

# *Pipeline Research Council International* 2023 Research Exchange

---



## **Use of machine learning in nondestructive material property verification**

*Innovate Track*

*PRCI-REX2023-052*

*NDE 4-8 (PR-335-173816)*

Intisar Rizwan I Haque, MMT  
Yasamin Salamat, MMT  
Simon Bellemare, MMT  
March 7, 2023  
Houston, Texas



LEADING PIPELINE RESEARCH

# Introduction

2

- **The aim of the presentation is to create awareness among the various stake holders of the pipeline industry about the role of machine learning in the non-destructive evaluation with an emphasis on model development and validation.**
- **Review the reasons behind the conflicting conclusion of the GTI report (DOT Project #729 and DOT/PHMSA CONTRACT NUMBER: 693JK31810003) issued September 28, 2021, and prior PRCI project NDE 4–8 (Catalog No. PR-335-173816 published May 08, 2018).**

# What is Non-Destructive Evaluation (NDE)?

3

## TRADITIONAL DESTRUCTIVE (DIRECT)



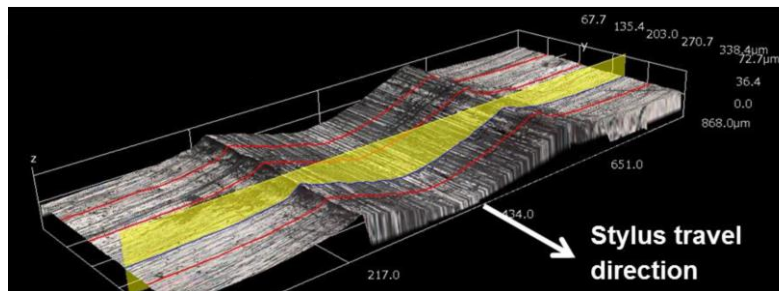
+



## NON-DESTRUCTIVE (INDIRECT)



+



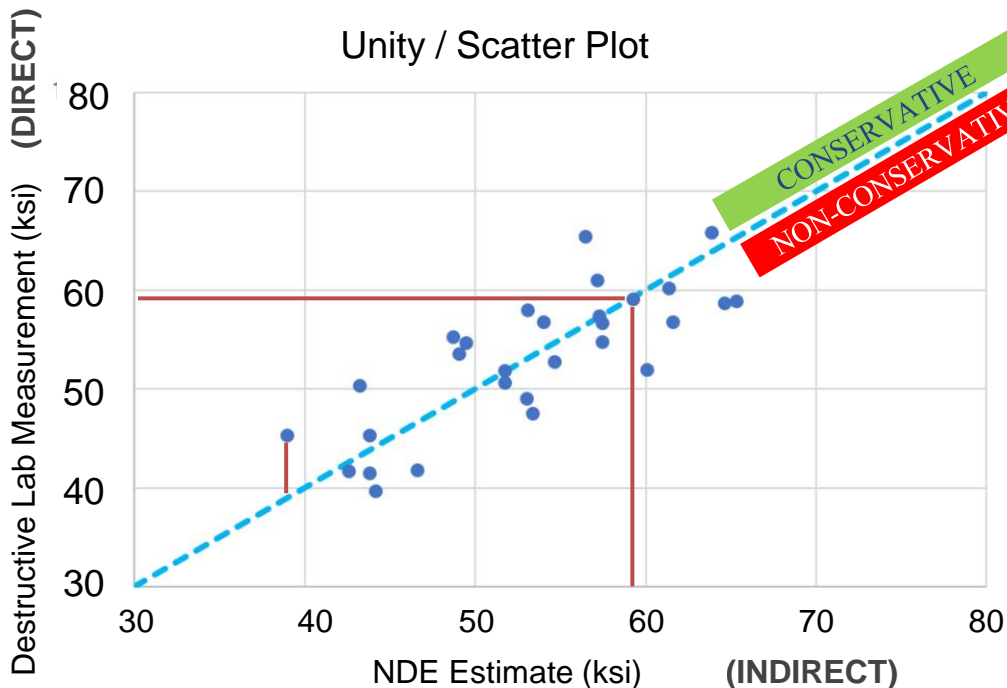
March 7-8, 2023 | PRCI Research Exchange

© 2023, PRCI

# Need for correlation between Lab and NDE

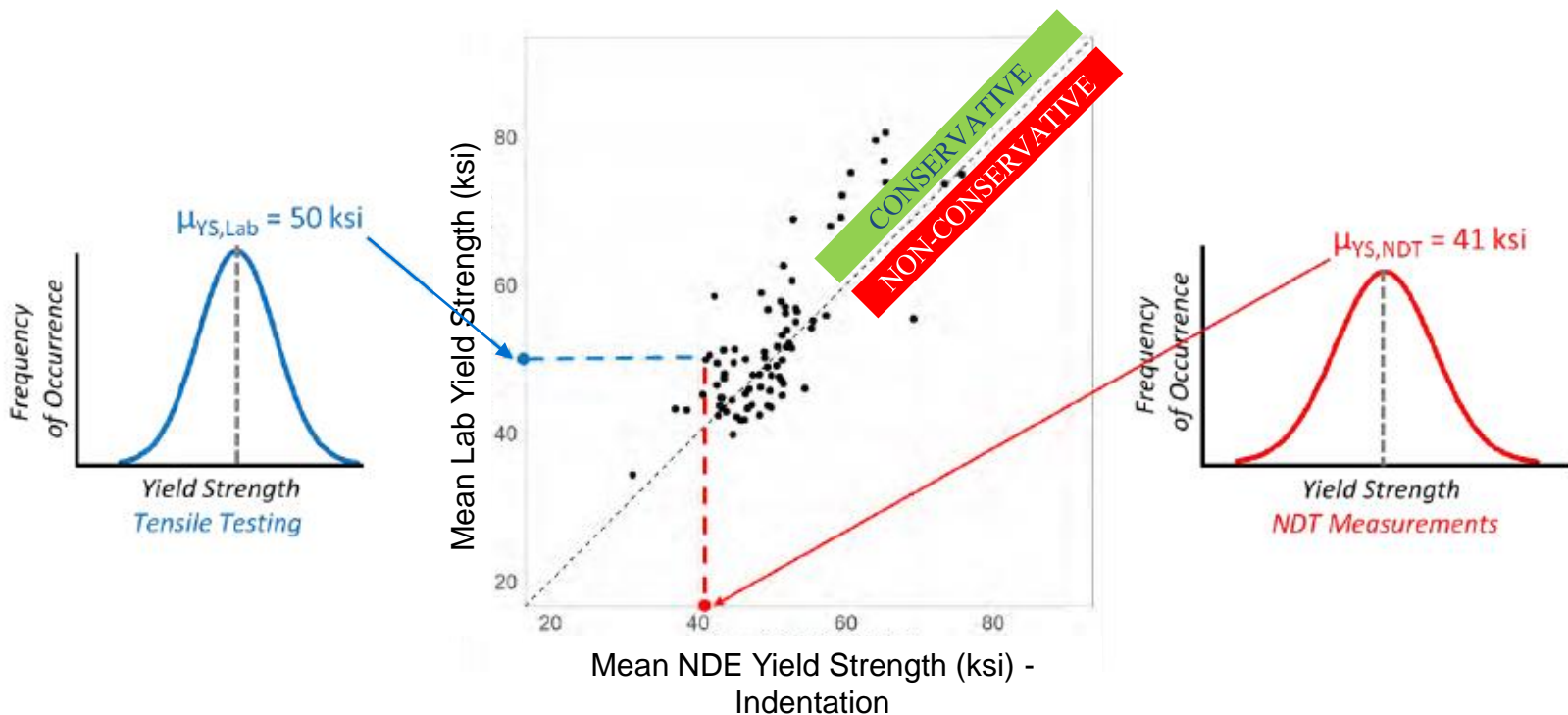
4

Unity / Scatter Plot



From §192.607(d)(1), “comparison with destructive test results on materials of comparable grade and vintage.”

# What each data point represents?



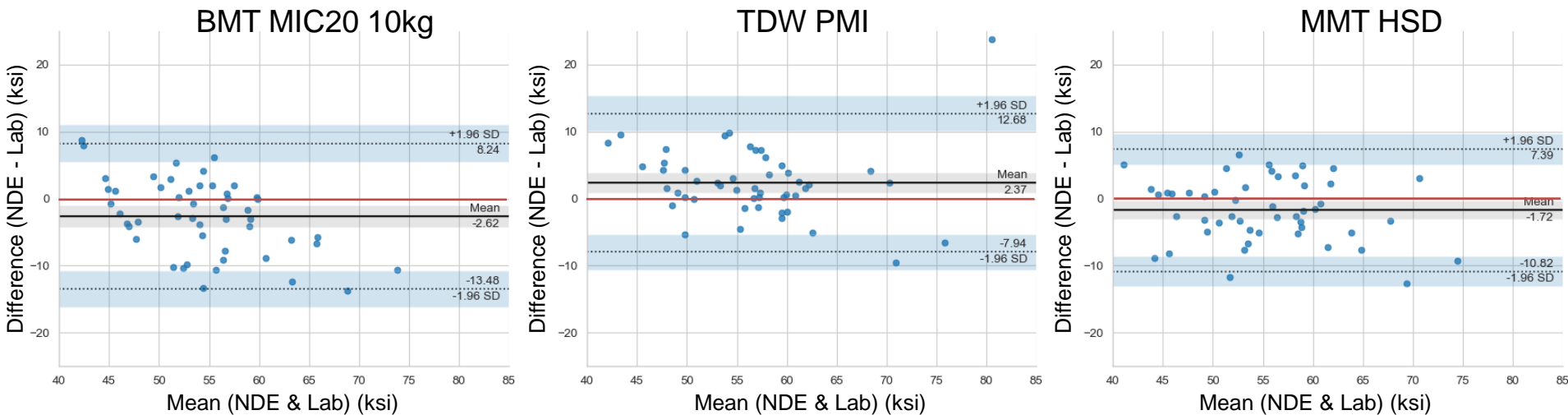
**Reference:**  
 "Validating and quantifying In-Situ NDT Uncertainty of Line Pipe Material Properties", PPIM Paper No. 2023.118:87

March 7-8, 2023 | PRCI Research Exchange

© 2023, PRCI

# Alternative to unity plot – Bland Altman plot

6



	BMT MIC20 10kg	TDW PMI	MMT HSD
Mean (Bias)	-2.6	2.4	-1.7
Positive limit of agreement (Overestimation)	8.2	12.7	7.4

# What is technology validation?

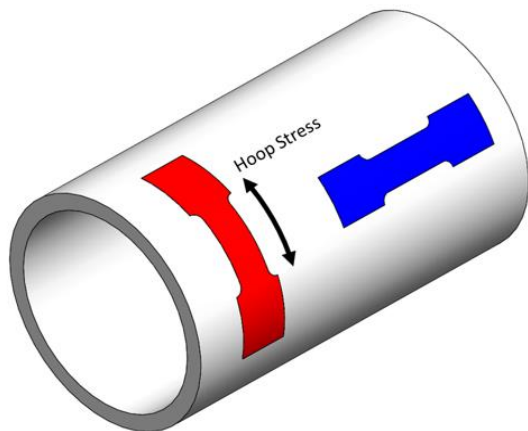
7

- **What is validated:** *“methods, tools, procedures, and techniques”*
- **How: Blind tests;**
  - Laboratory blind tests
  - In field blind tests
  - In field experience
- **Why: Risk of overfitting (overly complex models)**

# What is technology validation?

8

- Against what: A gold standard (tensile test per API 5L)



For seam welded pipes:

**transverse for larger OD** and  
**longitudinally for smaller OD**

Why:

**Steel texture / anisotropy**

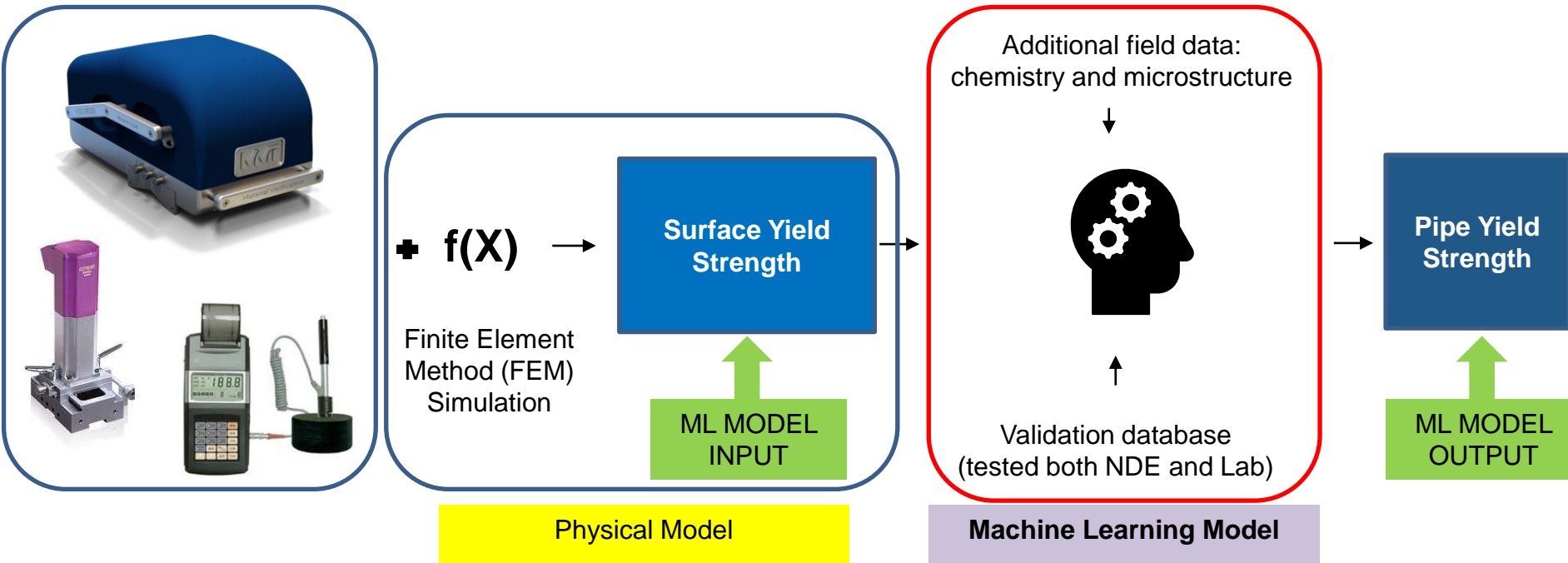
- What is quantified: “Measurement inaccuracy and uncertainty”



# Non-Destructive Process

LEADING PIPELINE RESEARCH

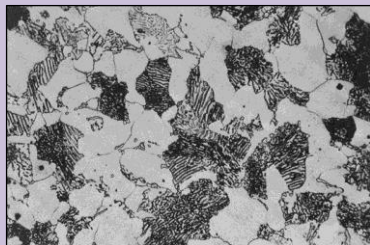
9



# Machine Learning Field Process

Surface Yield Strength

+



Material Grain Structure

+

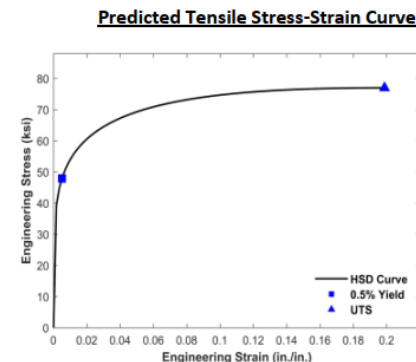
Element	Content (%)
Carbon, C	0.34
Iron, Fe	0.60
Manganese, Mn	0.44
Phosphorous, P	0.21
Sulfur, S	0.03
Chromium, Cr	4.78
Copper, Cu	0.08
Nickel, Ni	0.15
Molybdenum, Mo	1.61
Vanadium, V	0.51

Material Chemical Composition

+



=



# Key Steps to a Validated Machine Learning Model

11

**Dataset**

**Model  
Generation**

**Model  
Validation**

<b>Training Data</b>	<b>Model Training</b>	<b>Blind Validation</b>
<b>Testing Data</b>	<b>Model Selection</b>	<b>Troubleshooting</b>
<b>Validation Data</b> <ul style="list-style-type: none"> <li>- Internal Blind Validation</li> <li>- External Blind Validation               <ul style="list-style-type: none"> <li>- Lab Values Unknown</li> </ul> </li> </ul>	<b>Model Parameter Optimization</b> <b>Results Evaluation</b>	<b>Model Overfit Evaluation</b> <b>Outlier Detection</b>

# Model Generation

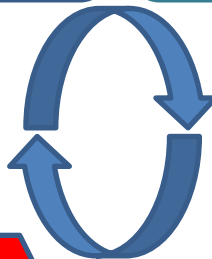
LEADING PIPELINE RESEARCH

12

**TRAINING SET**

**TEST SET**

Training  
Tuning  
Evaluation



**CROSS-VALIDATION – NOT SAME AS MODEL VALIDATION**

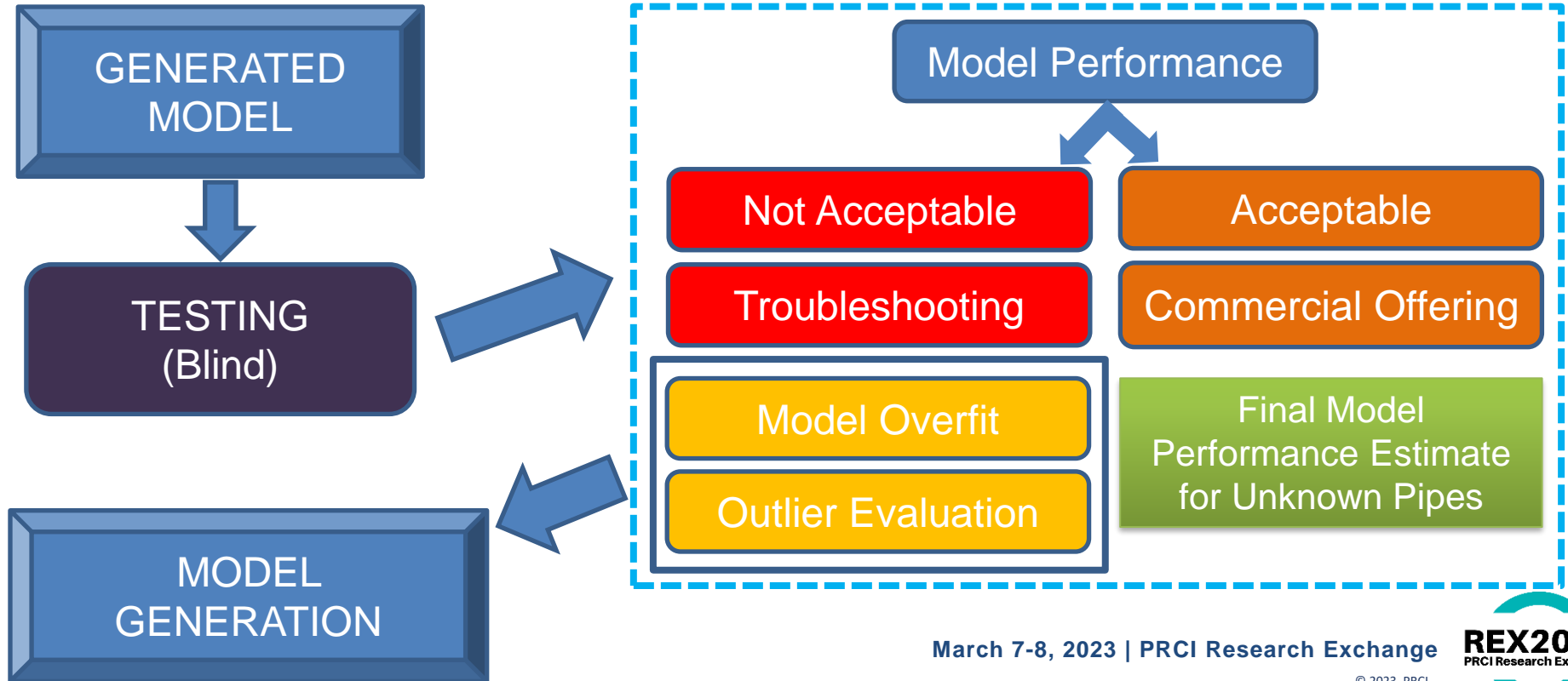
**MODEL SELECTION AND OPTIMIZATION**

KNOWN LAB VALUES

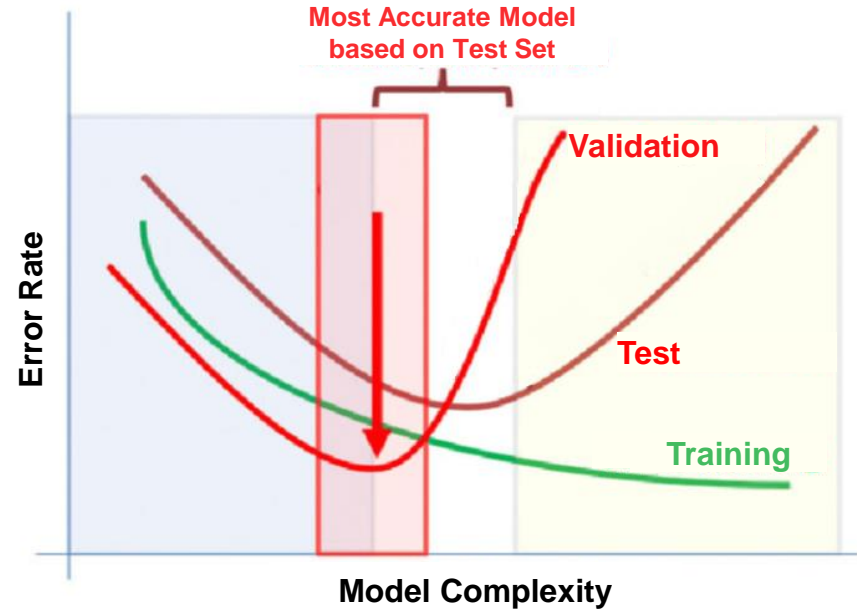
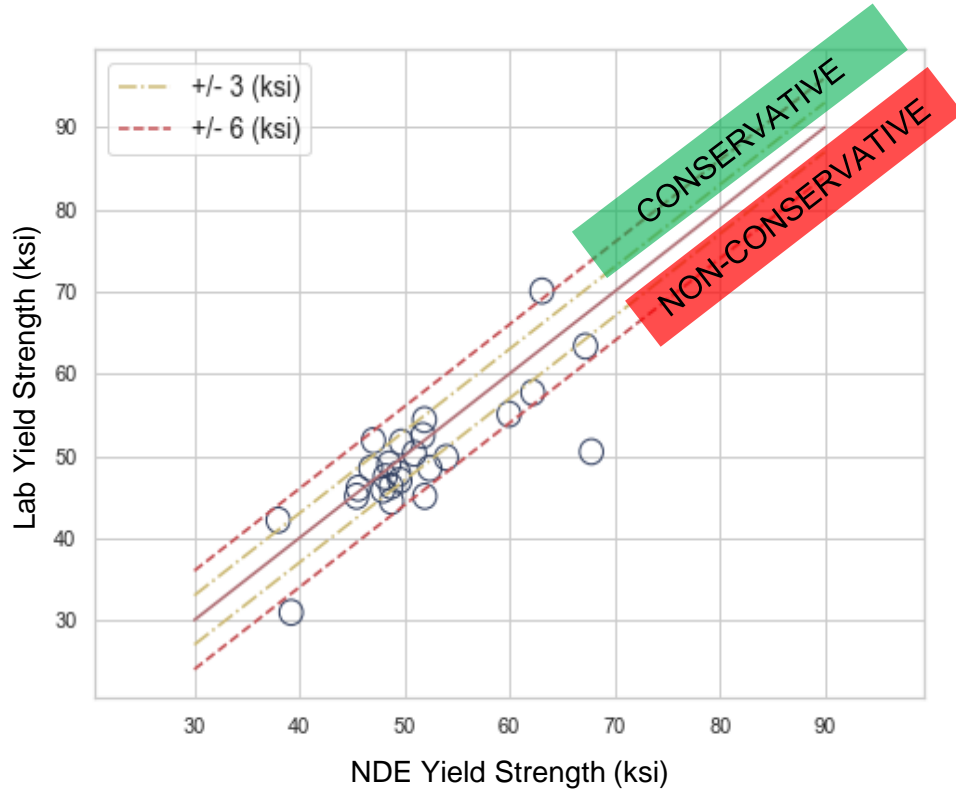
5 – Fold Cross-Validation				
Test	Train	Train	Train	Train
Train	Test	Train	Train	Train
Train	Train	Test	Train	Train
Train	Train	Train	Test	Train
Train	Train	Train	Train	Test
Fold-1	Fold-2	Fold-3	Fold-4	Fold-5

# Model Validation

13



# Model Performance



## GTI Report – Key Contradictions

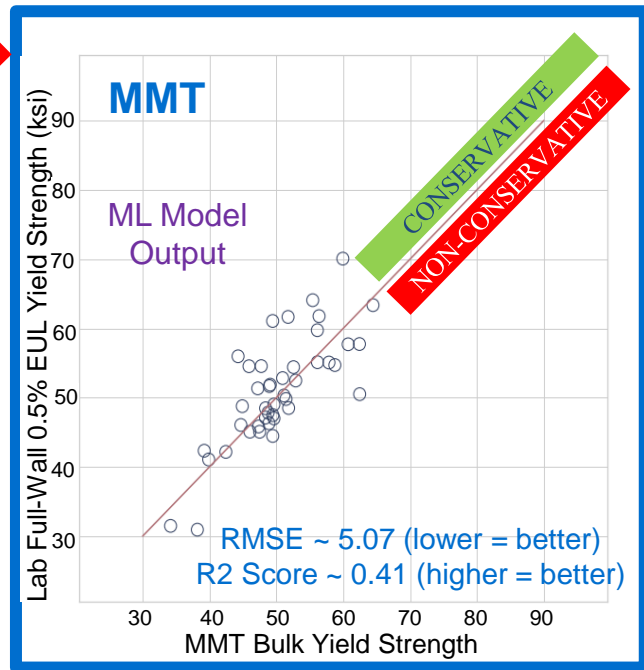
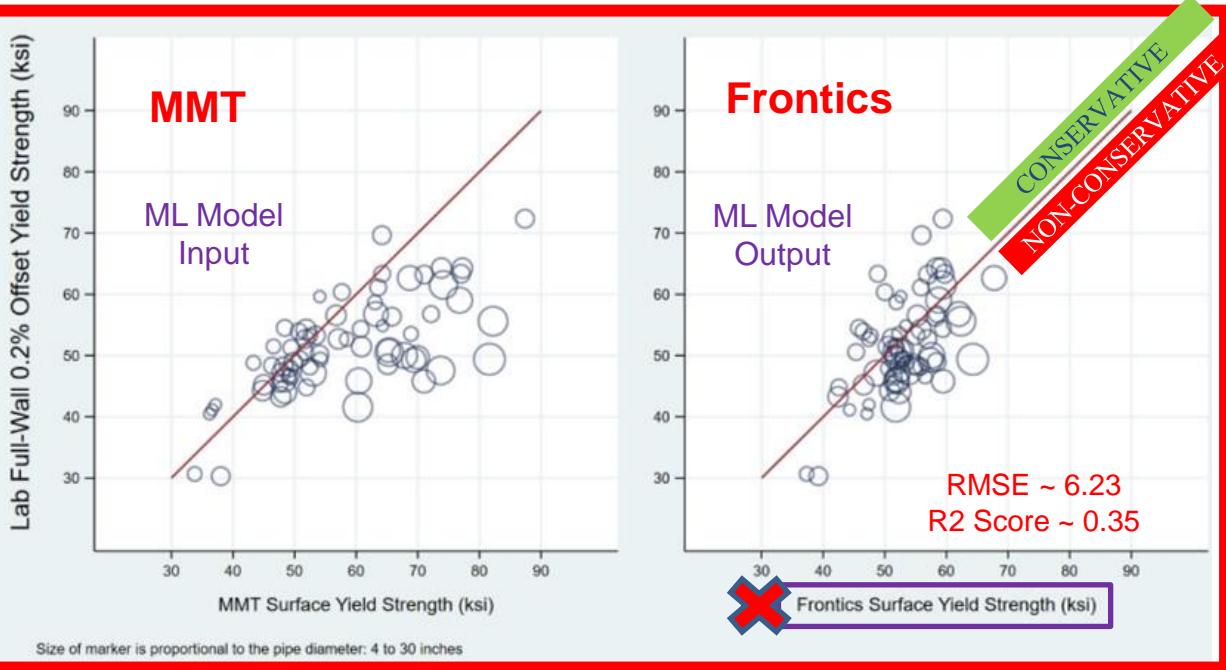
15

- **Tensile tests not in accordance with API-5L as specified in Mega Rule**
  - GTI conducted tensile testing in accordance with ASTM A370 where all samples were tested **longitudinally**
- **Risk of model overfit due to lack of blind testing**
- **Incompatible data comparison**
- **Dataset size not large enough**

# Case Example – GTI Data

LEADING PIPELIN

16



## Including non-compliant tensile tests

**Reference:**

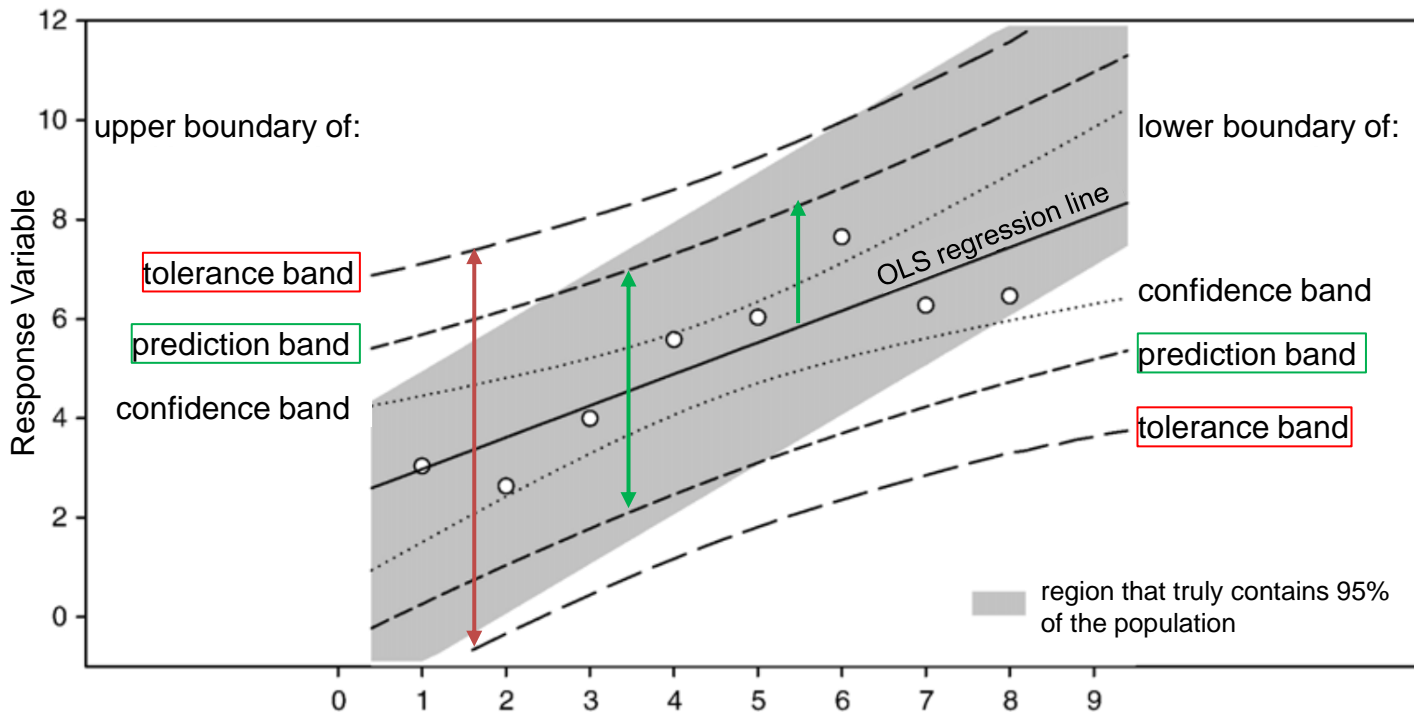
GTI Report Page 42 (DOT Project #729 and DOT/PHMSA CONTRACT NUMBER: 693JK31810003 issued September 28, 2021)

March 7-8, 2023 | PRCI Research Exchange

© 2023, PRCI



# Evaluating Conservative Shift



**Reference:**

Steven De Gryze, Ivan Langhans, Martina Vandebroek, "Using the correct intervals for prediction: A tutorial on tolerance intervals for ordinary least-squares regression", Chemometrics and Intelligent Laboratory Systems, Volume 87, Issue 2, 2007, Pages 147-154.

Explanatory Variable

March 7-8, 2023 | PRCI Research Exchange

# Evaluating Conservative Shift using Published Data

Data: Combined valid results from both the GTI and the PRCI study

Commercial Offering Methods	Symmetric 2-Sided 60% Prediction Interval (ksi)	True 1-Sided Prediction Interval (ksi) using Tolerance Interval
Ball Indentation	4.8	5.9
Frictional Sliding	4.4	3.1*

\* Note: For frictional sliding, a larger validation database is used to justify a 3.0 ksi conservative shift

## Conclusions

19

- **Validated non-destructive verification processes can eliminate the need for destructive testing of cutout samples to obtain material properties.**
- **ML models trained using an existing dataset perform differently when testing unknown pipe samples (blind).**
- **The reasons for conflicting findings between GTI report and prior PRCI project is errors in the GTI work.**
- **1-sided tool tolerance is a better approach to conservatively account for measurement uncertainty.**

Thank you



Pipeline Research  
Council International

LEADING PIPELINE RESEARCH

**Intisar Rizwan I Haque**

*Manager - Data Analytics, MMT*

+1 (617) 502-5636

**[i.rizwanihaque@bymmt.com](mailto:i.rizwanihaque@bymmt.com)**