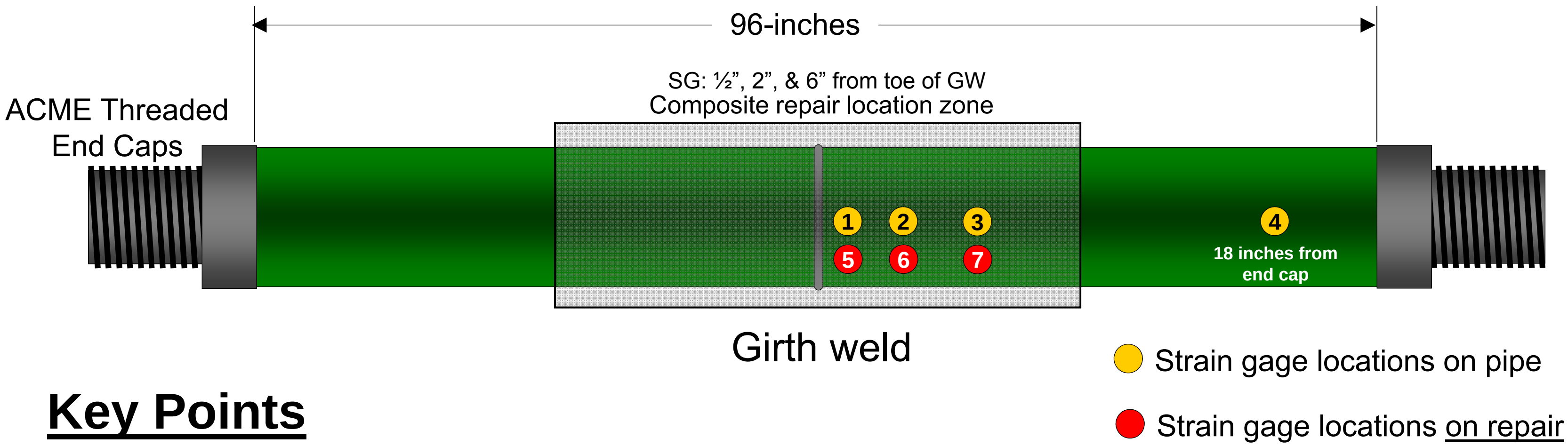
Reduced Bonding Area Sample



Sample with Mylar packing tape shown (to cover½ of the pipe's outer surface)

Configuration for 8-ft Tension Samples

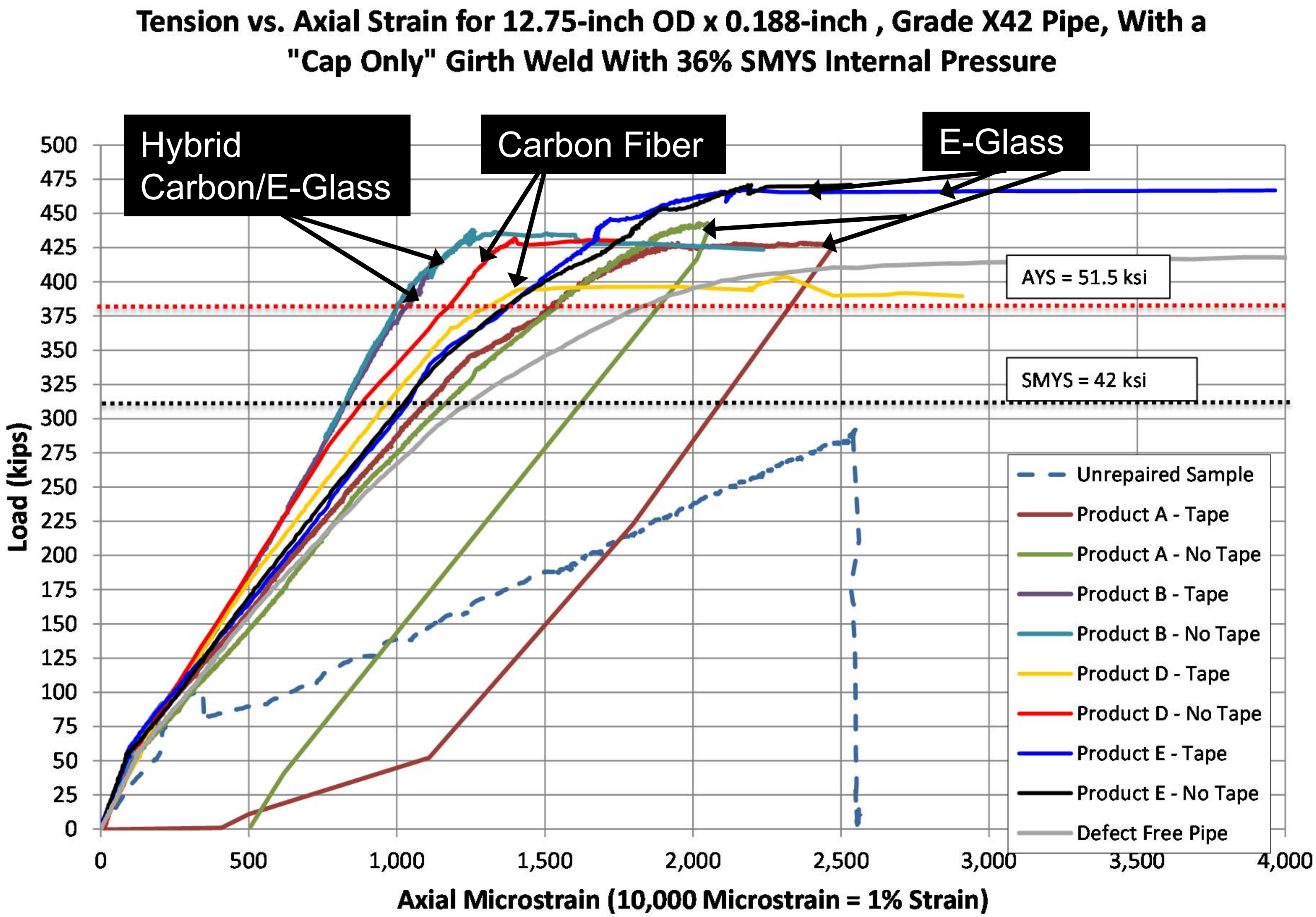
Measure wall thickness at each strain gage location



Key Points

1. Surface preparation
2. Length of reinforcement
3. Consistent girth weld fabrication
4. Instrumentation: strain gages beneath and on top of the composite
5. Generate load deflection curves for each manufacturer

Tension to Failure



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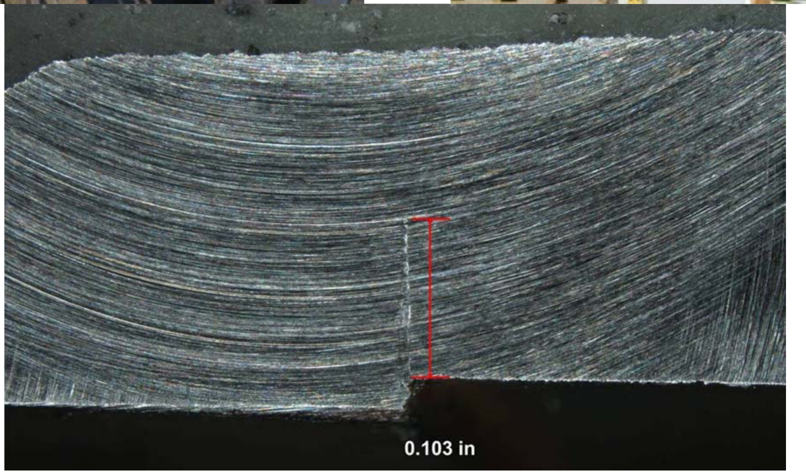
Bending to Failure



Case Study: Pipeline Re-Rating

- Objective was to determine how effective are composite materials at re-rating a pipeline
  - What does re-rate mean anyway?
  - How does one establish re-rate criteria?
    - Lower strain values?
    - Higher burst pressure?
    - Increased margin on safety?
  - Installed strain gauges on sample, reinforced and unreinforced, initial pressure cycles (current life), strain measurements, burst
- Conclusions:
  - Significant strain reduction was observed on the Xhab repaired system during normal operations
  - Burst pressure significantly increased

Case Study: Crack Arresting

- Objective was to repair cracks
- Challenges
  - Initial defect
  - Grow a crack (not through wall) through operating conditions
    - Monitor the growth
  - Stop the growth
  - Repair the crack
  - Continue operations
- Conclusions
  - XHab system was able to effectively extend the life of the samples; including no failure

Closing Comments

- Design standards are necessary to designate minimum performance requirements
- Products that cannot meet minimum standard requirements should not be used to repair high pressure pipelines
- Composite repair systems should be designed to restore integrity to damaged pipelines based on actual service conditions
- Don’t extrapolate – verify by testing and analysis

Questions?

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