Pipeline Pigging and Integrity Management

2024

36th YEAR

February 12 - 16 • Houston

#359 – Measuring Pipe Seam Toughness via Frictional Sliding

Ryan Lacy, Massachusetts Materials Technologies (MMT)

Co-authors

Intisar Rizwan I Haque, Massachusetts Materials Technologies (MMT)

Simon Bellemare, Massachusetts Materials Technologies (MMT)

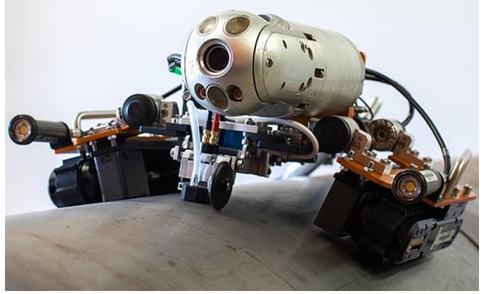
Background

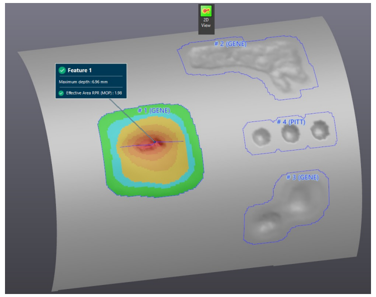
Asset management requires physical properties

(Diameter, Thickness, Seam Type, Strength, etc)

Technological advancements make property acquisition easier

(UT, Advanced X-Ray, Advanced Metrology, etc)





Toughness has not significantly advanced

Existing Methodology

Direct Toughness is largely limited to cutouts

Conventional methods are:

- Expensive
- Time-Consuming
- Environmentally Harmful
- Worker Safety Concern

Industry requires better methods for toughness measurement

- Top gap from October ’23 PHMSA R&D meeting

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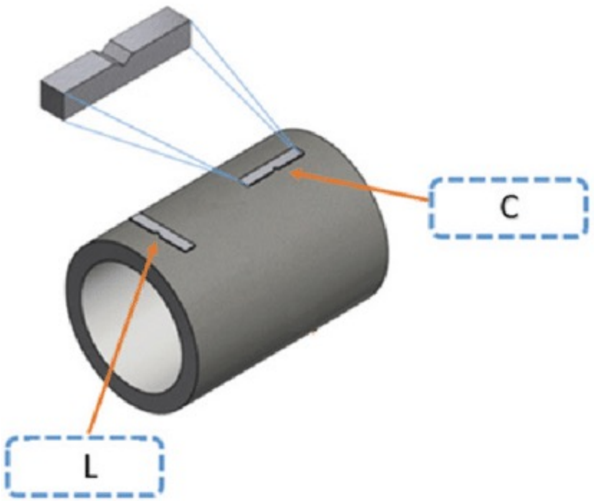
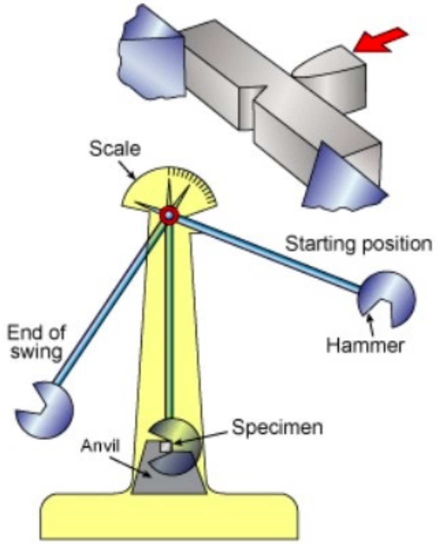
Destructive Process

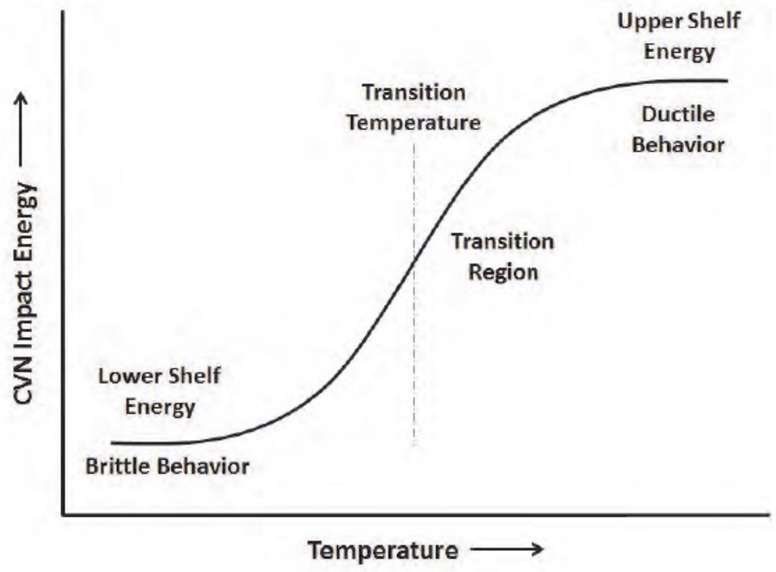
SAMPLE



TEST



RESULTS



NDE Alternative

Accurately determine toughness non-destructively

Non-destructive evaluations are:

- Safer
- Faster
- Cheaper
- Environmentally Friendly

- Address PHMSA top identified gap

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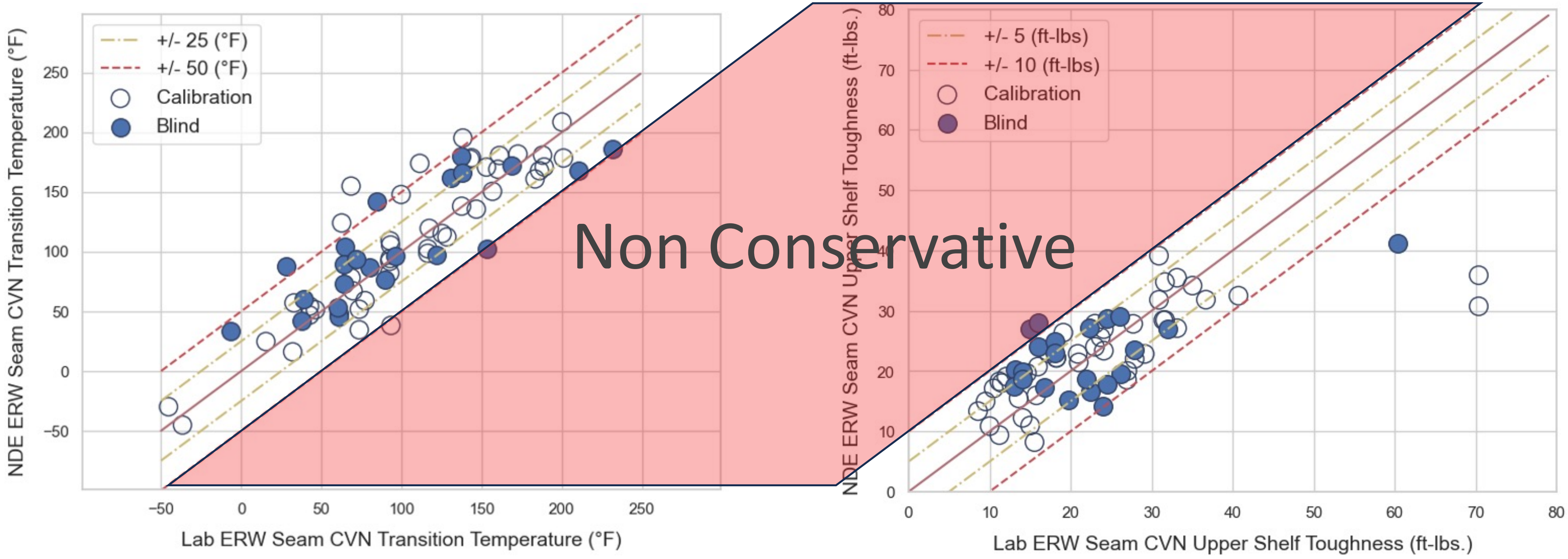
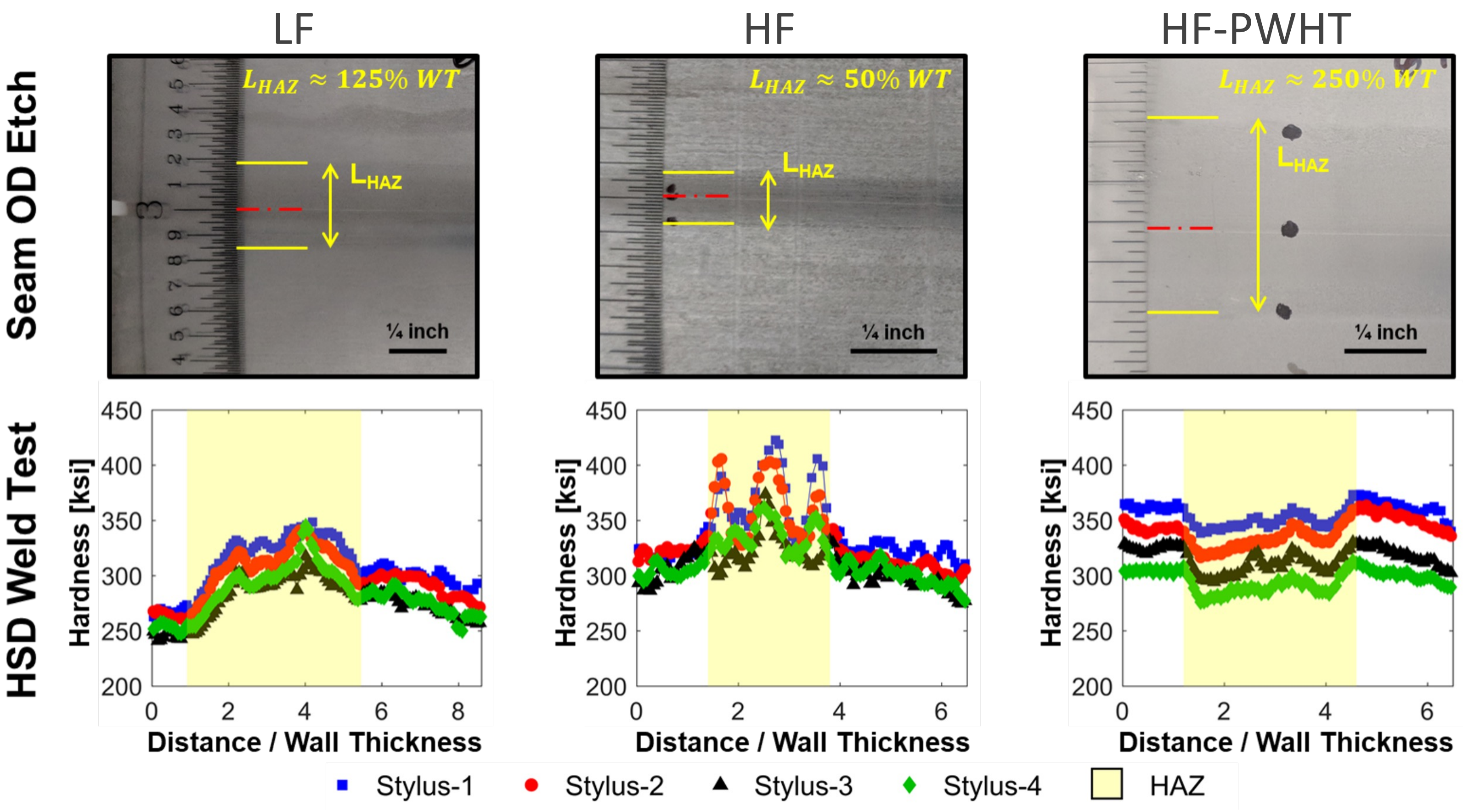
Blind Testing Results

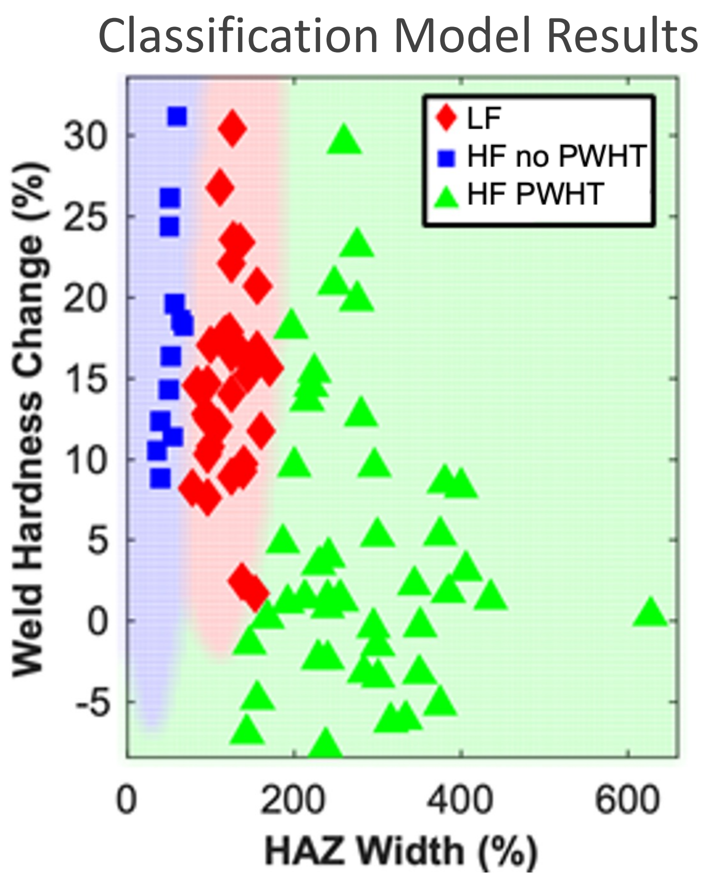
Transition Temperature Unity

Upper Shelf Toughness Unity

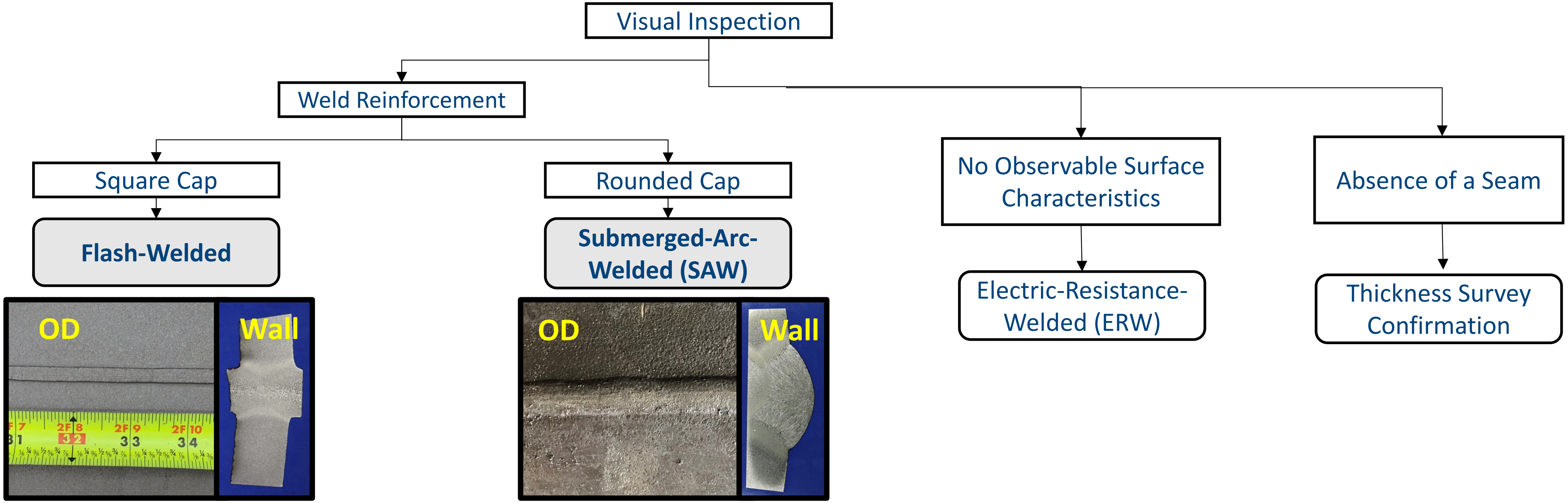


ERW Seam Classification





In-Field Seam Classification Process



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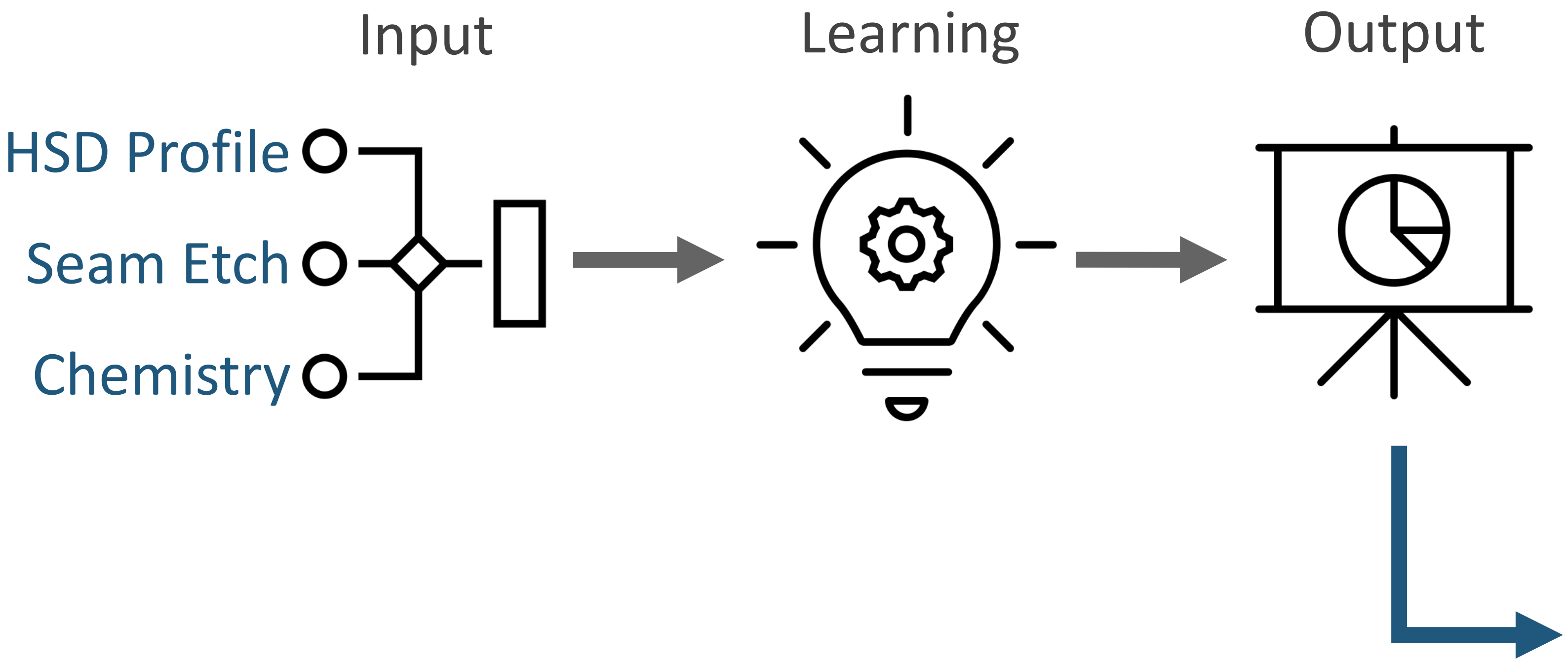
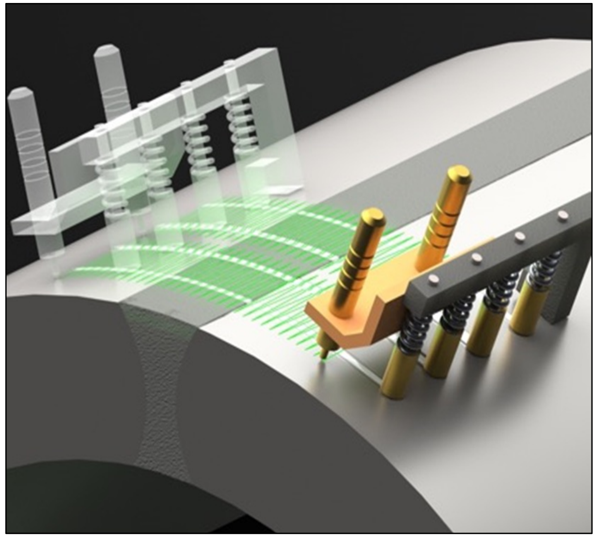
High-Level Seam CVN Overview





Transition Temperature

Upper Shelf Behavior

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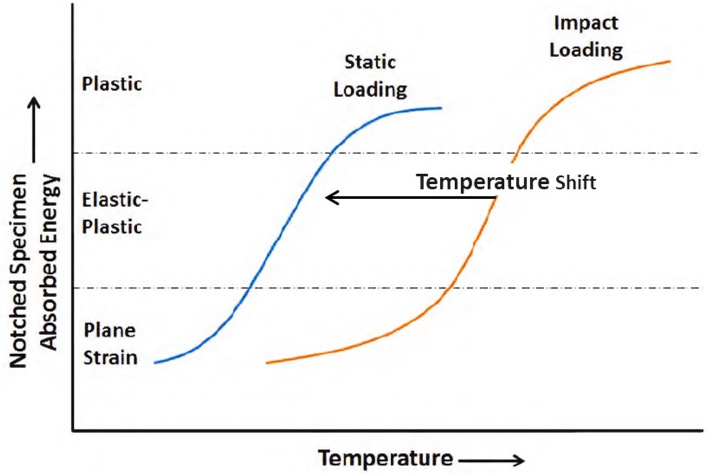
Determining Fracture Initiation

- NDE provides Fracture Propagation Transition Temperature (FPTT)
  - Fracture Initiation Transition Temperature (FITT) is critical
  - Strain rate requires adjustment (impact vs static load)

$$FITT = FPTT - \Delta T$$



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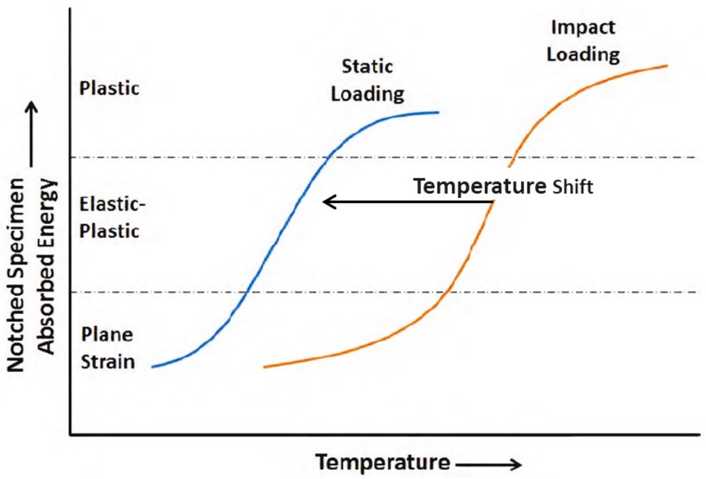
Fracture Initiation vs Fracture Propagation

- NDE provides Fracture Propagation Transition Temperature (FPTT)
  - Fracture Initiation Transition Temperature (FITT) is critical

$$FITT = FPTT - \Delta T$$



Measurement Uncertainty

Driven both via regulation and practicality

- Risky to assume conservatism from a single measurement

Applied to:

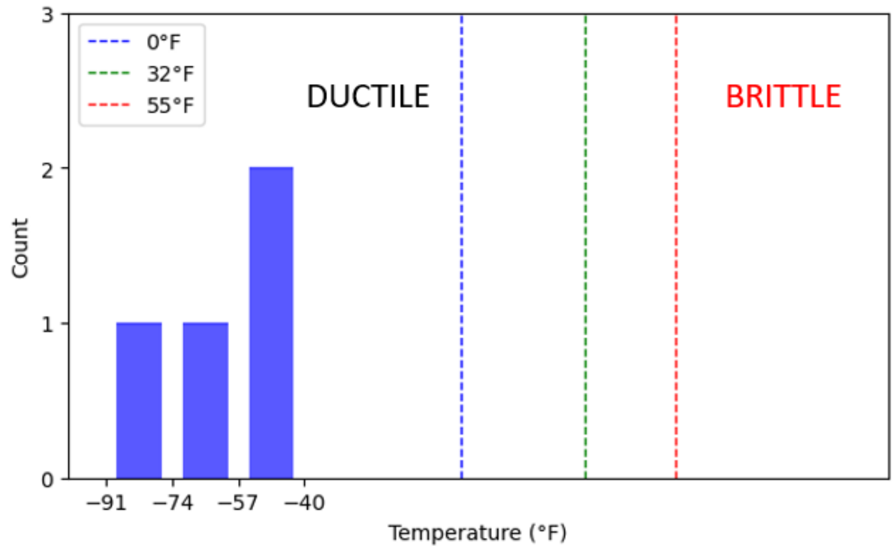
- Transition Temperature (+60°F)
  - Measured: -15°F → Conservative: 45°F
- Upper Shelf Energy (-10ft-lb)
  - Measured: 32 ft-lb → Conservative: 22 ft-lb
  - **Minimum of 10 ft-lb**
  - Measured: 18 ft-lb → Conservative: 10 ft-lb

Case Study – In-service testing

Field tested 4 ERW samples

- All transition temperatures below the operating temperature (Upper Shelf)
- Measurement consistency (+/- 5 °F)

Sample Name	Seam Type	Tests	NDE Impact Fracture (85% Shear Temperature)			
			Est. (°F)	Avg. (°F)	Cons. (°F)	Avg. (°F)
Sample 1	ERW HFN	01	-22	-23.5	38	36.5
		02	-25		35	
Sample 2	ERW HFN	01	-3	-4.5	57	55.5
		02	-6		54	
Sample 3	ERW HFN	01	14	17.5	74	77.5
		02	21		81	
Sample 4	ERW HFN	01	7	10	67	70
		02	13		73	



Case Study – Determining Toughness

Toughness Results

Low test to test variability (+/- 2 ft-lb)

Sample Name	Tests	Upper Shelf Impact Energy (ft-lbs.)	Avg.	Conservative Upper Shelf Impact Energy (ft-lbs.)	Avg.
Sample 1	01	30	32	20	22
	02	34		24	
Sample 2	01	28	28	18	18
	02	28		18	
Sample 3	01	27	26.5	17	16.5
	02	26		16	
Sample 4	01	28	28	18	18
	02	28		18	

NDE Measurement vs Regulation

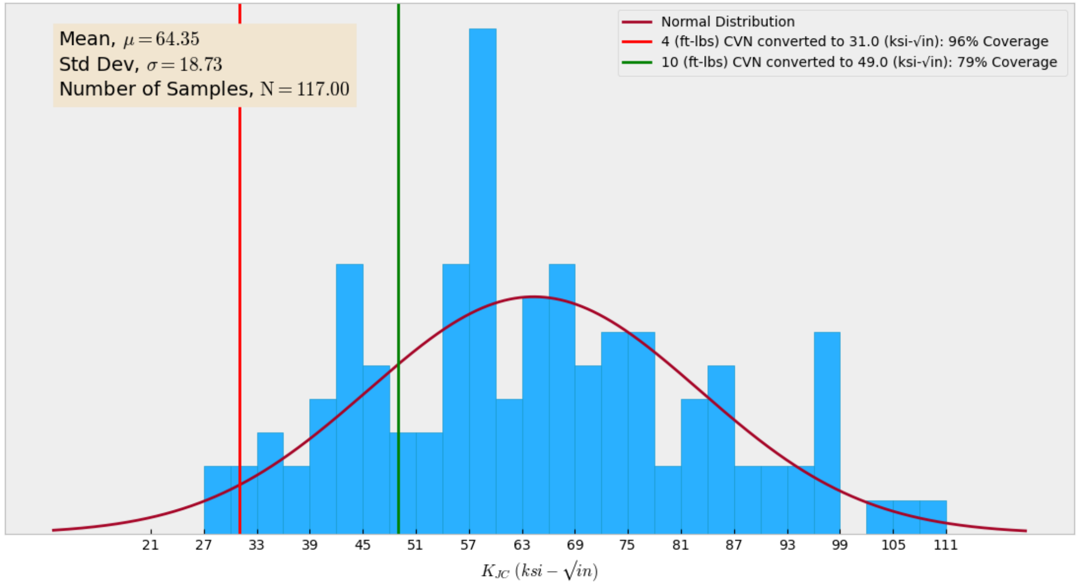
No Incidents: 4 ft-lb (31 ksi·√in)

Incidents: 1 ft-lb (15.5 ksi·√in)

(Regulatory Default)

~50% > 17 ft-lb (~64 ksi·√in)

(Conservative NDE: 7 ft-lb)



Recreated data, originally presented at IDT Expo, 2021

K. Bagnoli, N. Thirumalai, J. Furmanski, P. Sarosi, J. Ma, “Evaluation of Fracture Toughness of Pre-1970’s ERW Pipeline Steel for Improved Seam Integrity Management,” *IDT Expo*, 2021

Assuming Upper Shelf, > 95% exhibit higher conservative seam toughness than regulatory default.

Upper Shelf Considerations

If FITT is near Operating Temperature:

- Reduce excessive conservatism
  - Less stringent repair criteria, $
- Brittle fracture risk
- As FITT nears operating temperature, greater risk in assuming upper shelf

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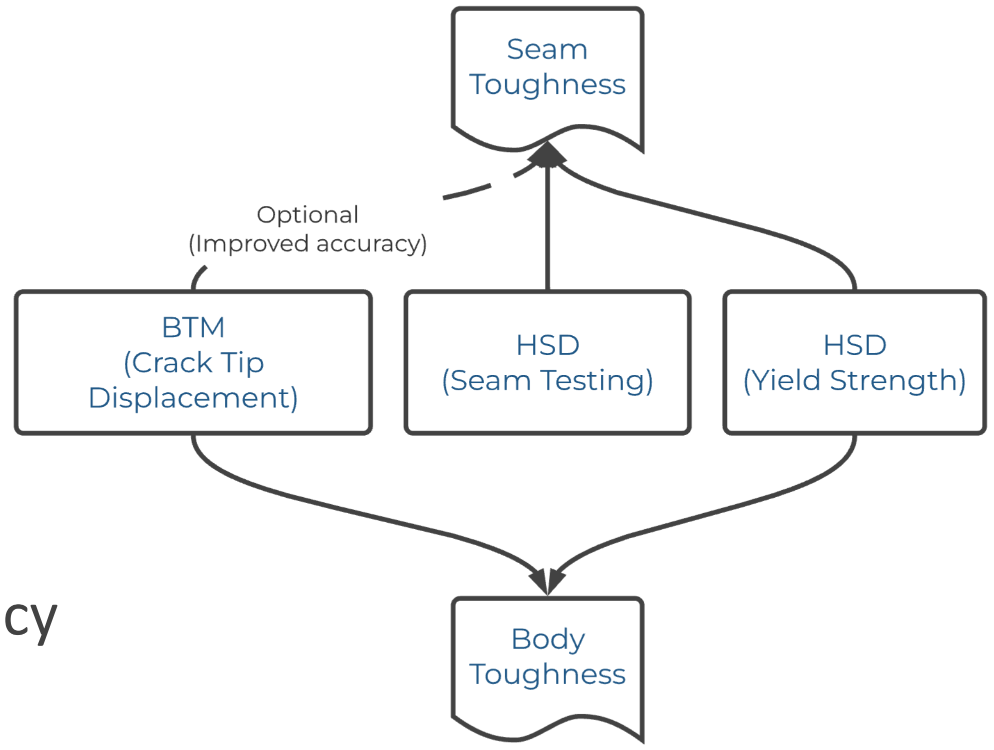
Future Work

- Additional Seam Type Support
  - Flash, Saw, etc.
- Increase database size
  - Reduce conservative shift, increase accuracy
- Incorporate body toughness
  - Empirical relationship suggests performance improvement



Joint Industry Project (JIP) will accelerate progress

Conclusions

- NDE processes can currently justify ERW seam toughness above regulatory defaults
- Meets regulatory testing requirements
    - 6 independent tests per seam
- NDE seam toughness accuracy increased by ~7% in a test dataset when introducing body toughness
    - Further explored in upcoming JIP
- Increased Database will further increase relevancy toward individual samples

PPIM 2024

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Thank You

Questions?