EPRG-PRCI-APGA
23rd Joint Technical Meeting
Edinburgh, Scotland • 6–10 June 2022

JTM-23-p32: Feasibility Assessment of LSM Technology for Geohazard Applications

Dr. Chris Alexander*, Atul Ganpatye
ADV integrity, Inc., Waller TX, US

Dr. David Xu
PG&E, San Francisco CA, US

Asad Hossain
TC Energy, Calgary AB, CA

Amanda Kapronczai
Enbridge Pipelines Inc., Calgary AB, CA

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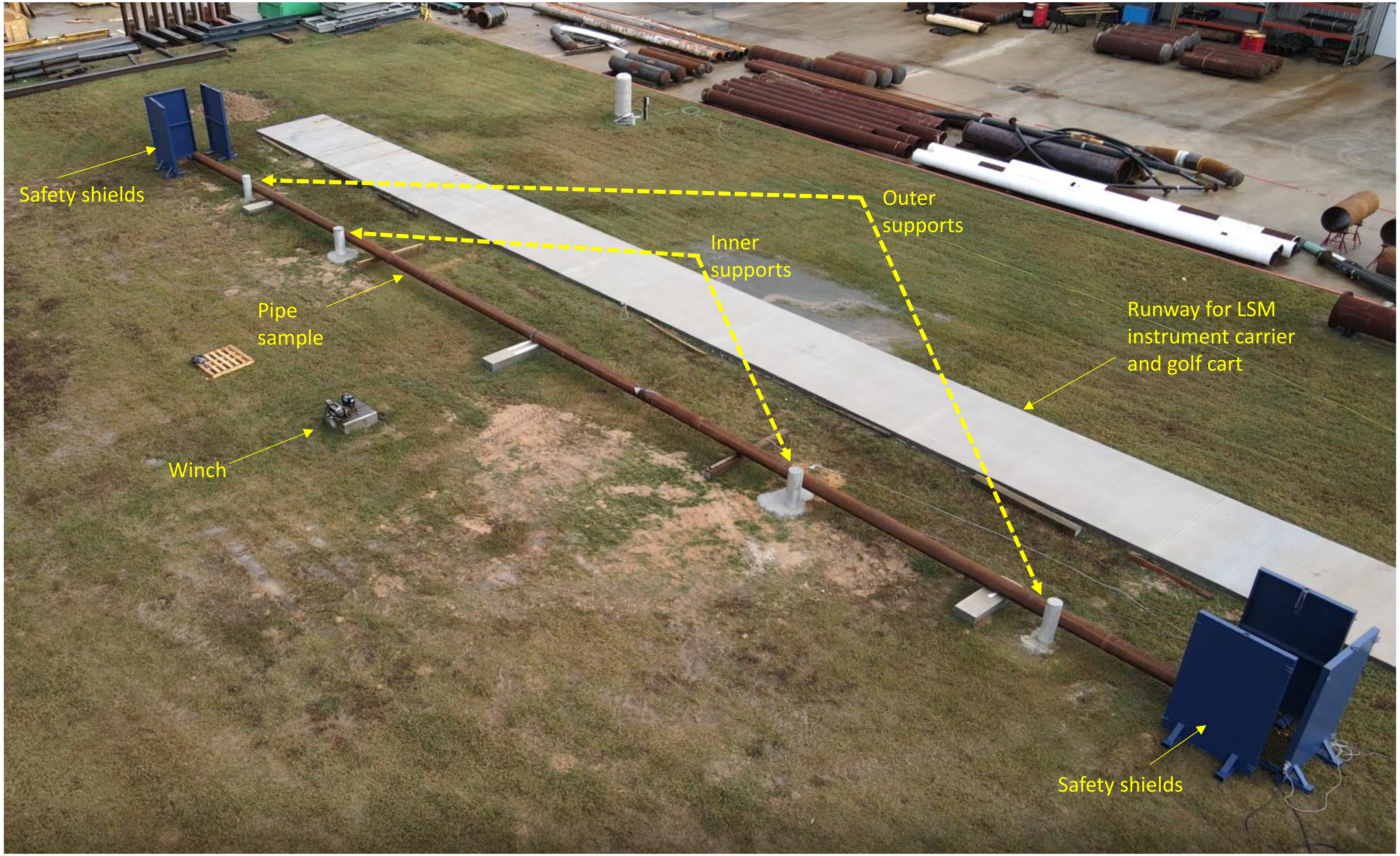
Background

- NDE 3-5 was established to evaluate the capabilities and limitations of Large Standoff Magnetometry (LSM) technology for quantifying stresses or strains in a pipeline subjected to geohazard loading conditions using full scale testing setups
- The project focused on global stresses/strains due to bending (not local stress fields due to flaws in the pipeline)
- Two fundamental concepts on which LSM is built:
  - Magnetrostriction (Joule effect)
  - Reverse-magnetostriction (Villari effect)

Project Highlights

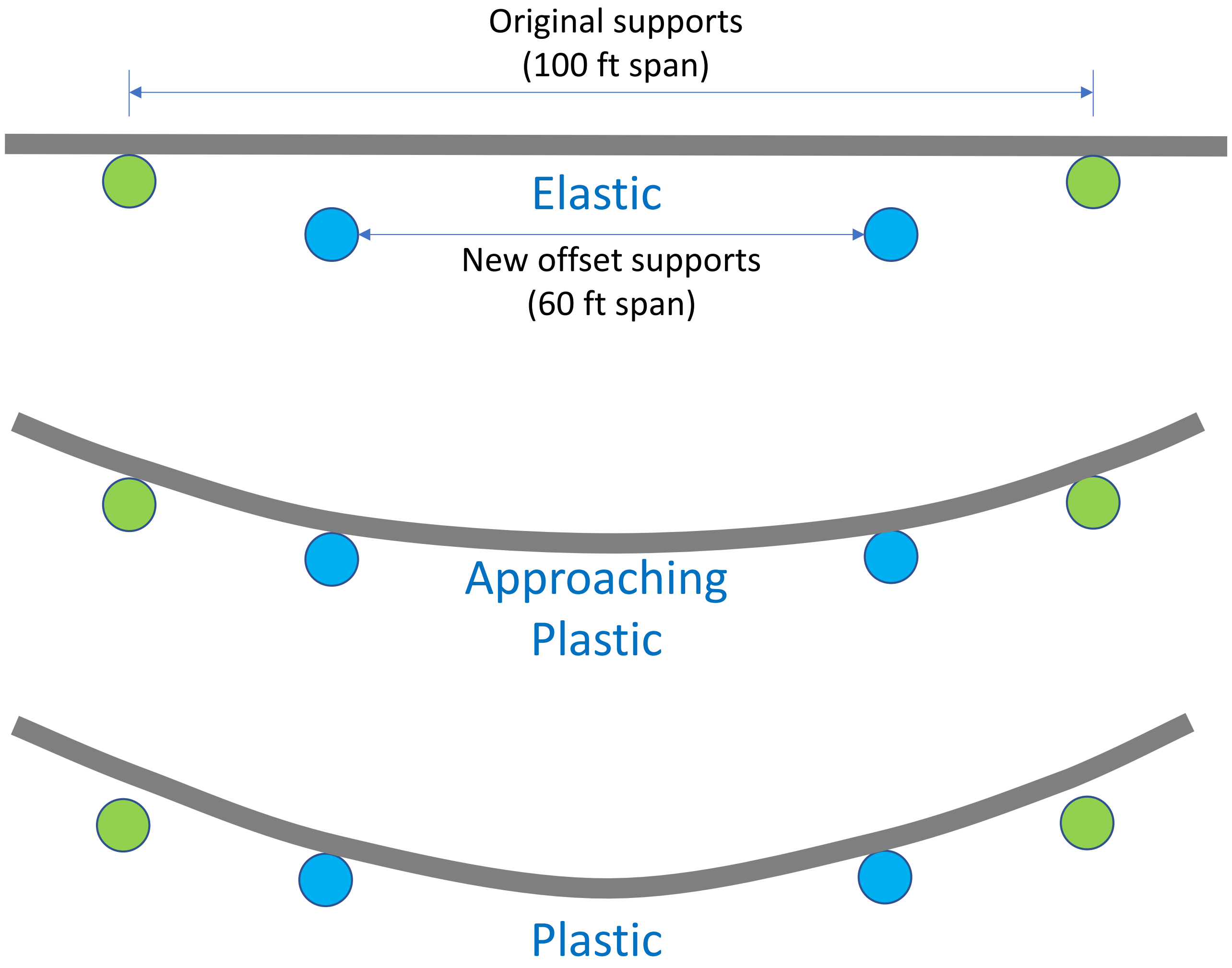
- Two LSM vendors participated in the study (Speir Hunter and Transkor) and successfully completed the planned test program
- Full-scale test facility and test equipment designed and constructed at ADV to perform LSM inspections on 12-inch NPS, 120 ft long pipe
- Vendors actively participated in pre-inspection and post-inspection discussions with the project team to discuss clarifications, gaps, and improvements in the data collected.
  - A great example of cross-continental cooperation – especially considering that the entire scope was executed around COVID lockdowns
  - Observations from experimental setup were discussed with the vendors and opportunities were provided to review and discuss the LSM results in the context of physical observations

General Test Setup



The Tale of Four Posts

- Balancing constraints from different perspectives
  - Exceed minimum central deflection for scanning in elastic regime ~ 10.2 cm (4 cm)
  - Achieve ~1% strain for the plastic loading step
  - Limit maximum central deflection at approximately 1% strain to ~ 0.635 m (25 inches)
  - Winch load capacity



The Tale of Four Posts

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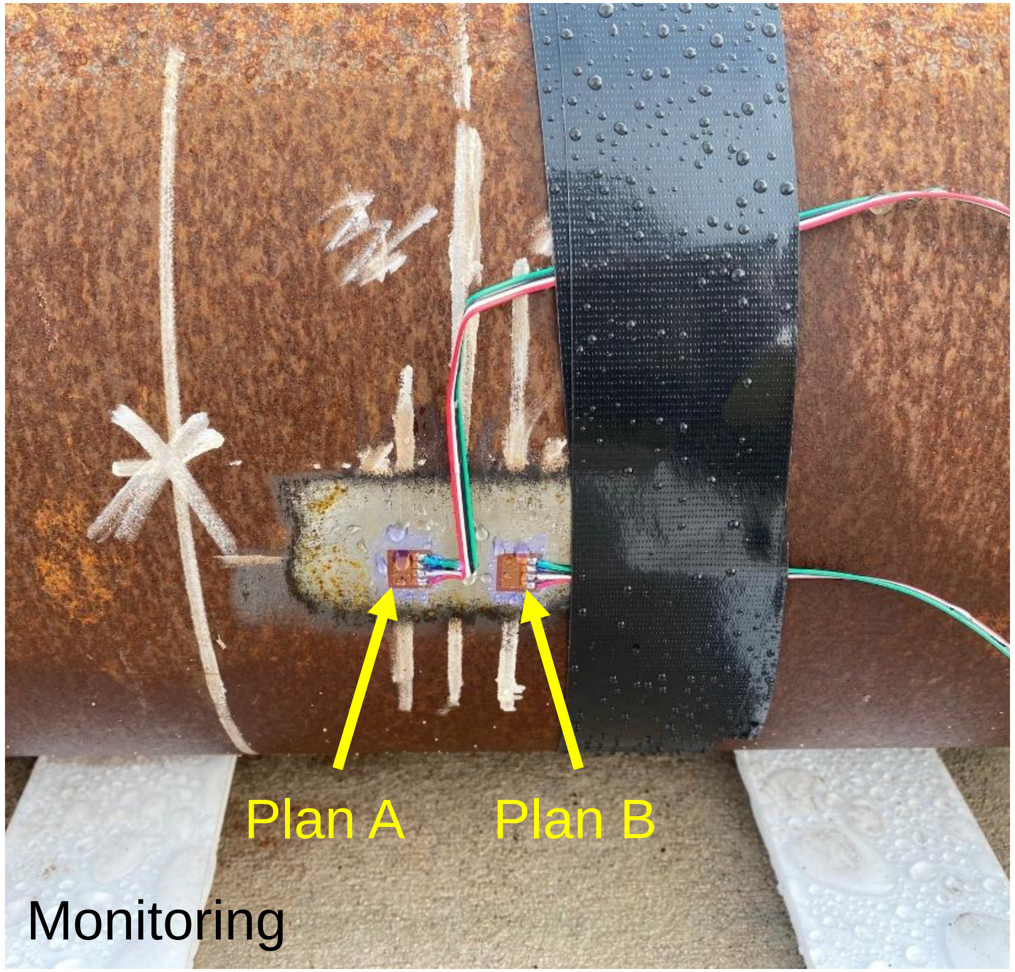
Low strains, elastic regime

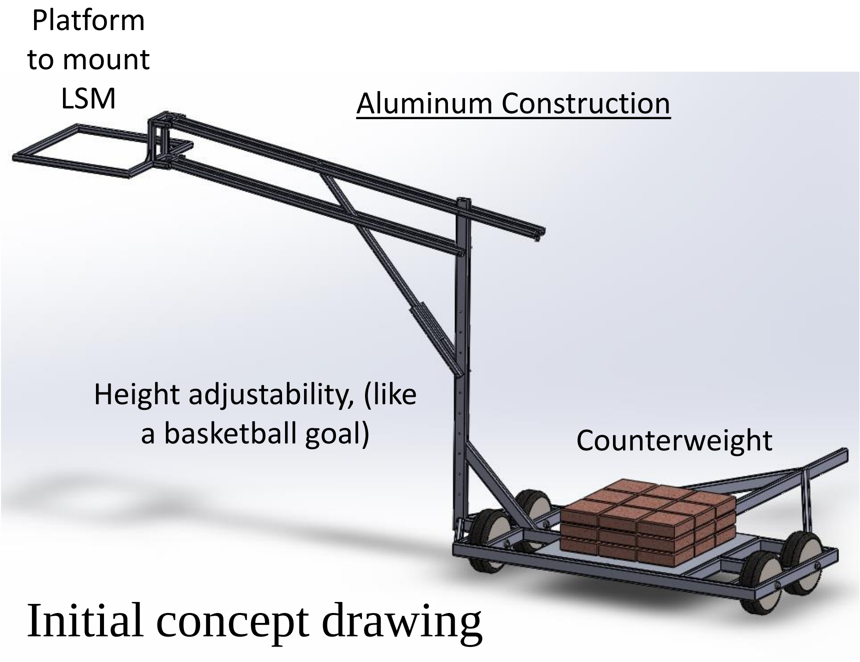
Approaching plastic regime

High strains, plastic regime

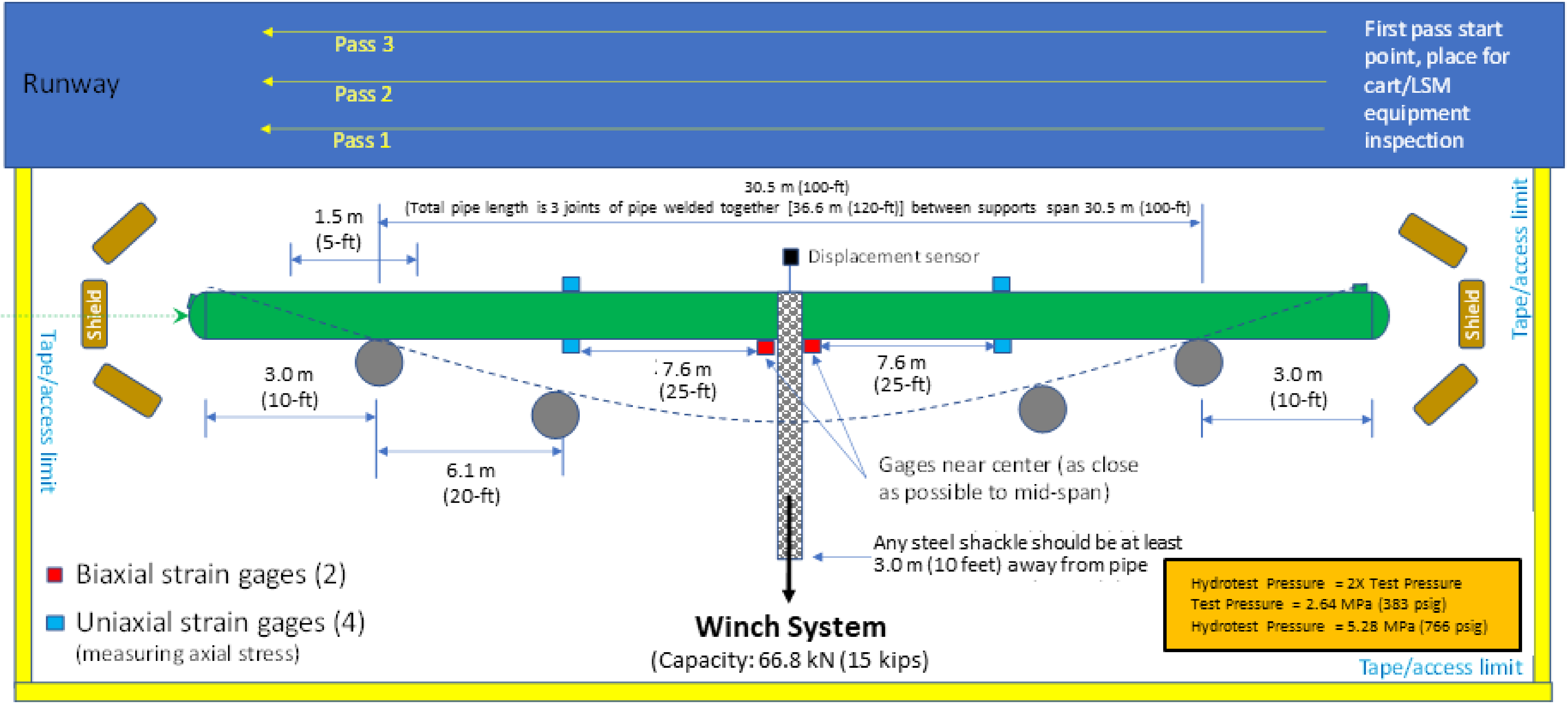
Sample Preparation



The Aluminum Cart



Test Sample Setup Details

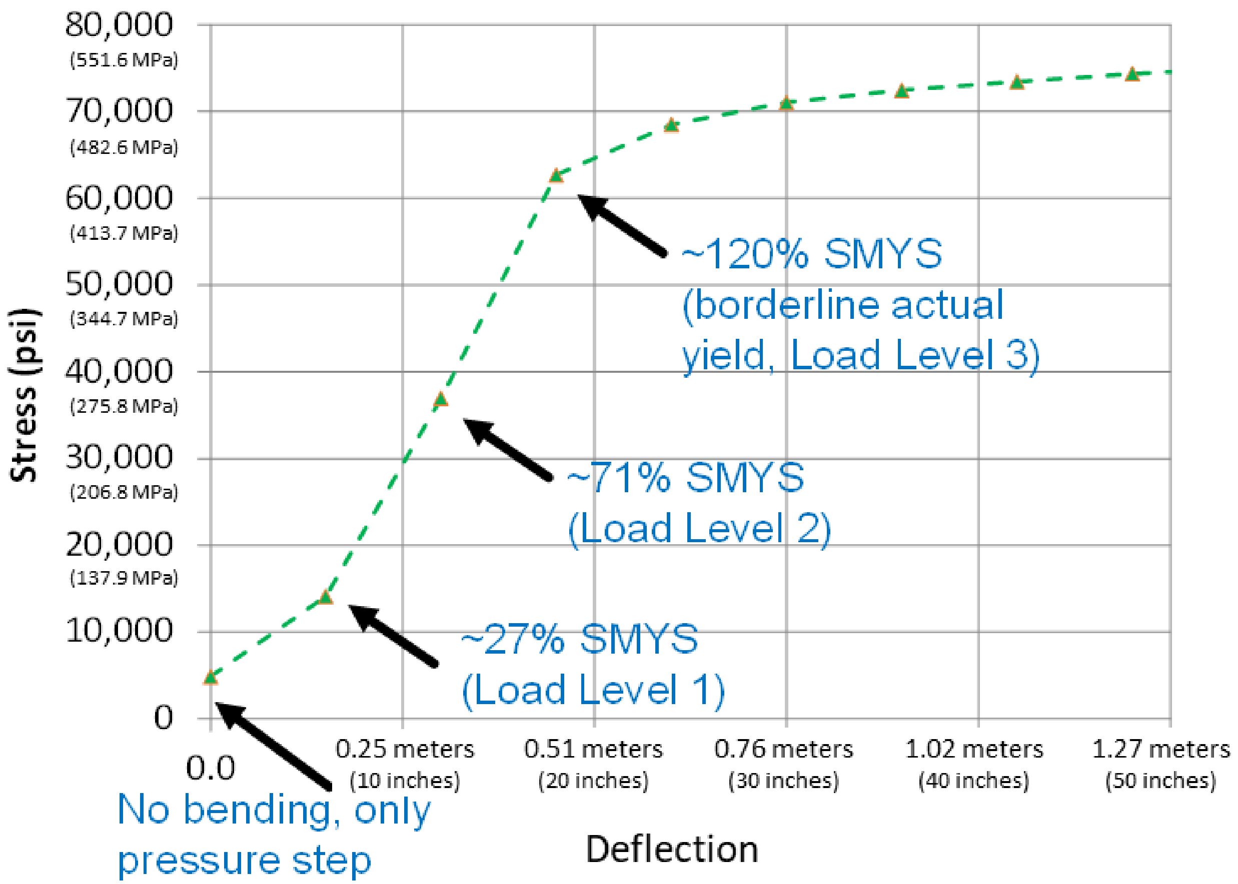


The Test Plan

- Initial hydrotest before first LSM run (2X test pressure = 5.28 MPa, 766 psig)
  - Critical for safety
  - "Pre-stress" in the pipe
- Test load
  - Internal pressure during runs = 2.64 MPa, 383 psig (~ 25% SMYS)
  - Five mid-span applied deflections ("load levels"), planned using FEA such that:
    - Two deflections with stress below yield
    - One deflection with stress approaching yield
    - Two deflections with stress above (targeting plastic strains)
- Multiple inspection runs for each load level

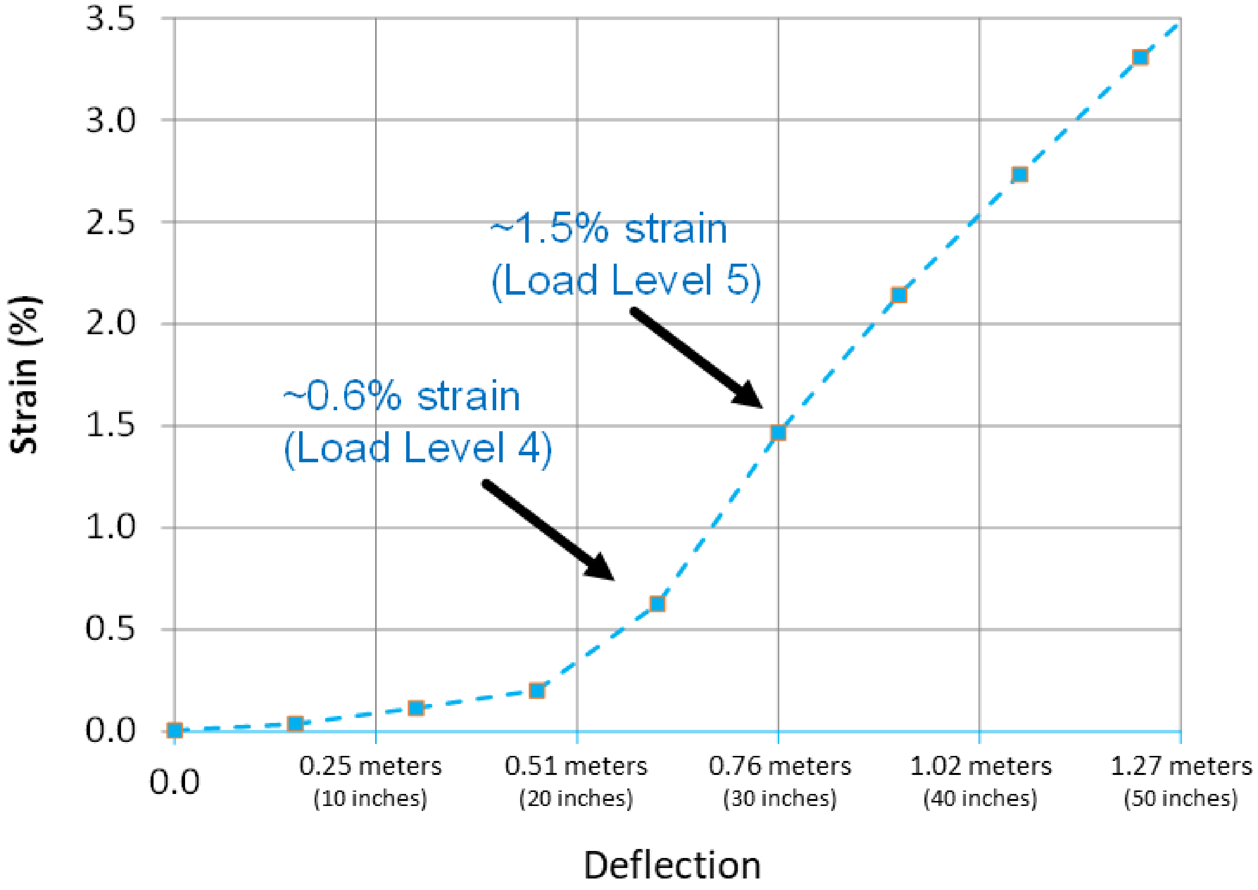
The Test Plan: Test Day 1 (Elastic)

Test Day	Load Level	Test Pipe Internal Pressure (psi)	Target Central Deflection (inches)
Test Day 1	No Bending Load	2.64 MPa 383 psi	0
	Load Level 1 (elastic)	2.64 MPa 383 psi	0.15 meters (6 inches)
	Load Level 2 (elastic)	2.64 MPa 383 psi	0.30 meters (12 inches)
Test Day 2	Load Level 3 (borderline yield based on actual properties)	2.64 MPa 383 psi	0.45 meters (18 inches)
	Load Level 4 (plastic)	2.64 MPa 383 psi	~0.61 meters (~24 inches)
	Load Level 5 - Max strain (plastic)	No pressure	~0.76 meters (~30 inches)



The Test Plan: Test Day 2 (Plastic)

Test Day	Load Level	Test Pipe Internal Pressure (psi)	Target Central Deflection (inches)
Test Day 1	No Bending Load	2.64 MPa 383 psi	0
	Load Level 1 (elastic)	2.64 MPa 383 psi	0.15 meters (6 inches)
	Load Level 2 (elastic)	2.64 MPa 383 psi	0.30 meters (12 inches)
Test Day 2	Load Level 3 (borderline yield based on actual properties)	2.64 MPa 383 psi	0.45 meters (18 inches)
	Load Level 4 (plastic)	2.64 MPa 383 psi	~0.61 meters (~24 inches)
	Load Level 5 - Max strain (plastic)	No pressure	~0.76 meters (~30 inches)



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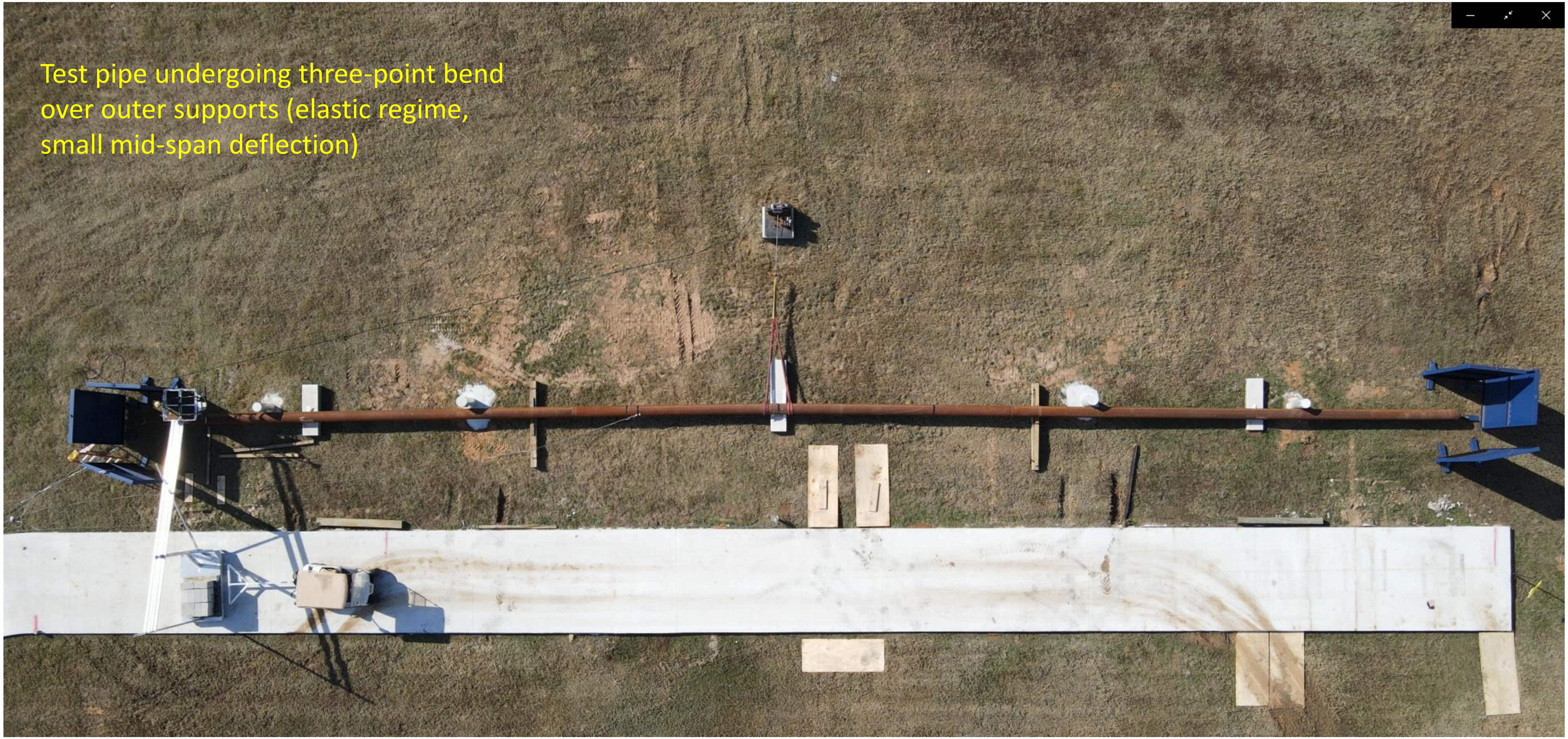
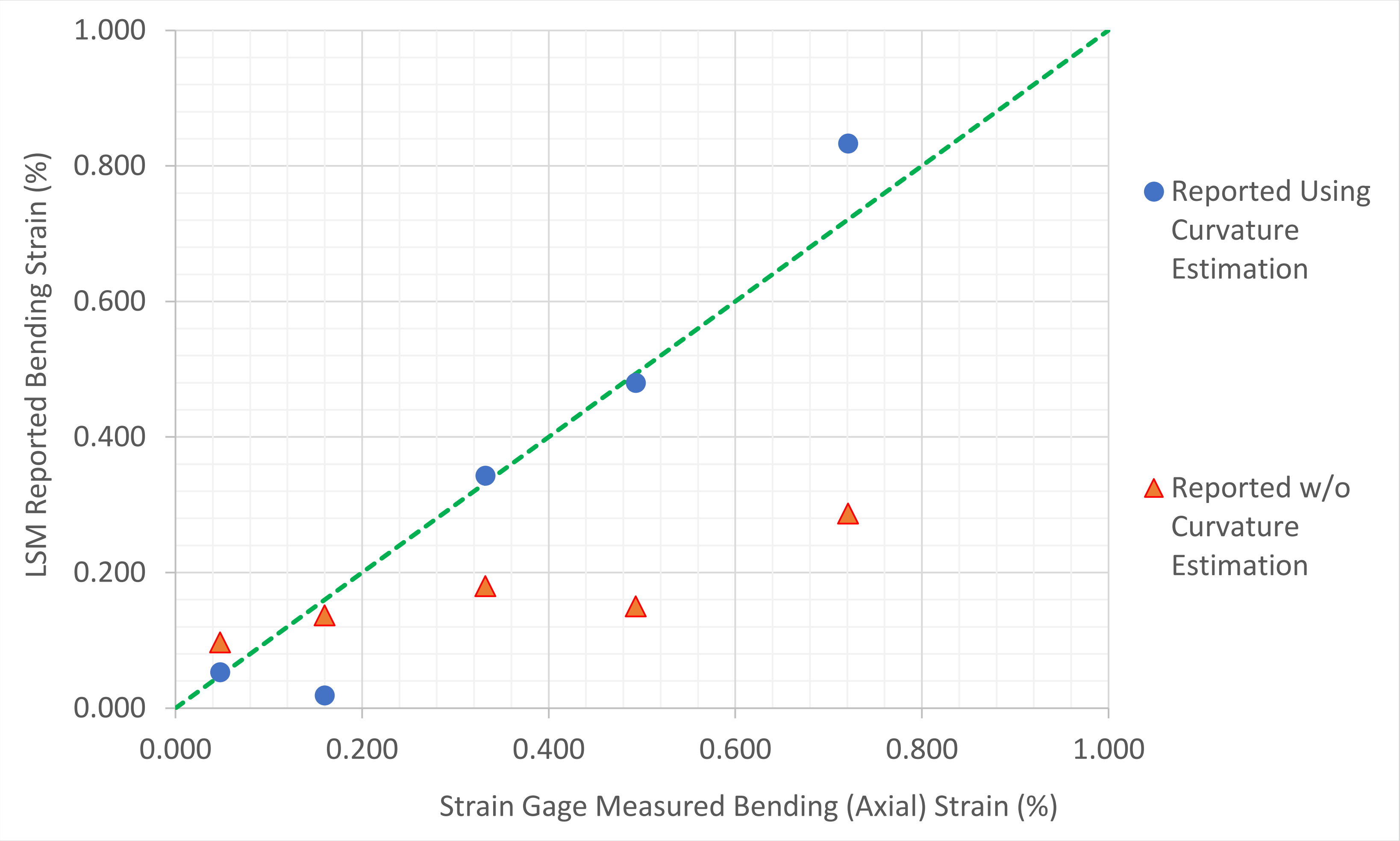
Elastic Regime – Bird's Eye View



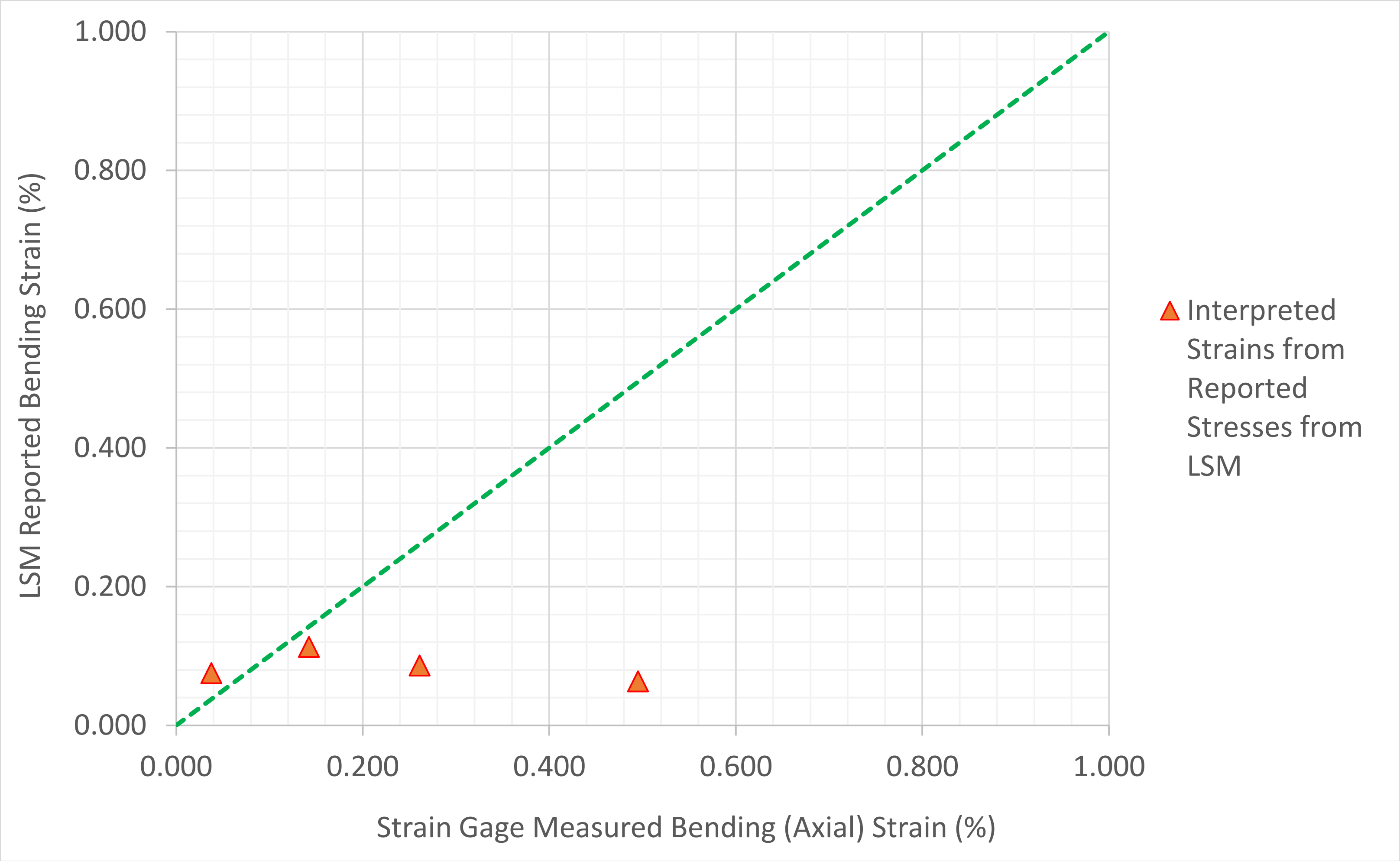
Plastic Regime – Bird's Eye View

Results – Vendor 1



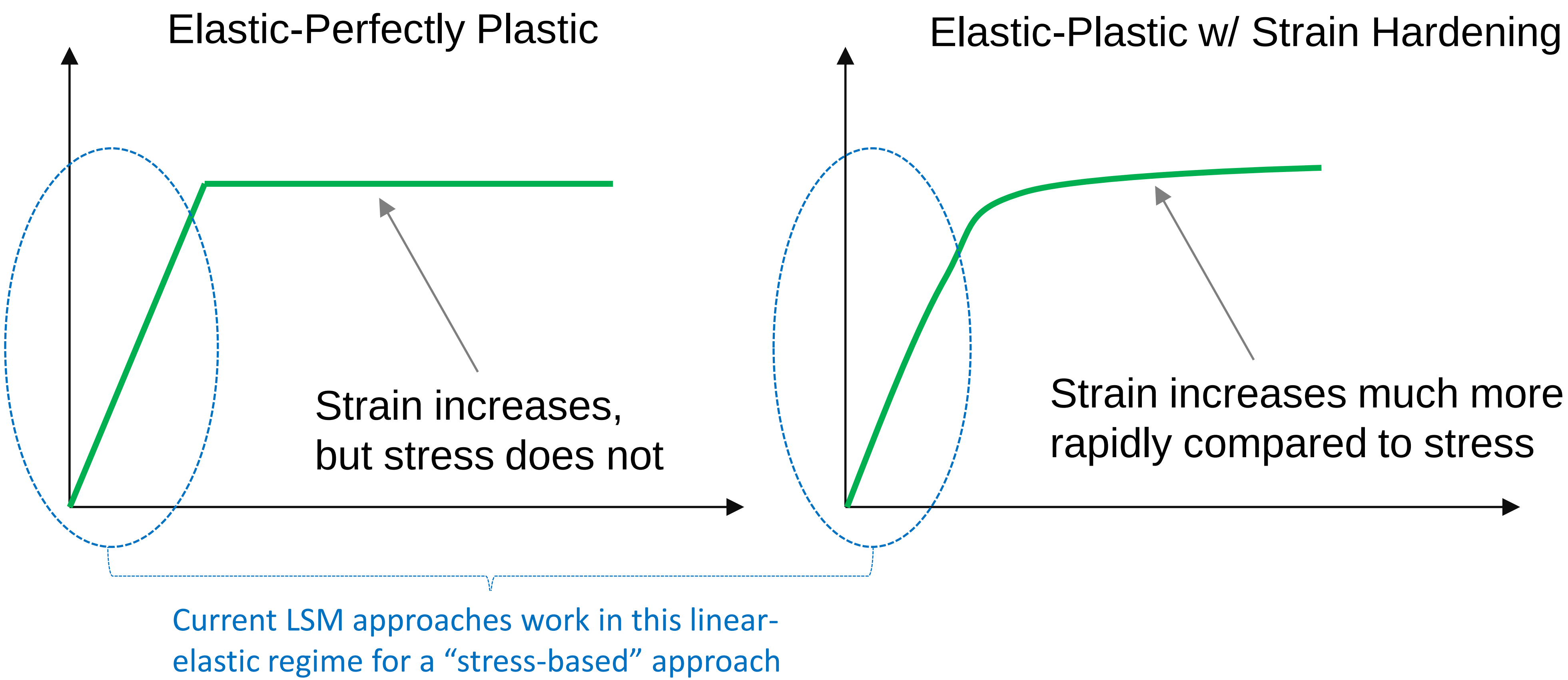
- Vendor 1 processed the data two using two different methods:
  - Method 1: classical method based on magnetostrictive theory
  - Method 2: alternative method using LSM for curvature estimates, and using the curvatures for calculating bending strain
- Method 1 correlation breaks down in the plastic regime

Results – Vendor 2

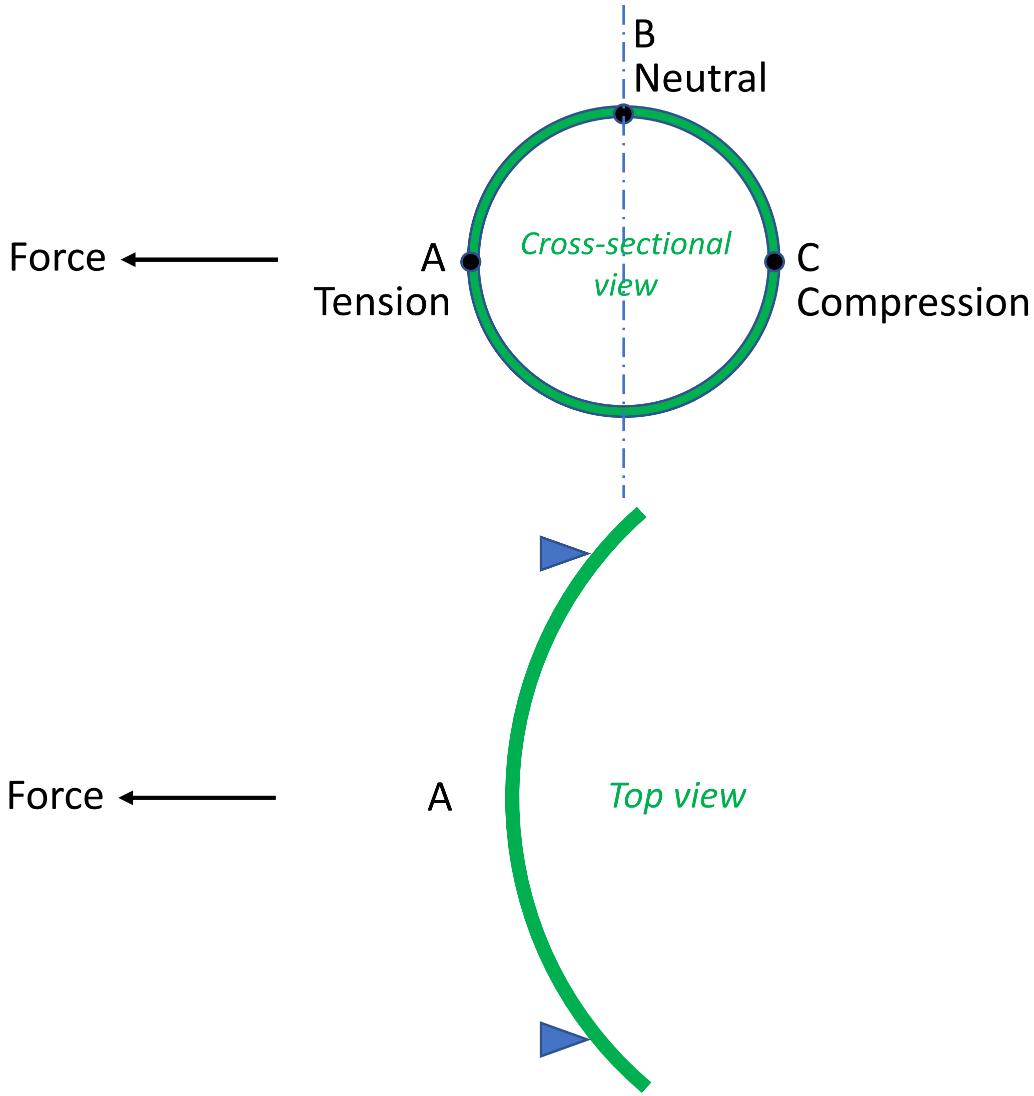


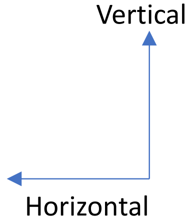
- Vendor 2 processed the data using the classical method based on magnetostrictive theory only; alternative methods were not explored
- As with Vendor 1, the correlation breaks down in the plastic regime

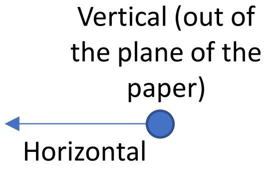
Results: Technology Challenges - 1



Results: Technology Challenges - 2







Project Challenges (and Victories)

- Both vendors had technical headquarters outside the US, so near real-time feedback was challenging
- No standard reporting structure exits for the LSM technology; vendors interpret and report results differently making comparisons difficult
- Both vendors expressed concerns regarding magnetic profiles and "proprietary" data
- Both vendors did not share details regarding GPS information used
- Apart from the proprietary data issues, vendor cooperation was very good

Conclusions

- Reasonable correlation between the data reported by strain gages vs that reported by LSM technologies when bending is in the linear-elastic regime
- Correlation breaks down when bending induces plastic strains in the pipe
- Technology appears to work from a proof-of-concept perspective, but several details that required of operators need more refinement and better definition
- Additional fundamental research is needed for correlation of plastic strains to magnetic signatures (or alternative approaches need to be developed to address plastic strains)

Path Forward

- Modeling and correlation of plastic strains to magnetic signatures
- Differentiating between local stress risers (flaws/features) from global stress/strain response
- Studying effect of pipe pressure on magnetic profiles
- Developing additional statistical confidence in the stress/strain determination in the elastic regime
- Studying drone mounted applications for future use

Thank you for your attention.

Dr. Chris Alexander, PE
ADV Integrity, Inc., President
chris.alexander@advintegrity.com