Pipeline Safety Research Development & Technology: Competitive Academic Agreement Program

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

Program Overview and Discussion
September 11, 2018

Competitive Academic Agreement Program (CAAP) Objectives

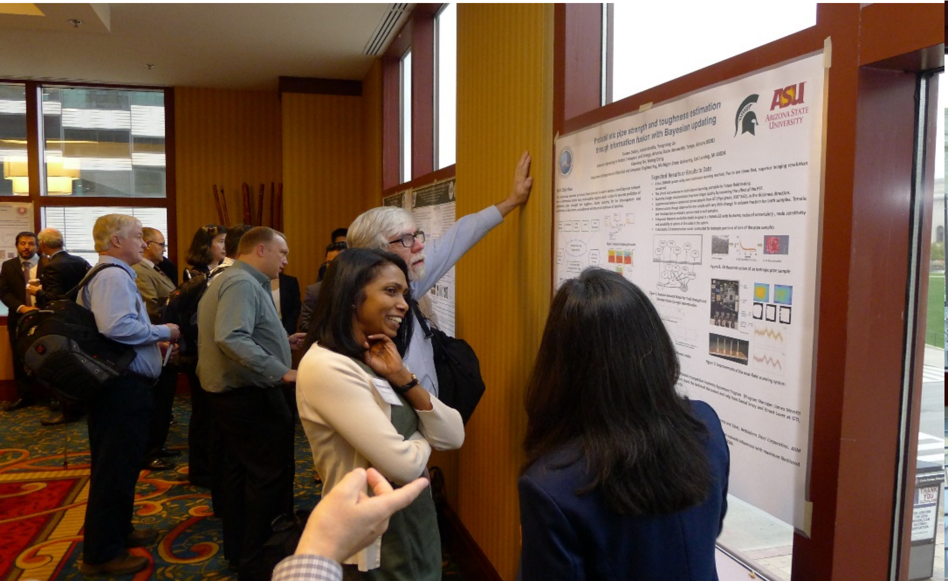
1. Spur innovation, high risk/high reward research
   – Feed hand-offs into PHMSA's core research program
2. Involve students with technical/engineering pipeline challenges

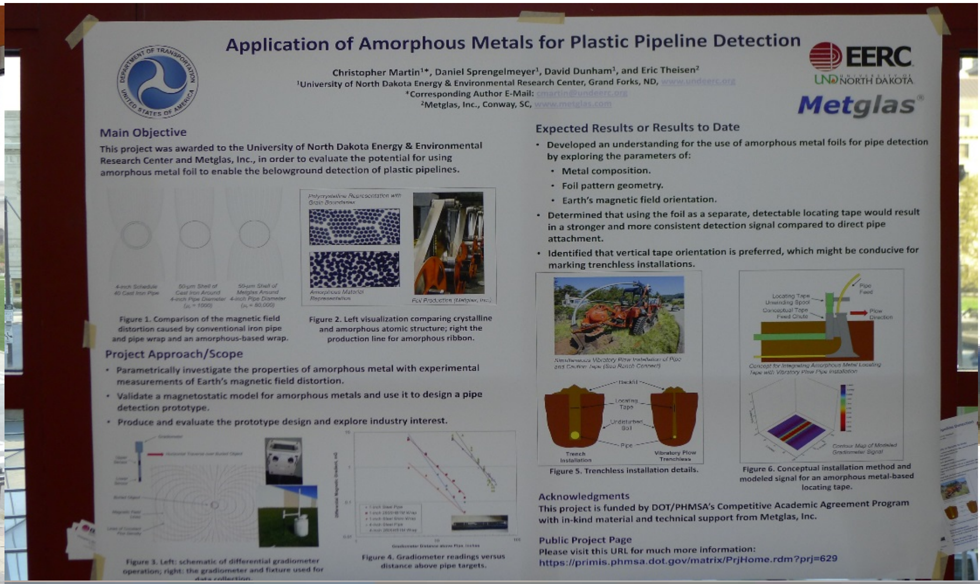
CAAP: Historical Summary

CAAP Summary Totals

Annual Announcement	# Awards	PHMSA	Resource Sharing	# HS Students	# U-Grad Students	# Grad Students	# PhD Students	Total # Students	# Interns (a)	# Career Employed (b)
CAAP-1-13	8	$814K	$353K	1	23	19	16	59	3	4
CAAP-2-14	7	$719K	$391K		4	14	10	28	1	3
CAAP-3-15	11	$2,968K	$888K		16	22	19	57	2	
CAAP-4-16	3	$909K	$368K		2	7	1	10		
Grand Totals:	**29**	**$5,411K**	**$2,002K**	**1**	**45**	**62**	**46**	**154**	**6**	**7**

Footnotes:
(a) Denotes the number of internships offered by engineering firms, research organizations, government agencies or pipeline operators to students involved with CAAP research projects.
(b) Denotes the number of full time career employment/jobs offered by engineering firms, research organizations, government agencies or pipeline operators to students involved with CAAP research projects.



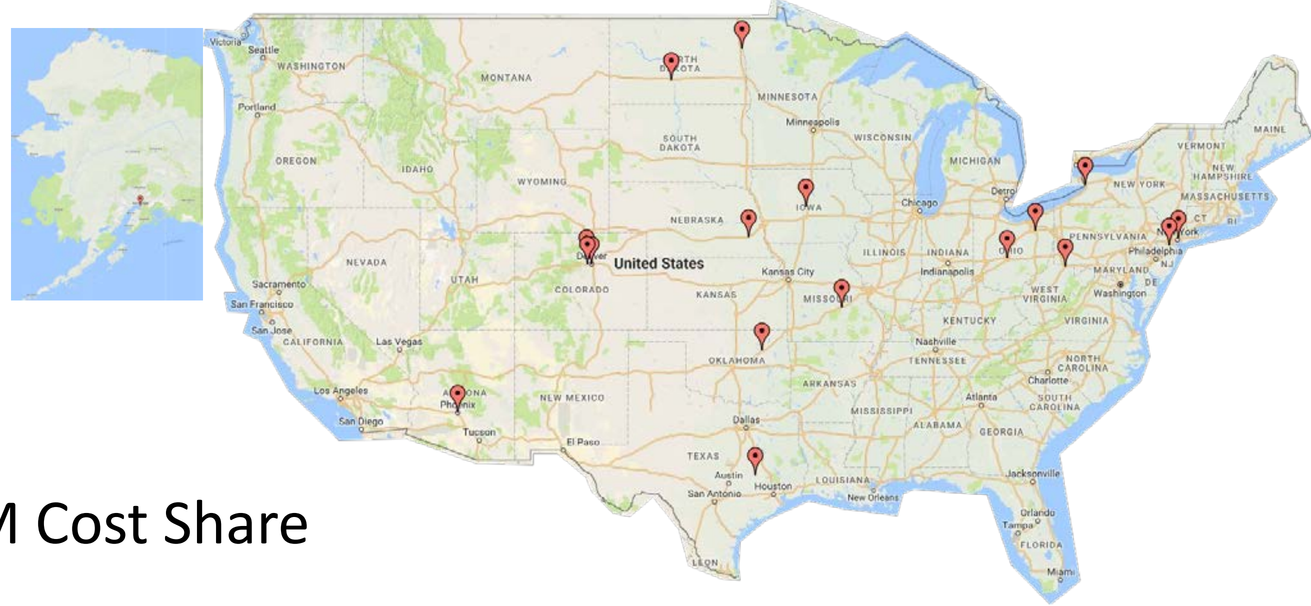


CAAP 2013-2016:

18 Universities

29 Projects

$5.39M PHMSA /$2M Cost Share



University	City, State
Arizona State University	Phoenix, AZ
Colorado School of Mines	Golden, CO
Columbia University	New York, NY
Iowa State University	Ames, IA
North Dakota State University	Bismarck, ND
Ohio University	Athens, OH
Rutgers University	New Brunswick, NJ
Texas A&M	College Station, TX
University of Akron	Akron, OH

University	City, State
University of Alaska, Anchorage	Anchorage, AK
University of Buffalo	Buffalo, NY
University of Colorado, Boulder	Boulder, CO
University of Colorado, Denver	Denver, CO
University of Missouri, Rolla	Rolla, MO
University of Nebraska	Lincoln, NE
University of North Dakota	Grand Forks, ND
University of Tulsa	Tulsa, OK
West Virginia University	Morgantown, WV

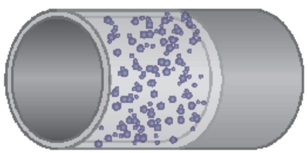
University of Tulsa

Electromagnetic Strategies for Locatable Plastic Pipe

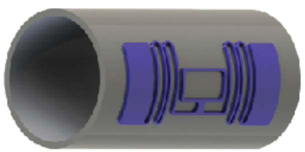
- PIs
  - Michael W. Keller – TU Mechanical Engineering
  - Peter J. Hawrylak – TU Electrical Engineering
  - Raman P. Singh – OSU Mechanical and Aerospace Engineering
- Students
  - Laura Waldman – TU (PhD 2020)
  - Jordan Trewitt – TU (MS 2018)
  - Ravi Venkata – OSU (MS 2018 - completed)

Objectives and Results

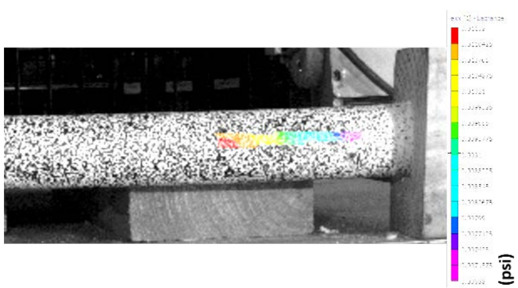
Achieve detection of plastic piping through the addition of simple-to-manufacture electromagnetically active materials and structures in plastic piping

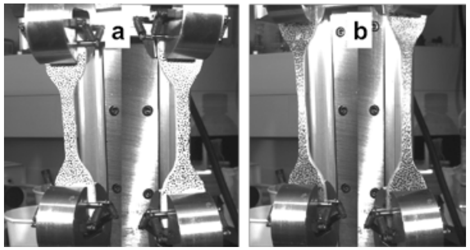


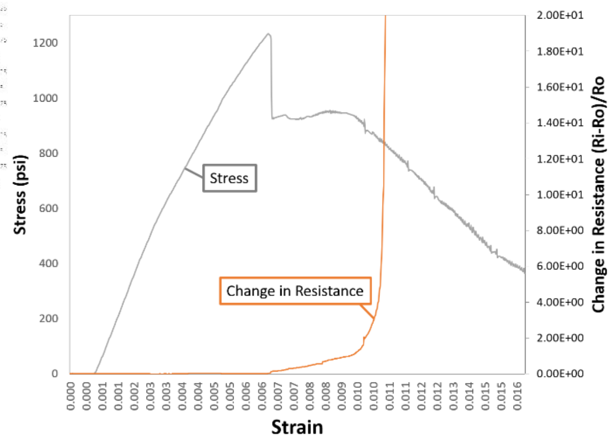
Capsule-Based

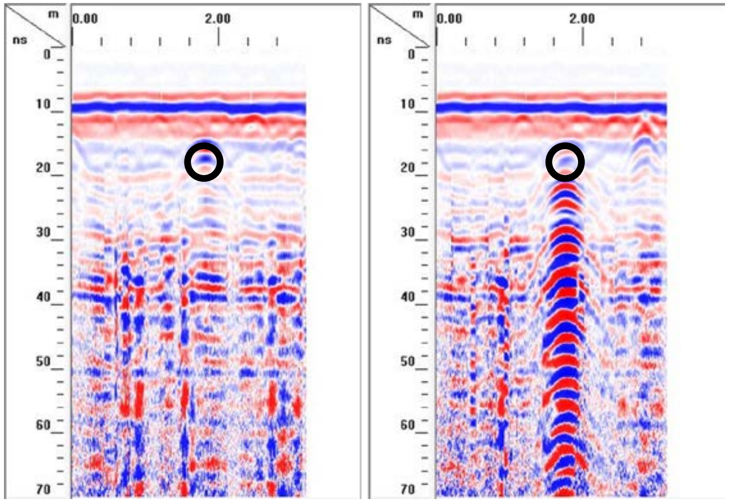


RF-Based









Rutgers

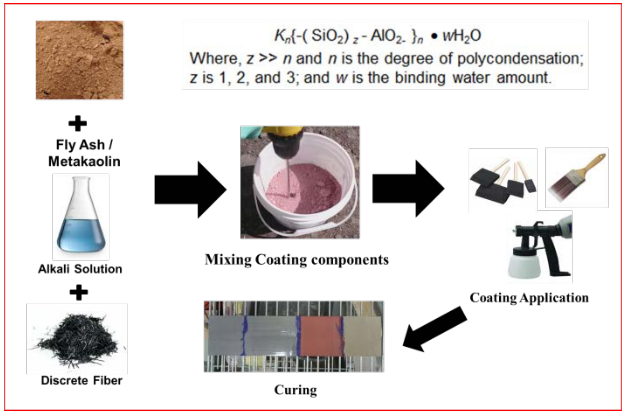
An Inorganic Composite Coating for Pipeline Rehabilitation and Corrosion Protection

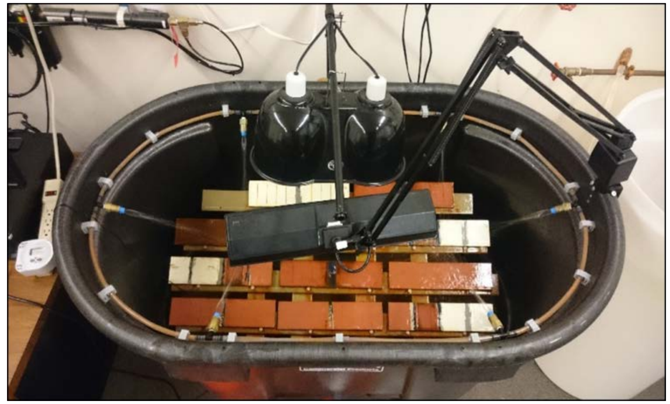
(DTPH56-15-H-CAP04)

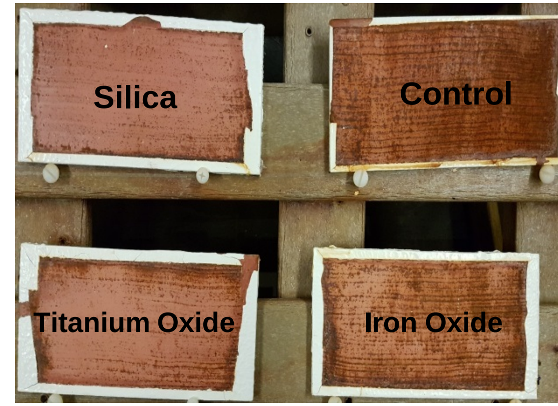
- **Project Objectives:**
  - Develop an inorganic coating system for protection of pipeline from corrosion and mechanical damage
  - Expose students to subject matter of pipeline safety challenges and engage talent to consider career in pipeline industry
- **Project Team**:
  - Dr. Hao Wang (PI); Dr. P.N. Balaguru (Co-PI) at Rutgers University, Dr. Ning Xie at Montana State University
  - Students: Milad Salemi, David Caronia and Wei Huang (graduate student) at Rutgers University; and Yujun Liang (undergraduate student) at Montana State University

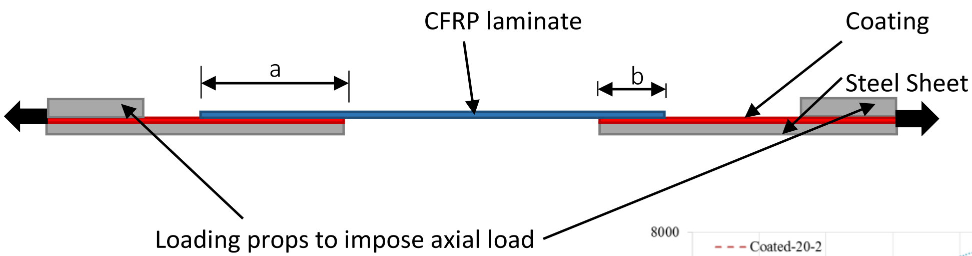
An Inorganic Composite Coating for Pipeline Rehabilitation and Corrosion Protection
(DTPH56-15-H-CAP04)

- **Project Approach and Tasks**
  - Development of Inorganic Coating Formulations
  - Corrosion Testing of Coating with Electrochemical Measurements
  - Durability and Adhesion Testing of Coating
  - Strength Testing of Fiber-Reinforced Coating Composite
  - Analytical Study of Pipeline Strengthening System
- **Major Results:**
  - Geopolymer coating was made using alkali activation and fiber
  - The effectiveness of nano-modification was observed with variation
  - Coating can be used with CFRP for composite repair of pipeline (wrap repair vs. patch repair)

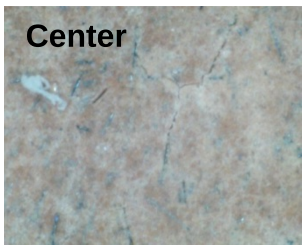

$K_n\{-(SiO_2)_z-AlO_2-\}_n \bullet wH_2O$
Where, $z >> n$ and n is the degree of polycondensation; z is 1, 2, and 3; and w is the binding water amount.
Fly Ash / Metakaolin
Alkali Solution
Discrete Fiber
Mixing Coating components
Coating Application
Curing

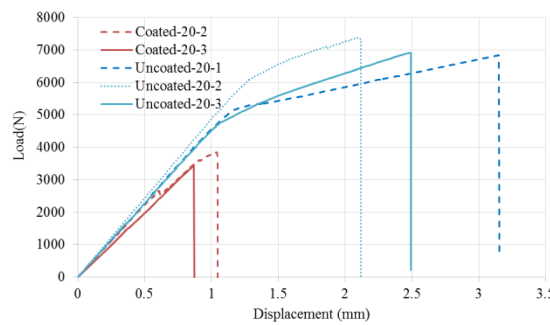


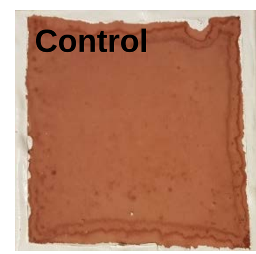

Silica
Control
Titanium Oxide
Iron Oxide

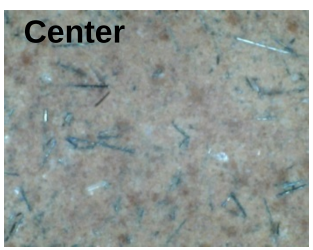

CFRP laminate
Coating
a
b
Steel Sheet
Loading props to impose axial load

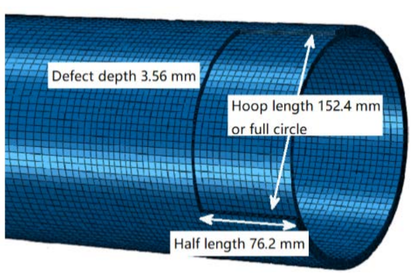

3% Silica

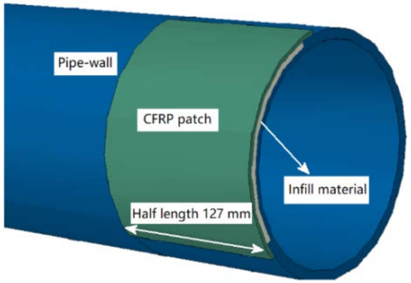

Center

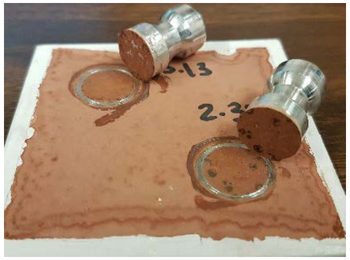

Coated-20-2
Coated-20-3
Uncoated-20-1
Uncoated-20-2
Uncoated-20-3
Load(N)
Displacement (mm)
0
1000
2000
3000
4000
5000
6000
7000
8000
0.5
1
1.5
2
2.5
3
3.5


Control


Center


Defect depth 3.56 mm
Hoop length 152.4 mm
or full circle
Half length 76.2 mm


Pipe-wall
CFRP patch
Infill material
Half length 127 mm



North Dakota State University 1

Mitigating Pipeline Corrosion Using A Smart Thermal Spraying Coating System

PI: Fardad Azarmi

Associate Professor
Department of Mechanical Engineering (ME)
North Dakota State University

Current Graduate Students:

Amir Darabi (MS.C)-ME
Fodan Deng (Ph.D)- CEE
Babak Jahani (Ph.D)- ME

Co-PI: Ying Huang

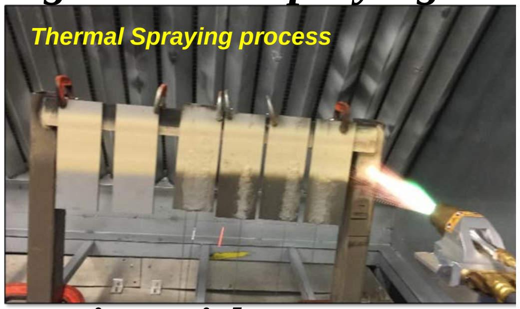
Assistant Professor
Department of Civil & Environmental Engineering (CEE)
North Dakota State University

Project Objectives

Achieve an ultimate and affordable corrosion mitigation solution for onshore pipelines using thermal spraying coating technology.

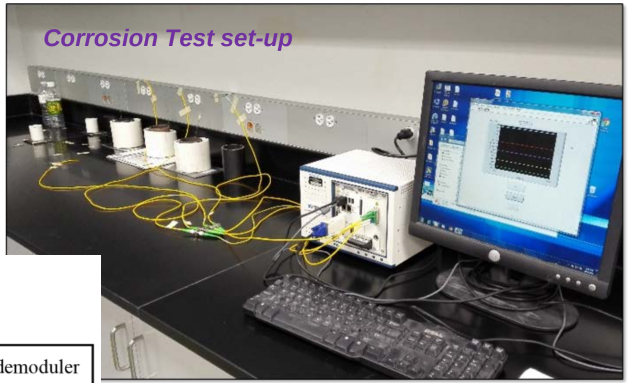
✓ ***Deposition of the Optimum Coatings for Corrosion Mitigation using Thermal Spraying***

- ***Development of Automatic Rotational Fixture***
- ***Material Selection with Environmental Considerations***
- ***Optimization of Coating Thickness***
- ***Coating Sealing Approaches***



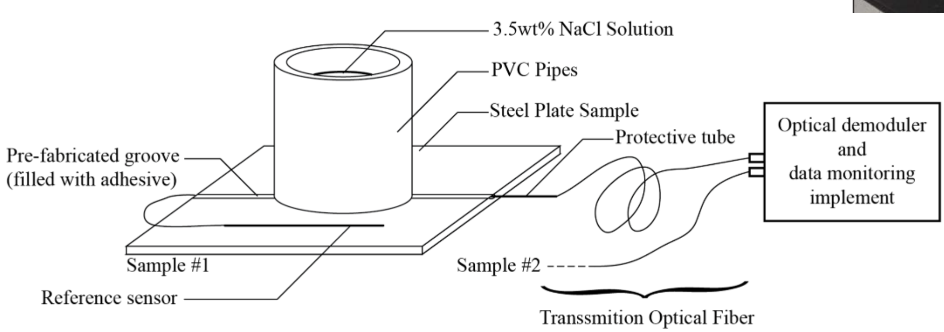
✓ ***Development of an In-line Assessment Technique for Pipeline Corrosion Risk Management***

- ***Quantitative Corrosion Measurement using Fiber Optic Sensors***
- ***The System Integration for In-line Corrosion Assessment***
- ***Development of A Model for Corrosion Risk Management***



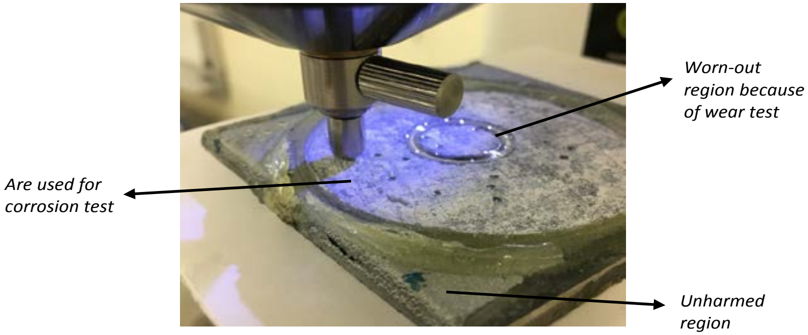
❖ ***Performance Estimation of the Optimized Coating System***

- ***Experimental Tests–In-Progress***
- ***Numerical Simulation (FEA) –In-Progress***



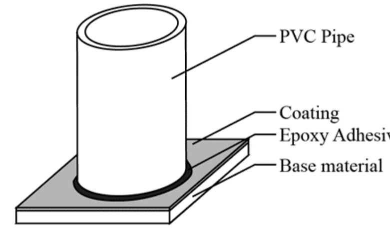
Results

-- This study, for the first time, applies the self-sensing technology into the thermally sprayed coating to test and monitor the performance of the onshore pipeline.



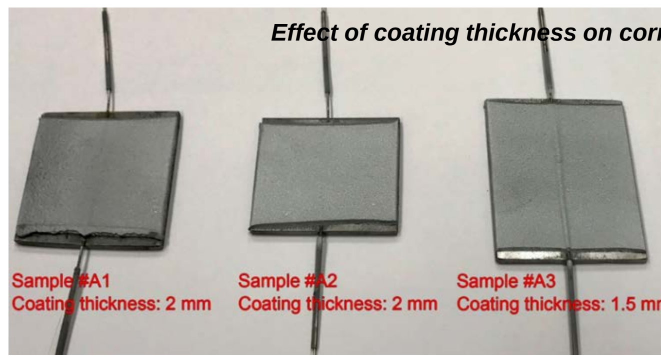
Wear Test on Corroded samples

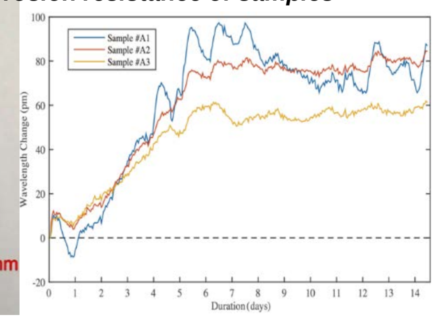
Corrosion test on full size samples in real service condition

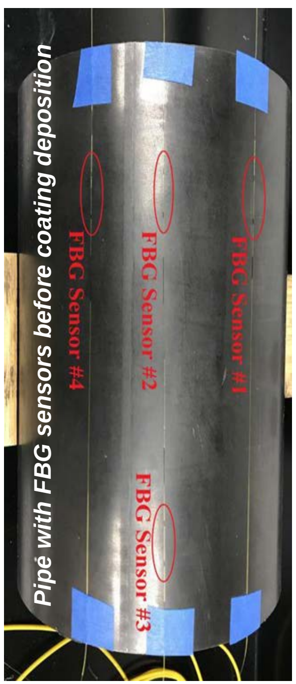


Schematic of corrosion sample set-up

Effect of coating thickness on corrosion resistance of samples

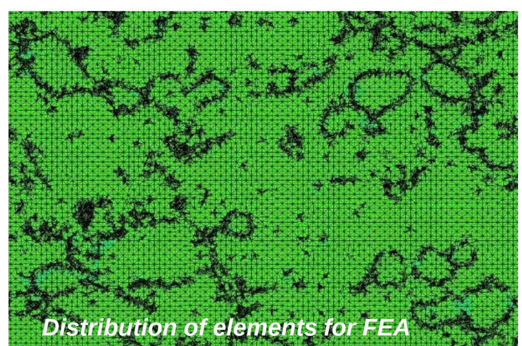




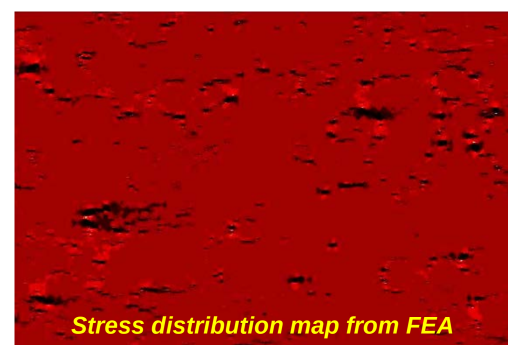


Pipe with FBG sensors before coating deposition

Al-Zn coated Full size pipes with sensors



Distribution of elements for FEA



Stress distribution map from FEA

North Dakota State University 2

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

PI: Dr. Zhibin Lin [a]

Co-PIs: Dr. Dante Battocchi[b]

Dr. Xiaoning Qi[b]

Graduate student:

Xingyu Wang[a], Ph.D.

Mingli Li[a], Ph.D.

Matthew Pearson [a], M.S.

Funded by U.S. DOT Pipeline and Hazardous Materials Safety Administration

[a]Department of Civil and Environmental Engineering, North Dakota State University

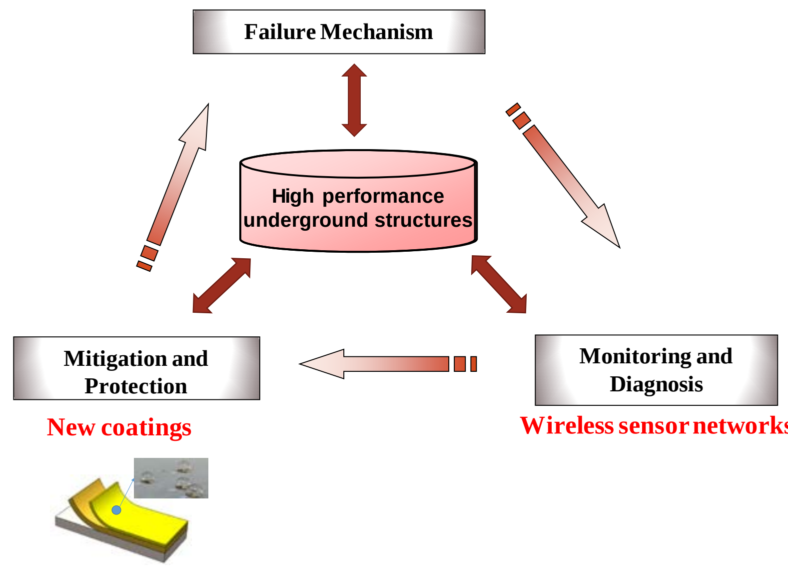
[b]Department of Coatings and Polymeric Materials, North Dakota State University

NDSU NORTH DAKOTA STATE UNIVERSITY

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

❖ Objective:

Develop and implement new multifunctional composite coatings for new-constructed or existing pipelines to achieve a design with the integration of the anti-corrosion, anti-fouling and superior abrasion into one compact unit (composite coating).



West Virginia University

PHMSA Pipeline Safety Research and Development Forum

September 11th-12th 2018

Baltimore, MD

Hota GangaRao, PhD, P.E.

CREATIVE PULTRUSIONS

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

PHMSA

CFC CONSTRUCTED FACILITIES CENTER

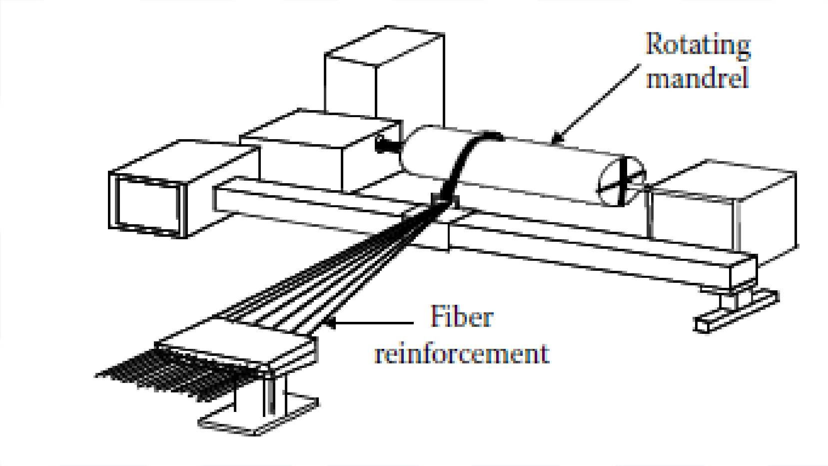
WestVirginiaUniversity

Research Objectives

- Conduct hydrostatic burst testing of pipes and joints for strength, failure modes
- Evaluate Classical Lamination Theory for burst pressure prediction
  - CLT for elastic prediction
  - Failure progression, failure criterion, degradation for failure prediction

GFRP Pipe Manufacturing

- Fibers are wetted by running through a resin bath
- Wet fibers are wound around a mandrel
- Curing is activated by applying heat to the pipe
- Shrink wrap is wrapped around pipe to insure a void free surface



Glass Fiber Reinforced Polymer Pipe

- Corrosion resistance, soil interaction, pH, Moisture
- Resistance to hydrogen embrittlement
- Less electrical conductivity than steel
- Less thermal conductivity, fire resistance
- Higher strength to weight ratio than steel
- Better flexibility-differential settlement
- Potential for easier detectability

Concluding Observations

- Burst pressure testing to 5,200 psi
  - 3,000 psi for the thin wall specimens
- Burst pressure testing of joints near 1,000 psi
- CLT predict stress/strain behavior up to ≈ 30 percent ultimate stress
  - Failure predictions through CLT not yet produced
- Failure modes appear to be related to shear forces within the resin
  - Deboning of corrosion barrier layer
  - Fiber strain, debonding between fiber and resin, leakage
  - No fiber failure

Future Work

- Produce failure predictions through CLT
- Further testing with higher D/t ratio-test fiber failure
  - Test fiber strengths, determine failure modes
- Perform free-end burst tests
- Investigate S-glass pipes
- Continued development of high strength joints

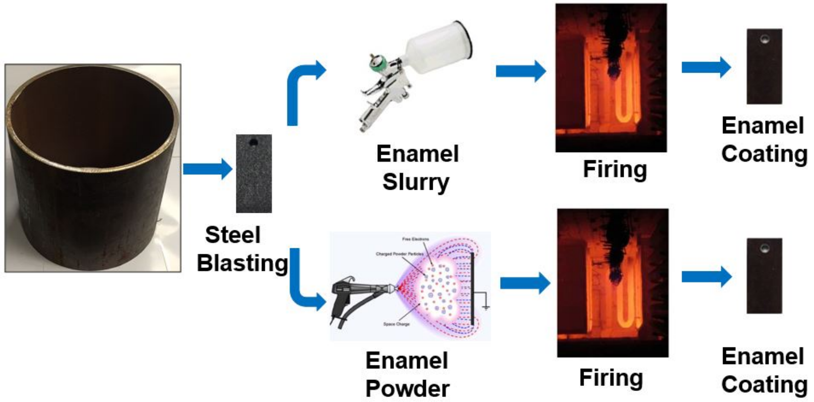
Missouri University of Science and Technology

Chemically Bonded, Porcelain Enamel Coated Pipe for Corrosion Protection and Flow Efficiency

PI: Dr. Genda Chen - Missouri University of Science and Technology

Student: Liang Fan - Missouri University of Science and Technology

Industrial Collaborator: Michael L. Koenigstein - Roesch Inc.



Wet vs. dry enameling process

Main Objective

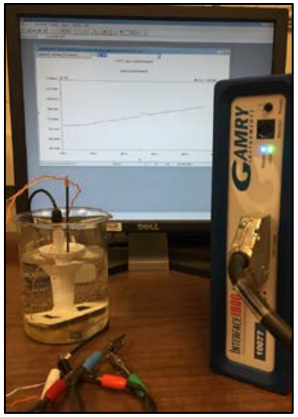
- The aims of this project are to explore chemically-bonded porcelain enamel coating for corrosion protection and safety of metallic pipes, and develop a rapid field-applicable coating process for flow efficiency and cost reduction in the operation of metallic pipelines.

Project Approach/Scope

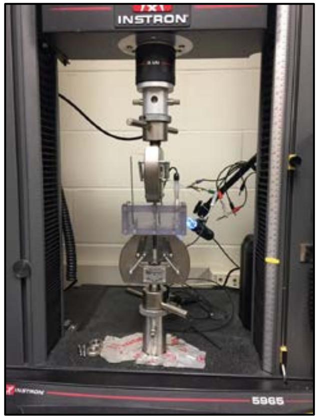
- Optimization of enamel materials for durability and thermal compatibility with steel.
- Enameling process for coating uniformity, low surface roughness, and operation efficiency.
- Characterization of enamel coated pipes for microstructure, chemical adhesion on steel, and corrosion resistance.
- System performance of *in-situ* enamel coated pipelines - stress distribution under thermal and pressure effects, and stress corrosion cracking.

Results to Date

- Enamel coating provides chemical bond with steel substrate.
- Enamel coating shows a significant barrier effect and thus high resistance to the corrosion of steel substrate in NaCl solution.
- Cathodic protection (CP), when applied to deaccelerate the degradation process of enamel coating, does not compromise the integrity of bonding between the enamel coating and its steel substrate.
- The more negative the applied potential, the more susceptible the steel to stress corrosion cracking in the NS4 solution.
- The specimens experience ductile failure with apparent necking when tested without CP, and cleavage fracture when tested at a cathodic potential of -1200 mV.



Corrosion Test



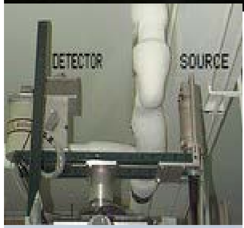
Slow Strain Rate Test

Iowa State University

IOWA STATE UNIVERSITY

Center for Nondestructive Evaluation

Fundamental Mechanochemistry Based Detection of Early Stage Corrosion Degradation of Pipeline Steels



Profs. Ashraf Bastawros, Pranav Shrotriya, Kurt Hebert, Leonard Bond

Grad. Students: D. Yavas, P. Mishra, A. Alshehri

Under Grad. J. Duffy, A. Still, K. Aguirre

BP Products North America Inc. Mark Lozev and Tom Eason

CENTER FOR NDE

This material is based on work supported by the DOT-US Department of Transportation under Contract #DTPH5616HCAP01, and performed at Iowa State University

Overview

Materials
Ashraf Bastawros

Mechanics
Pranav Shrotriya

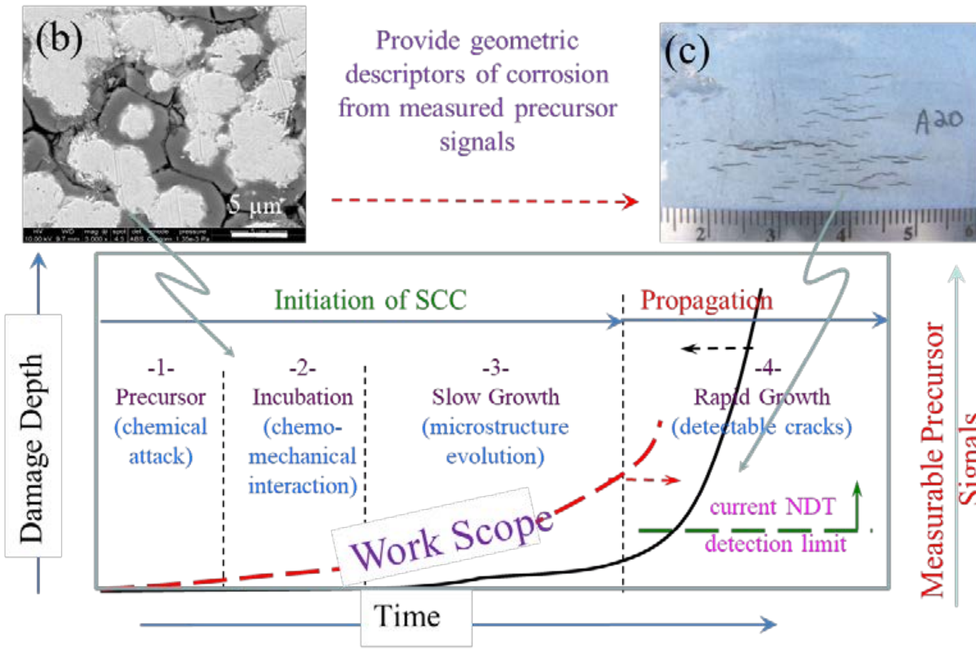
Electrochemistry
Kurt Hebert

NDE-protocols
Leonard Bond

Objective:

Enhance pipeline safety

Explore and quantify prospective measurable precursor signals associated with the initiation stage of near surface damage and cracking.



Tasks and prospective impacts

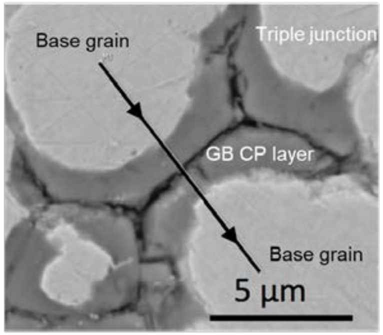
(1) Develop mechanochemistry modeling framework for early stage SCC: prospectively increase the pipeline total fatigue life.

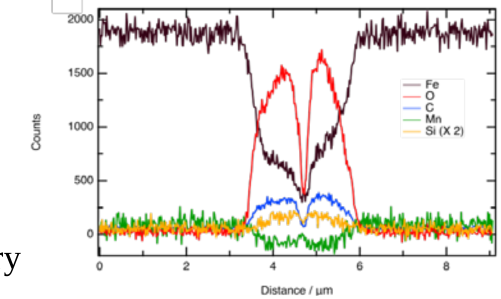
(2) Quantify physical and mechanical changes during the early stage of SCC (EIS, 4PB resistance: pathway for potential in-line inspection (ILI) methodologies.

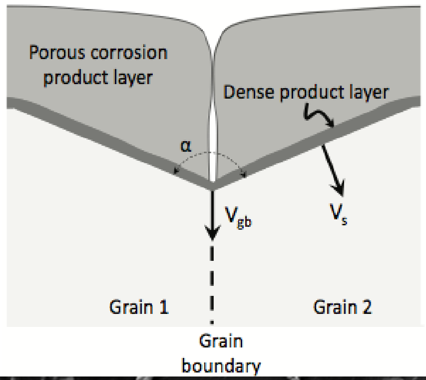
Accomplishments

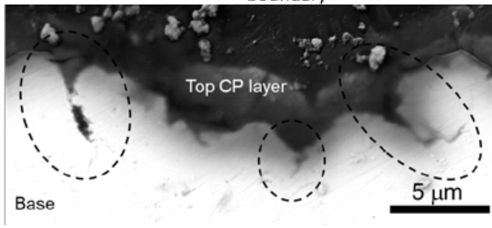
- Completed laboratory and modeling studies for; (i) Initial morphology evolution, (ii) Species distribution and exchange mechanisms, (iii) Residual stress build up, (iv) Mechanistic understanding of IGC/SCC, (IV) Predict proper physical parameter
- Publications:
  - D Yavas, P Mishra, A Alshehri, P Shrotriya, AF Bastawros, KR Hebert, "Morphology and stress evolution during the initial stages of intergranular corrosion of X70 steel," Electrochimica Acta, 2018. https://doi.org/10.1016/j.electacta.2018.07.207
  - D Yavas, P Mishra, A Alshehri, P Shrotriya, KR Hebert, AF Bastawros, "Nanoindentation study of corrosion-induced grain boundary degradation in a pipeline steel," Electrochemistry Communications 88:88-92, 2018. https://doi.org/10.1016/j.elecom.2018.02.001
  - D Yavas, P Mishra, AF Bastawros, KR Hebert, P Shrotriya, "Characterization of sub-surface damage during the early stage of stress corrosion cracking by nano indentation," Experimental and Applied Mechanics, 4:37-44, 2017. https://doi: 10.1007/978-3-319-42028-8_5

- Ultimate Goal:
  - Identify physics of precursors: Provide fundamental understanding of the early corrosion mechanisms in high strength pipeline steels.
  - Develop inspection protocols: Develop two innovative measurement protocols to provide quantitative measure of the extent of the damage during the early stage of SCC.









University of Akron

Understanding and Mitigating the Threat of AC Induced Corrosion on Buried Pipelines

CAAP #DTPH5615HCAP02

PIs:

Profs. Scott Lillard & Hongbo Cong
University of Akron

Kevin Garrity & Dan Wagner
Mears Group, Inc.

Students:

Andrew Moran, Elmira Ghanbari, & Lizeth Sanchez
University of Akron

Ian Stallman
Marathon Pipe Line, LLC.

The University of Akron
College of Engineering

Overview

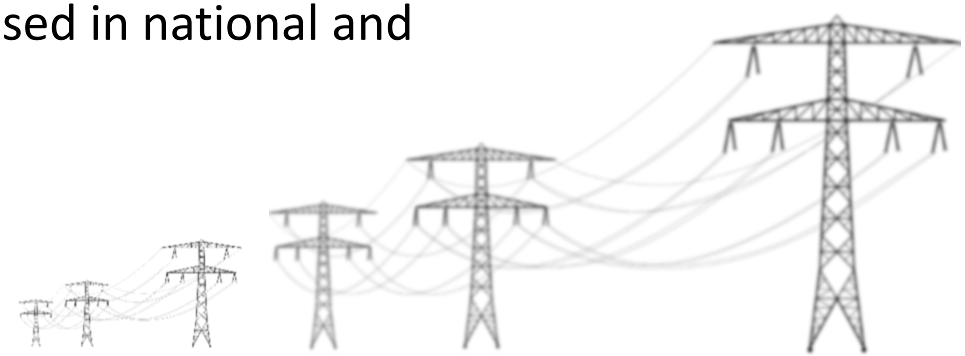
Objectives:

- Determine the combined effects of AC and Cathodic Protection (CP) on the risk of corrosion of in-service pipelines.

- Establish criteria for AC corrosion risk based on physicochemical soil-environment characteristics and their effect on the steel/soil interface.

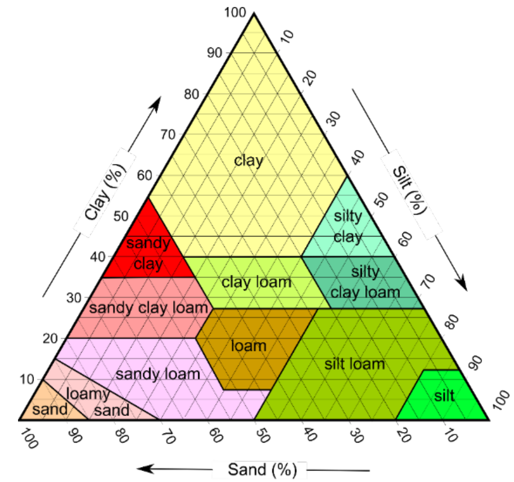
Impact:

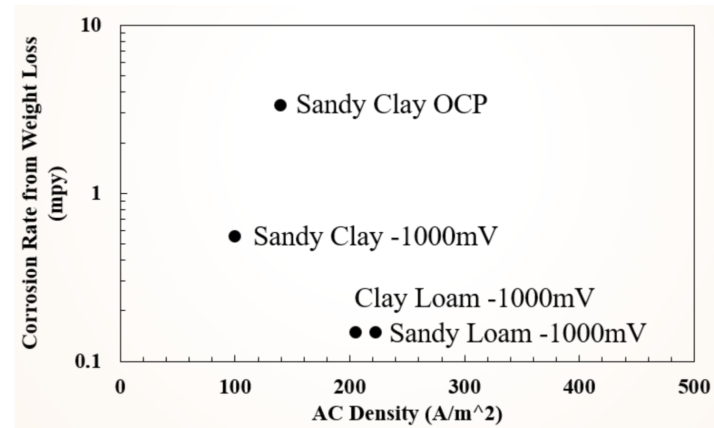
- Results are meant to improve the assessment of corrosion risks due to induced AC currents as well as indirect inspection methods and could be used in national and international standards.



Accomplishments

- A theoretical model of AC corrosion, along with laboratory testing, has helped to identify parameters of interest in assessing AC corrosion risk.
    - Ghanbari, E., M. Iannuzzi, and R. S. Lillard. "The Mechanism of Alternating Current Corrosion of API Grade X65 Pipeline Steel." *Corrosion* 72.9 (2016): 1196-1210.
- Mass loss testing is being used to investigate the general trends of AC corrosion at CP potentials.
- The categorization of soils and their effect on relevant physical/electrochemical parameters, especially the interfacial capacitance, is expected to better indicate AC corrosion risks.
- SCC and hydrogen permeation experiments are also being conducted to determine the effects of AC on these phenomena.





Michigan State University

CAAP15: Embedded Passive Tags Towards Intrinsically Locatable Buried Plastic Materials

PI: Yiming Deng
Associate Professor

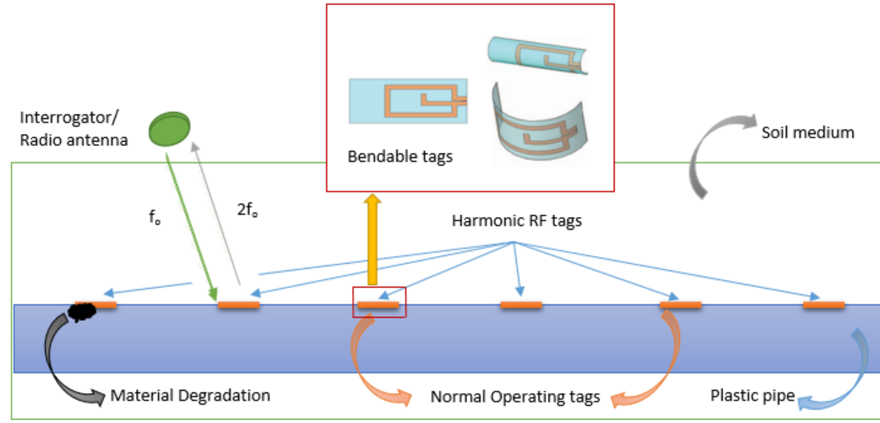
Co-PI: Premjeet Chahal
Associate Professor

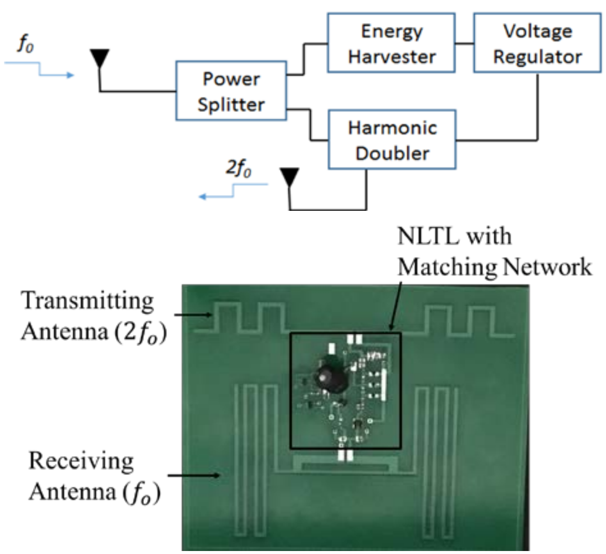
Students: Saikat Mondal, and Deepak Kumar

Department of Electrical and Computer Engineering

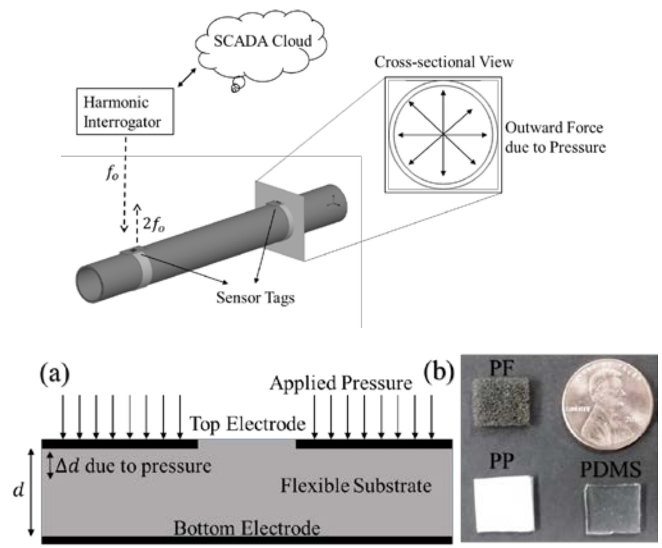
Funded by: DOT Pipeline and Hazardous Materials Safety Administration (PHMSA)
Program Manager: Joshua Arnold

Objective: Design and development of passive harmonic radar RF tags; investigate on-tag sensing capabilities and efficient data transmission; RF tag must be able to withstand high temperature processing of plastic and stress involved within horizontal tunneling/ drilling of buried pipes; develop a learning a learning based pipeline hazardous prognostics methodology using discrete sensing data.





Harmonic RF Tag



Capacitive Pressure Sensor

Field Testing

Arizona State University

CAAP 15: Bayesian Network Inference and Information Fusion for Accurate Pipe Strength and Toughness Estimation

PI: Yongming Liu[1]

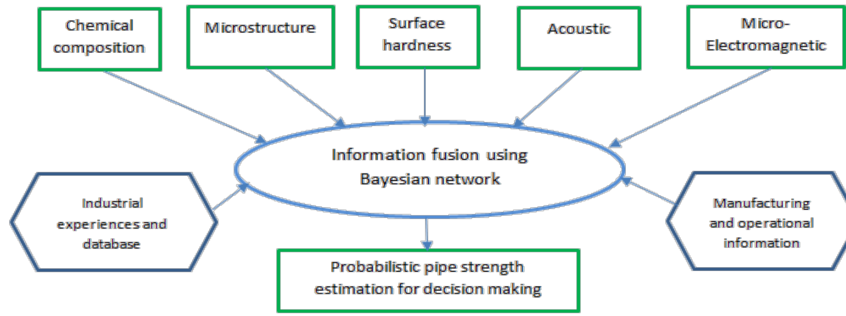
Co-PI: Yiming Deng[2]

Students: Sonam Dahire[1], Xiaodong Shi[2] , Shou Zhang[2], Shubham Vinay Shedge[2], Aishwarya Vidyachandra Bhatlawande[2]

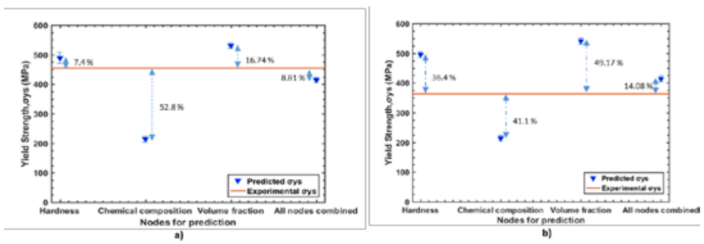
[1] School for Engineering of Matter, Transport, and Energy, Arizona State University
[2] Department of Electrical and Computer Engineering, Michigan State University

Funded by: DOT Pipeline and Hazardous Materials Safety Administration (PHMSA)
Program Manager: Joshua Arnold

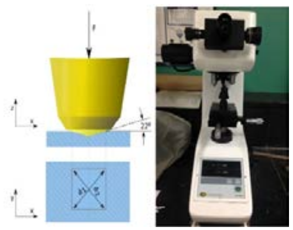
Objective: Develop a novel Bayesian network tool to fuse detection information from multimodality diagnosis results for the probabilistic pipe strength and toughness estimation. The information about material's chemical composition, microstructure, surface hardness, and acoustic/electromagnetic properties as well as historical information and database are integrated for the accurate estimation.



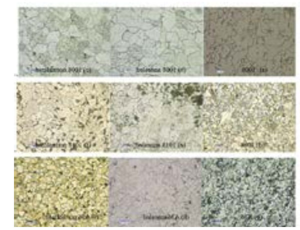
Schematic illustration of the proposed pipe strength estimation framework



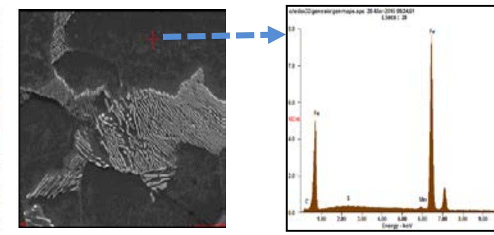
BN model validation; prediction of yield strength from individual nodes as well as put together a) Pipe 45 b) Pipe 47



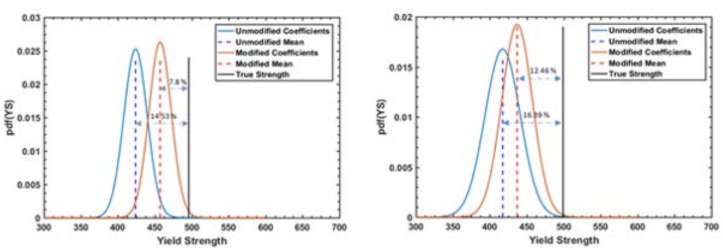
Surface hardness test



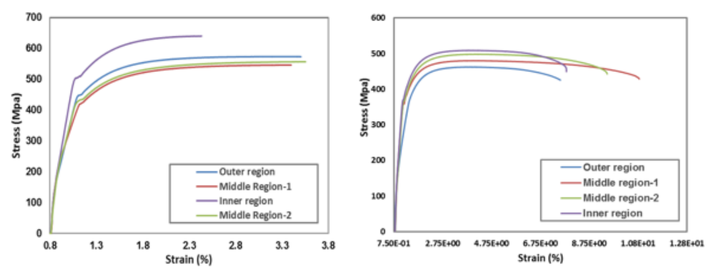
Microstructure



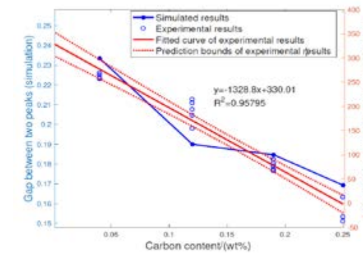
SEM image with EDS spectrum



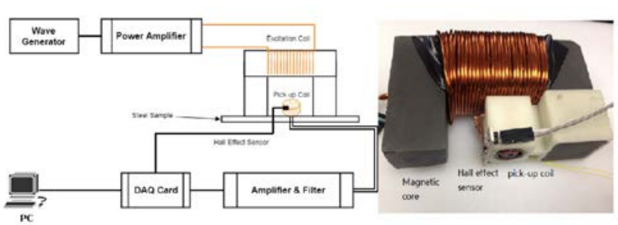
Improved prediction with modified regression coefficients a) Pipe X65 1 b) Pipe X65 2



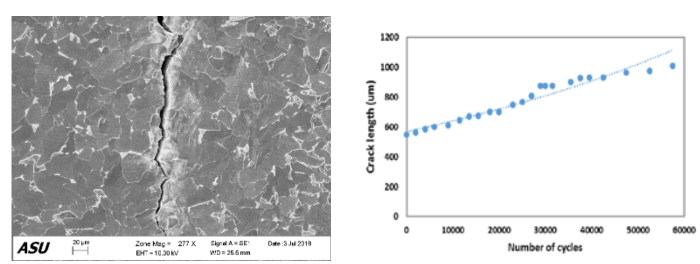
Stress-strain plot for through thickness specimens for Pipe 45 and 47



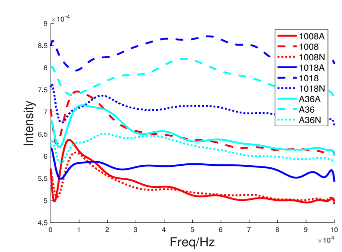
MBN vs Carbon contents



The schematic and prototype for MBN



Fatigue crack growth study



MBN vs Grain sizes

Thank You!/Program Contacts

Kenneth Lee
Director – Engineering & Research
Department of Transportation
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
P(202) 366-2694
Email kenneth.lee@dot.gov

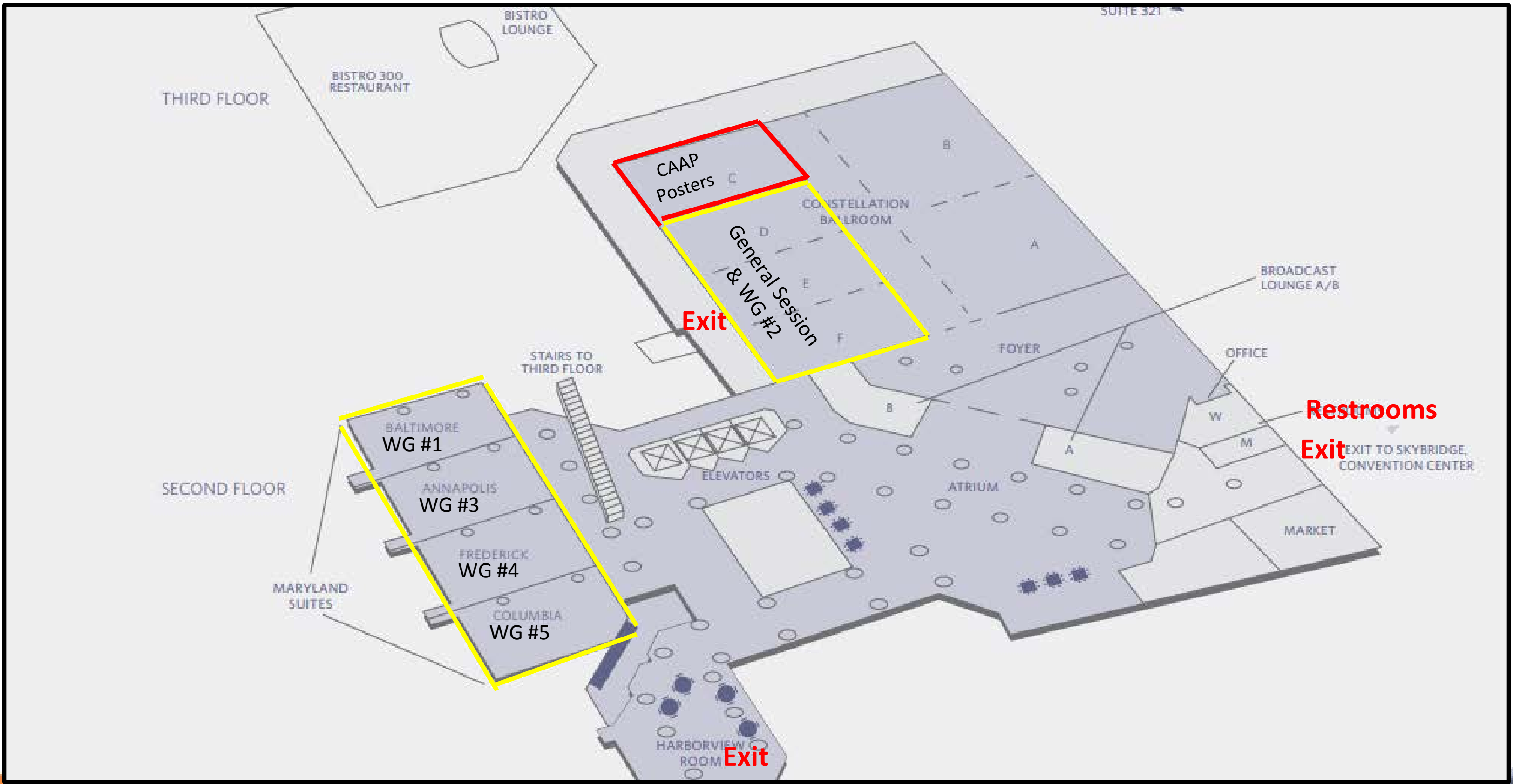
Robert Smith
Department of Transportation
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
P(919) 238-4759
Email robert.w.smith@dot.gov

Joshua Arnold
Department of Transportation
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
P(202) 366-6085
Email joshua.arnold@dot.gov

PHMSA RD&T Providing/Supporting:

WHERE TO FIND POSTERS

- Constellation Ballroom C



LUNCH INFO

- On your own, but treat yourself!
- See Hyatt Bistro 300 Restaurant or Google your options as shown
- **Return for 2PM sharp Working Groups start!**