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Quantifying Probe Coverage Error in Feeder Thinning Assessment

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Outline

- Background
  - Feeder wall thickness measurement
- Study objectives
- Methodology
  - Simulation approach
- Results
  - Maximum coverage error
  - Correlation with thinning pattern
- Summary and conclusions

Wall Thickness Measurement

animation

- The wall thickness of feeder pipes is measured using bracelet type ultrasonic NDE tools

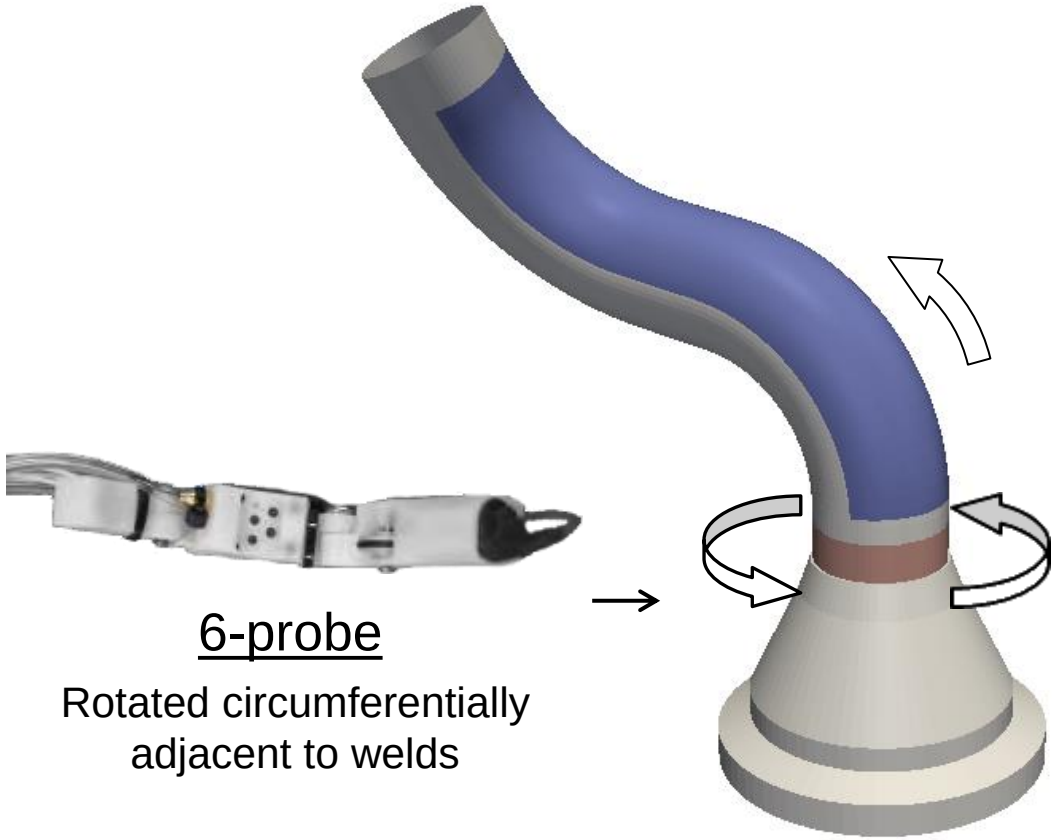

Image courtesy of Zetec

6-probe

Rotated circumferentially adjacent to welds

14-probe

Advanced axially along the pipe bends

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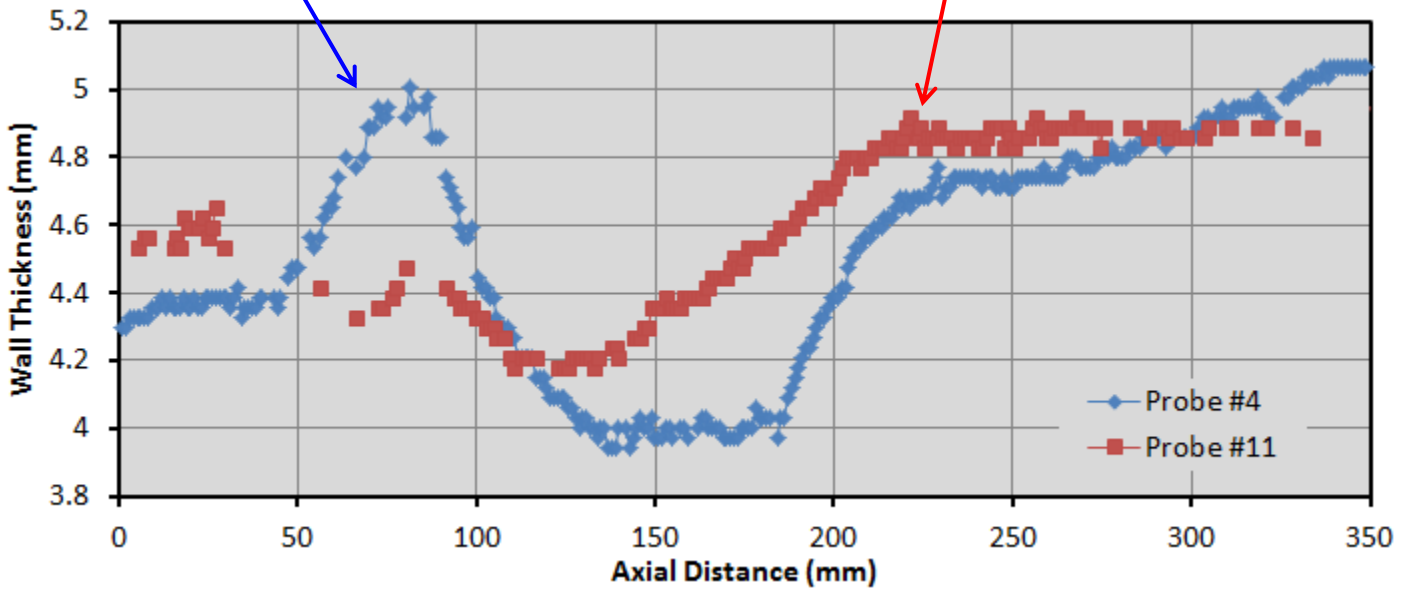
Inspection Data

animation

Example 14-probe trending file

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Axial						Probe Wall Thickness (mm)								
2	Distance	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14
3	(mm)														
4	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5	1.006	NaN	4.2674	4.2971	4.2971	4.3267	4.3267	4.3563	4.4156	NaN	4.5045	NaN	4.5934	4.6527	NaN
6	2.012	NaN	4.2674	4.3267	4.2971	4.3563	4.3267	4.386	NaN	NaN	4.5045	NaN	4.6231	4.6823	NaN
28	24.144	NaN	4.3563	4.3267	4.386	4.386	4.386	NaN	4.386	NaN	4.5638	NaN	4.6231	4.6527	NaN
29	25.15	NaN	4.3563	4.3563	4.386	4.386	4.3563	4.4453	4.386	4.4749	NaN	4.5638	4.6231	4.6527	NaN
30	26.156	NaN	4.3267	4.3563	4.386	4.386	4.386	4.4156	NaN	4.4749	NaN	4.5934	NaN	4.6823	NaN

Easy to plot individual probe results in Excel



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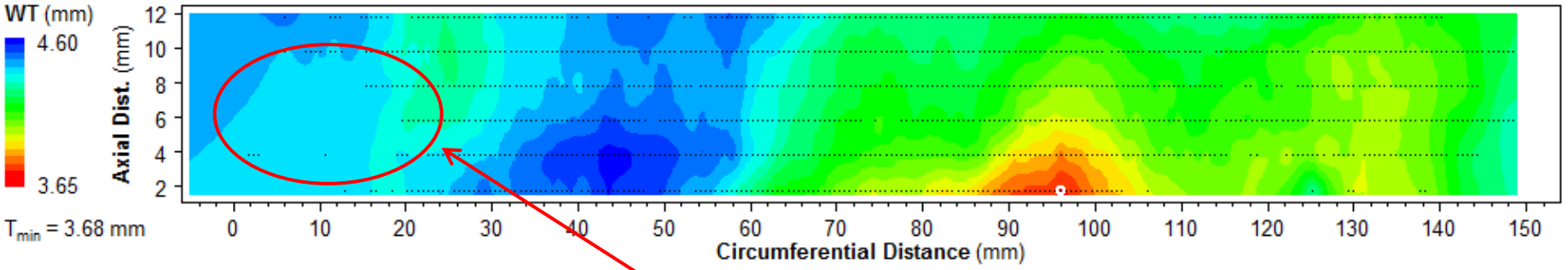
Data Visualization

animation

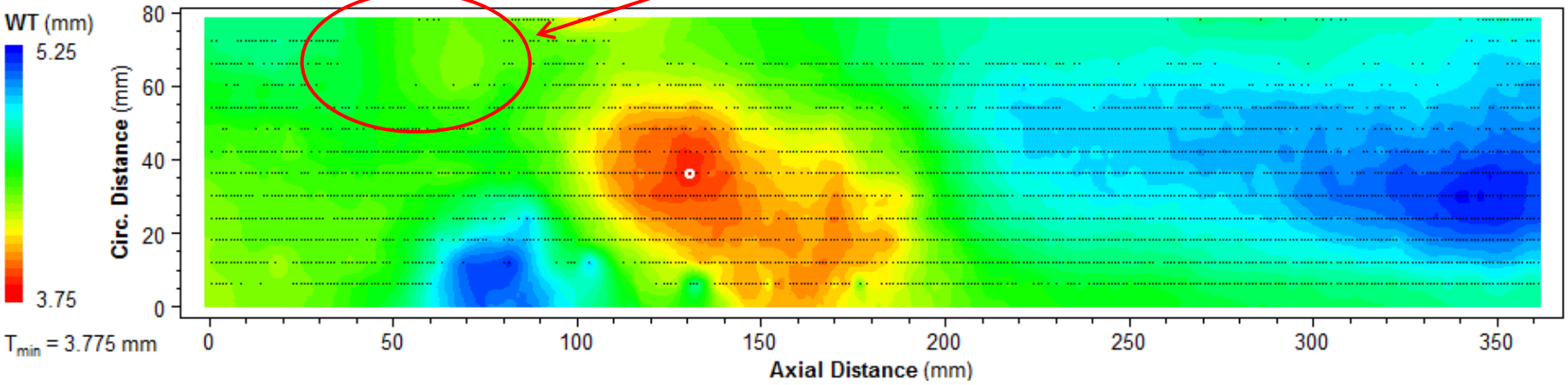
- Interpolate values between individual transducers (and missing data) using the method of kriging

6-probe Grayloc weld scan



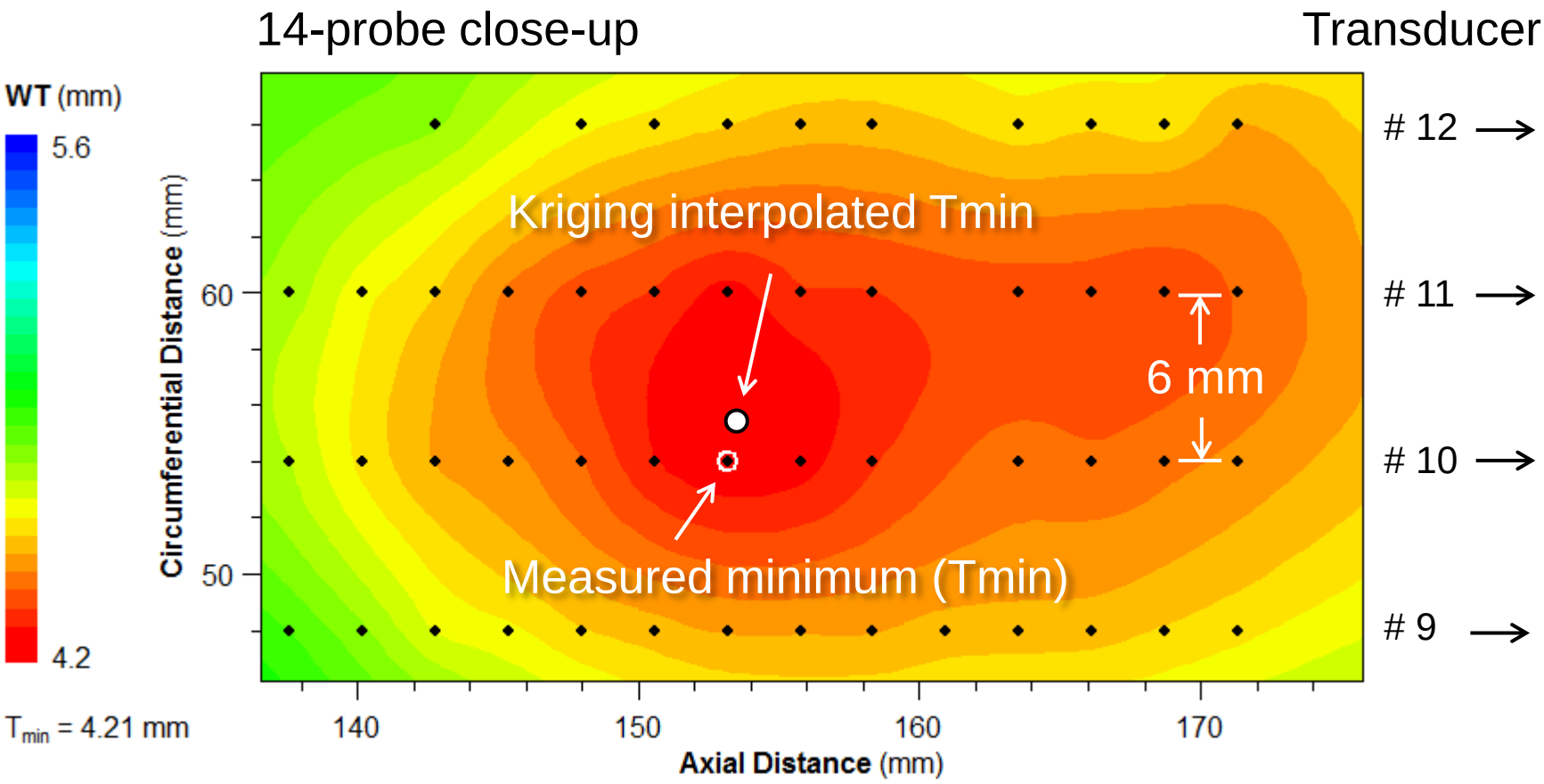
Missing data (probe signal loss)

14-probe Left Cheek scan



Characterizing “Actual” Tmin

animation



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Study Objectives

- The main objective is to quantify the coverage error intrinsic to the feeder inspection tools
  - Coverage error arises from the fixed spacing between the individual UT transducers (2 mm for 6-probe, 6 mm for the 14-probe)
  - Depending on the (manual) placement and operation of the tools, the “actual” Tmin may be missed by the individual transducers

$$\text{Measured Tmin} \geq \text{Actual Tmin}$$

- Also investigate whether the coverage error is correlated with other variables
  - e.g., feeder geometry, size, minimum thickness, etc.

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Methodology

Simulation approach

Representative Scans

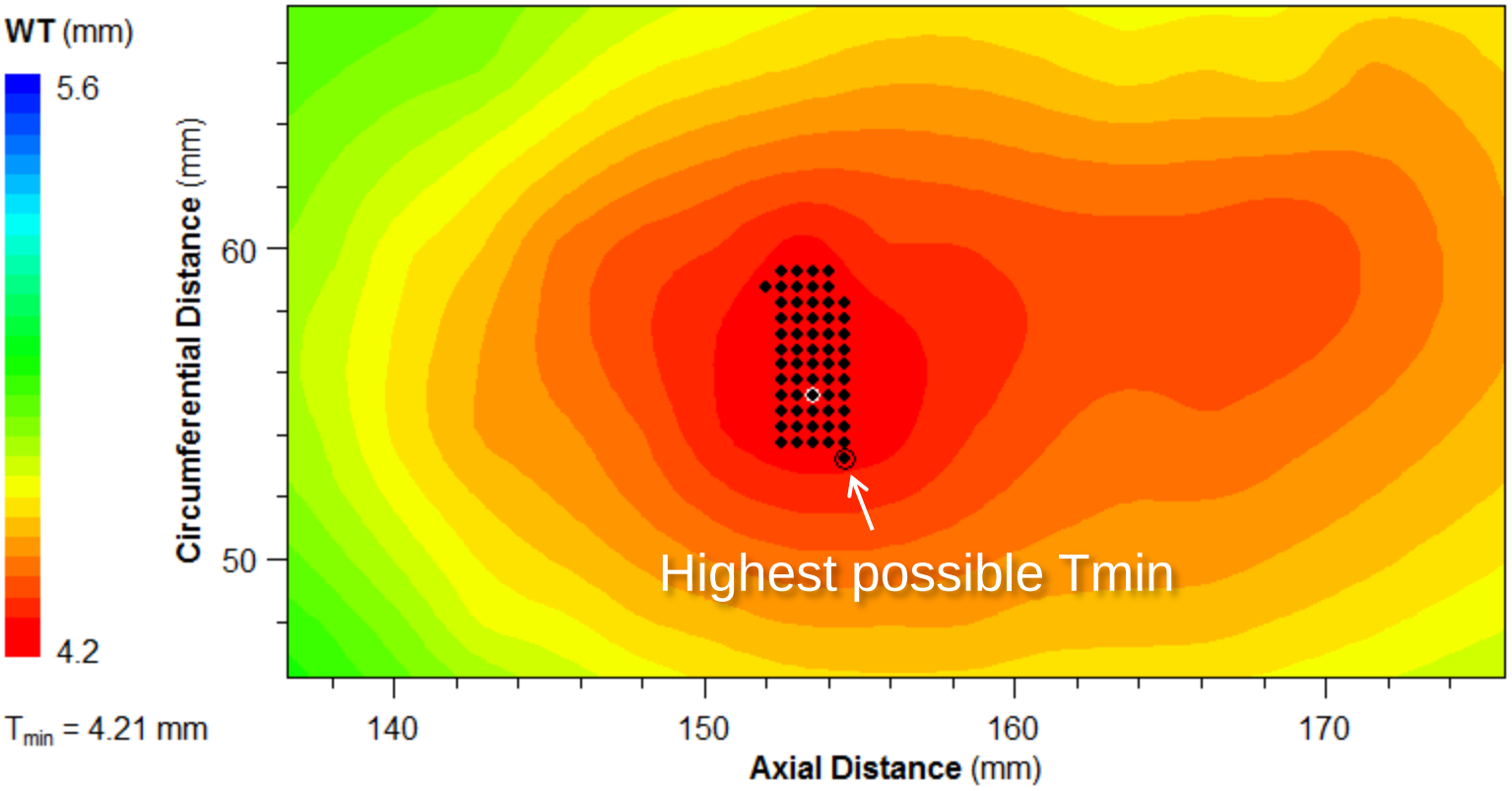
- It is not possible to analyze the true coverage error associated with the probes
  - The actual (true) Tmin is not known for each feeder/scan
- Use the interpolated wall thickness profiles as a reference
- Choose **representative scans** from a total of over 4,400 scans from Darlington and Pickering units
  - Single scan for any one feeder
  - Very low signal loss near the measured Tmin
  - Thinned area near the middle of the scan
  - Representing different patterns of thinning (geometry)

Simulation Approach

- Well characterized thinned areas from
  - 209 representative 14-probe scans, and
  - 193 representative 6-probe scans of different feeders
- The reference scans are expected to be very close to the “actual” wall thickness profiles
- The inspection process was simulated by applying numerous virtual probe passes over the reference profiles
  - Multiple inspection grids, spatially offset in both circumferential and axial directions
  - Compute the maximum possible probe coverage error for each reference scan

Simulation Example

animation

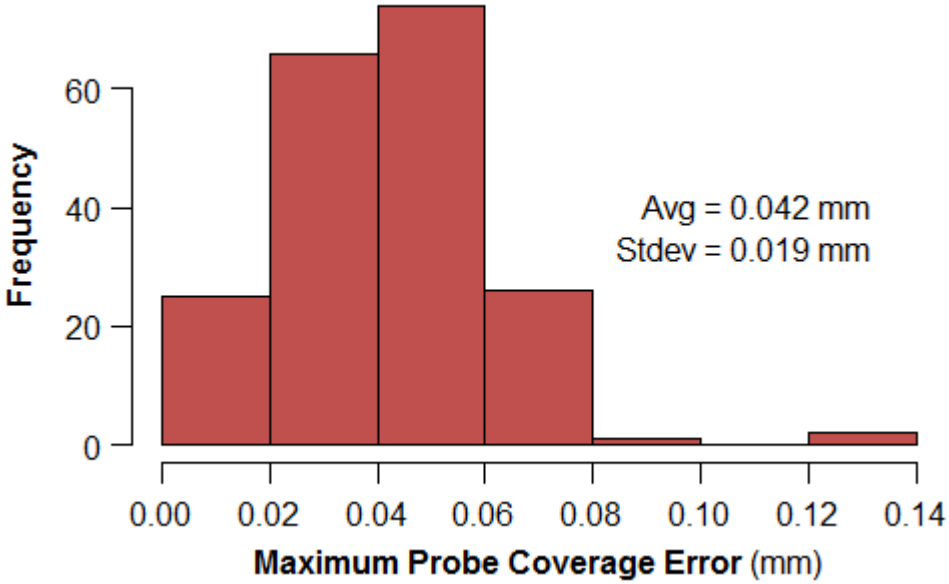


Max Coverage Error = Highest Tmin – “Actual” Tmin

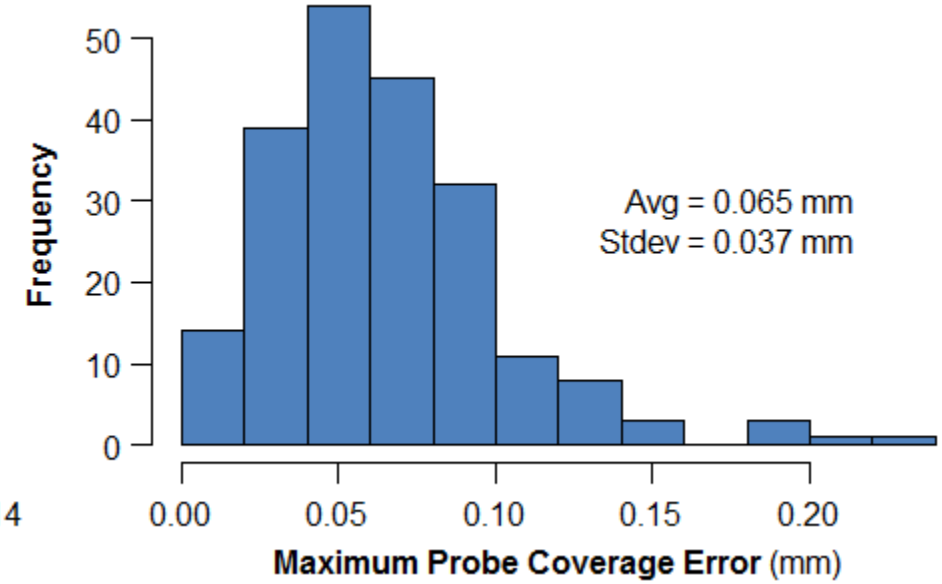
Results

Maximum Coverage Error

6-probe



14-probe



- The maximum error is generally lower for the 6-probe, due to the closer spacing of the transducers
- The results were found to be uncorrelated with feeder geometry, feeder size, reactor unit, etc.

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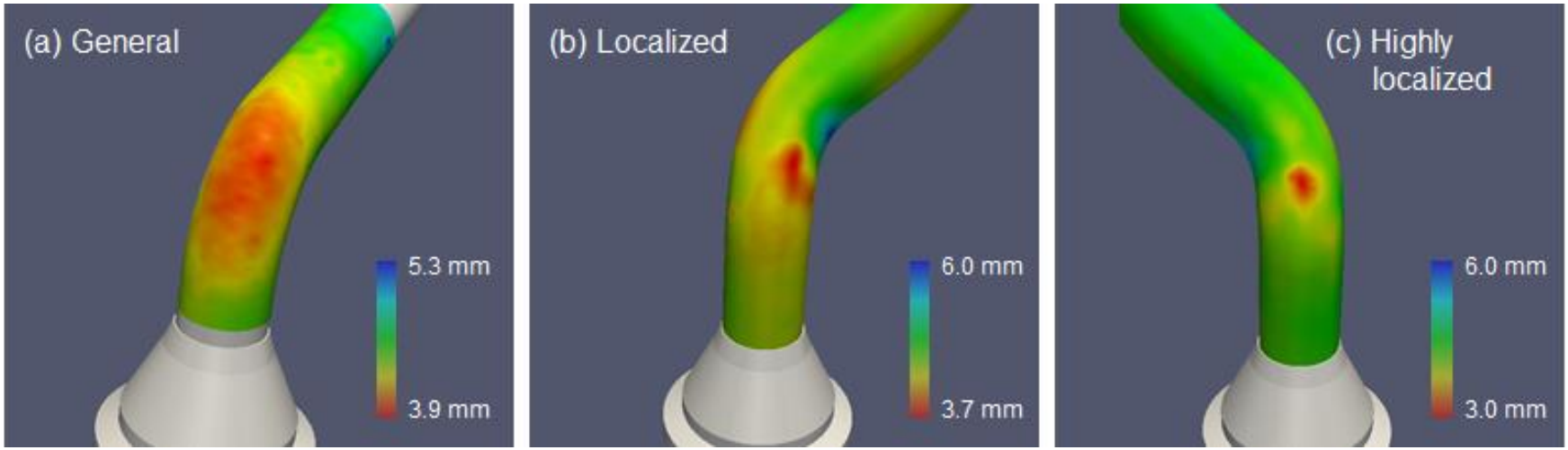
Correlation with Thinning Profile

animation

- Flow accelerate corrosion (FAC) can be categorized into three different types



- The probe coverage error should be directly dependent on the underlying “morphology” of the thinned area
  - i.e., change or slope of the wall thickness profile

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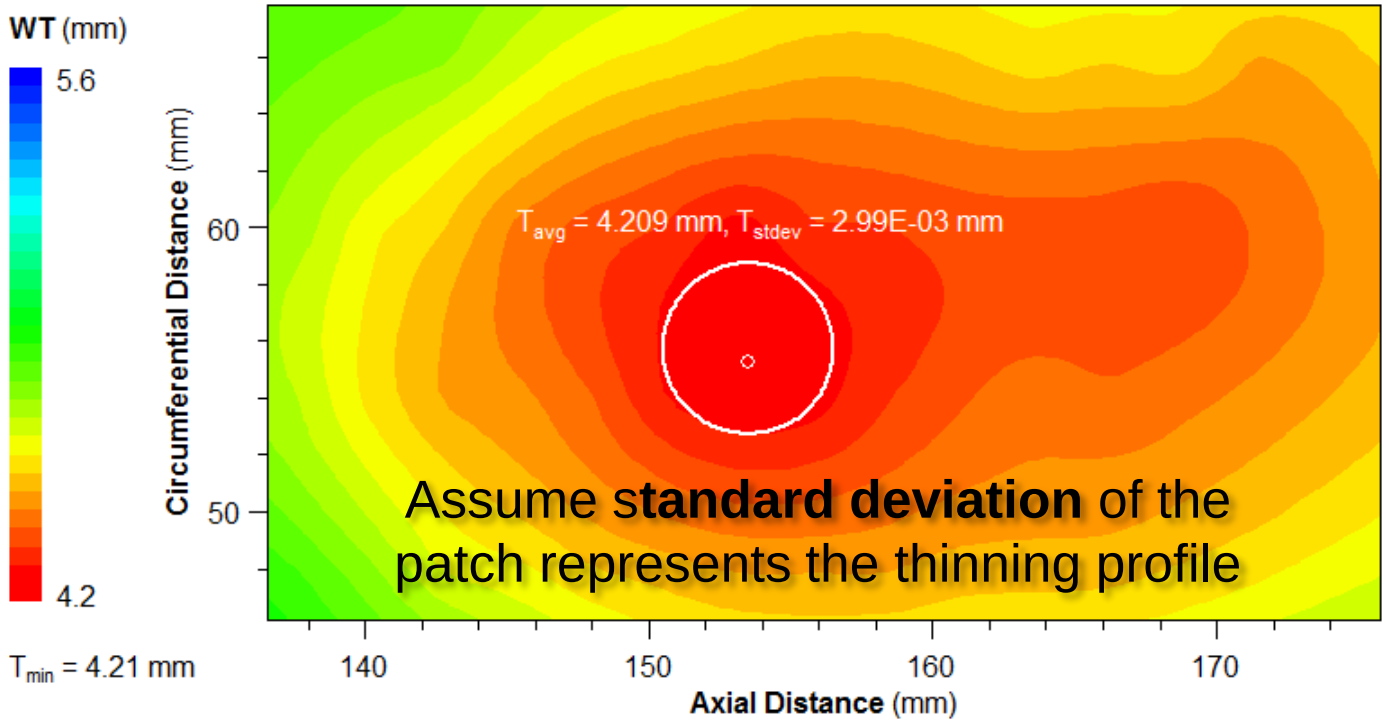
Thinning Characterization

animation

- Use a small circular patch to characterize Tmin
  - Minimize average wall thickness inside the patch
  - Patch size equals probe spacing (2 mm or 6 mm)



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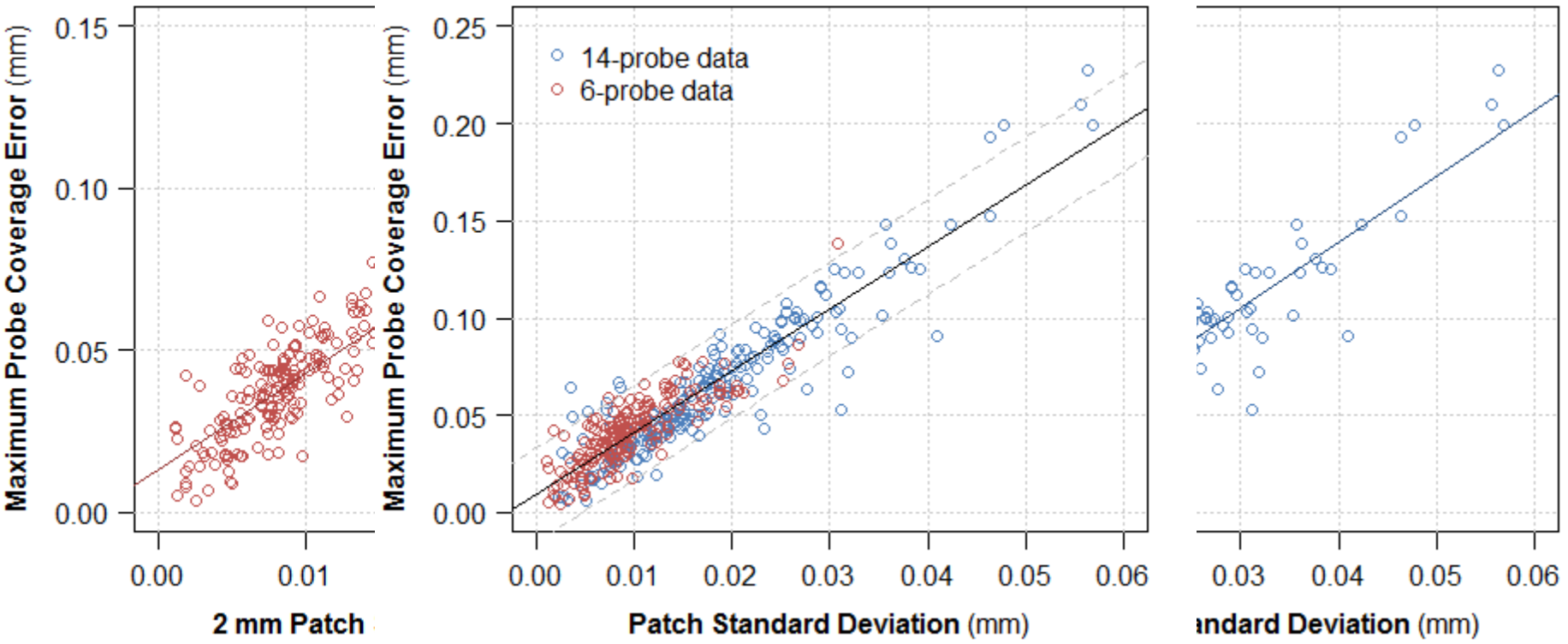
Correlation Plots

animation

6 Combined robe



Good correlation ($R^2 = 0.85$)
Standard error = 0.012 mm

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Summary and Conclusions

- The coverage error associated with the 6-probe and 14-probe feeder inspection tools was quantified using a simulation approach
- The error is well correlated with the type of thinning pattern
  - General thinning has lower error
  - Localized thinning has higher error
  - Thinning pattern was characterized using the patch area method
- Estimating the “actual” minimum thickness is critical for feeder replacement planning
  - May have an impact on feeder end of life (EOL)