1

Beam Modeling, Novel Mockup Fabrication Approach, and Preliminary Phased Array Ultrasonic Testing (PAUT) Data Analysis Supports Viability of an Artificial Intelligence-based Aid for Single-Bevel Weld Inspection in 6-inch Schedule 120 304 Stainless Steel Pipes

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Bastien Clausse, EXTENDE
Jason Landers, Top Notch EDM

6 - 9 October 2025 | Orlando, Florida

2

Can AI help you analyze your PAUT data?

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3

KEY TAKEAWAY #1

Include a welding engineer in decisions made on inspection configuration

KEY TAKEAWAY #2

Beam modeling and inspection simulation are nice-to-haves but not necessary steps for AI model development

KEY TAKEAWAY #3

Include the AI model developer on decisions made with the data generation plan

KEY TAKEAWAY #4

Push the limits on mockup technology

KEY TAKEAWAY #5

Keep all the data that you encode!

KEY TAKEAWAY #6

AI is an aid to the qualified inspector, not a human replacement

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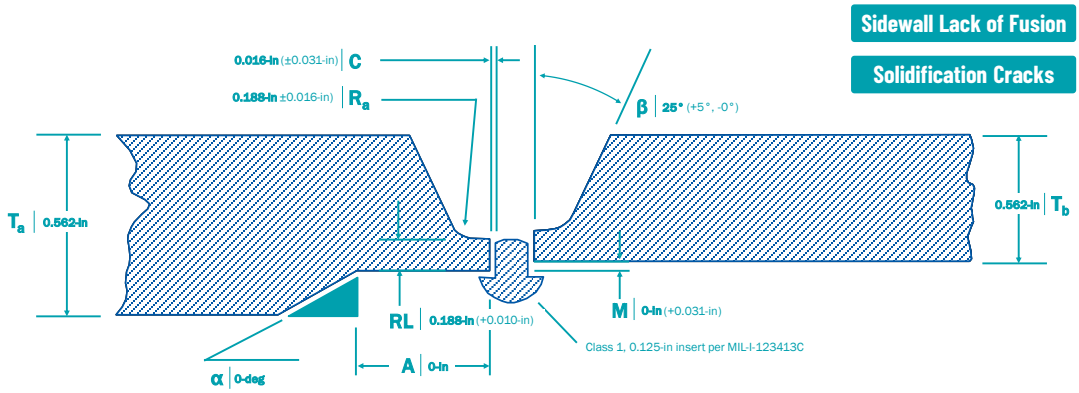
4

Single-bevel J-groove Weld Mockup Configuration



304 Stainless Steel | 6-in Schedule 120 | Welds Off-Center | Crown Ground Flush | AWS B2.1-8-215:2023

5

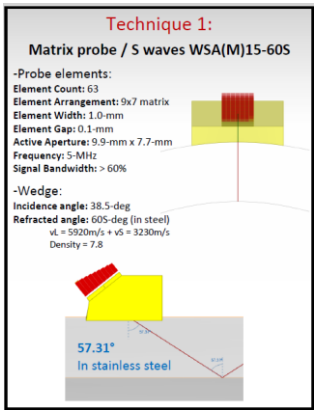
Modeling + Simulation: Why Do It?

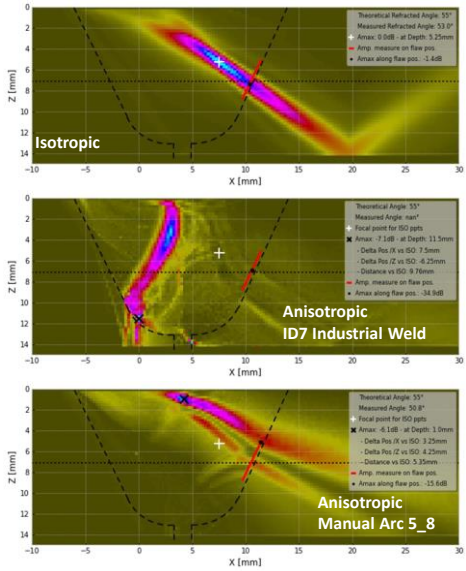
1. Investigate shear wave vs. longitudinal wave
2. Investigate single-matrix array vs. dual linear array
3. Progress the state-of-the-art for modeling anisotropic materials

6

Modeling: Technique 1

Single-Matrix Array Probe, Shear Wave

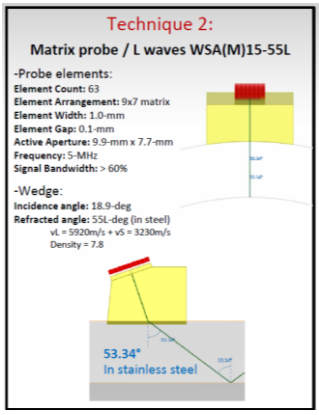


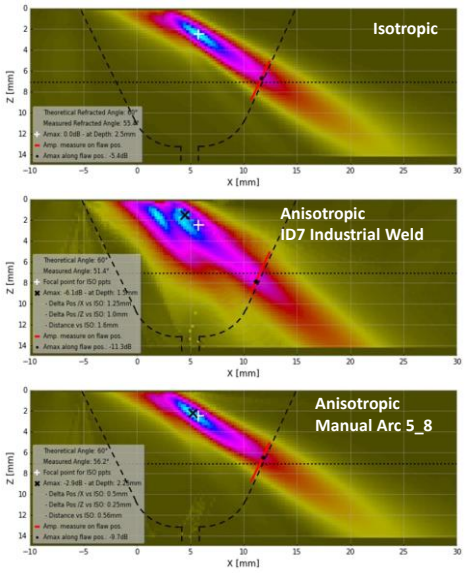


7

Modeling: Technique 2

Single-Matrix Array Probe, L-Wave

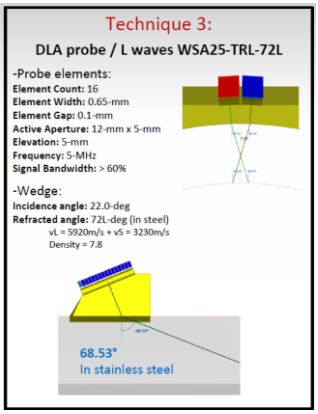


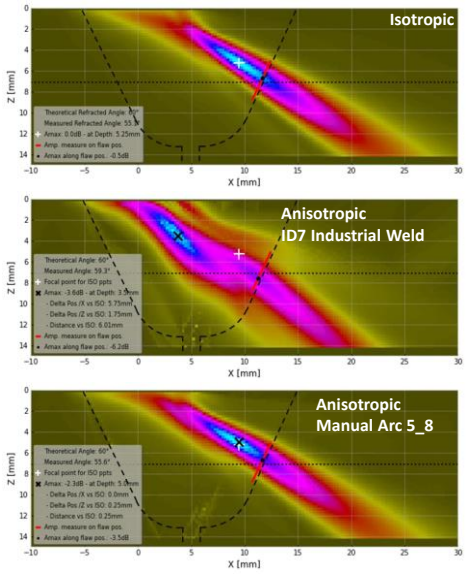


8

Modeling: Technique 3

Dual Linear Array Probe, L-Wave





9

Modeling + Simulation: Conclusions

Technique #2, single-matrix array using longitudinal waves performed best

- Longitudinal waves performed significantly better in anisotropic material than shear waves
- Skewed flaws were better detected with the matrix array

Beam modeling and inspection simulation is possible with anisotropic material, but…

- CIVA requires many inputs for proper simulation of anisotropic material, which may or may not be in the literature

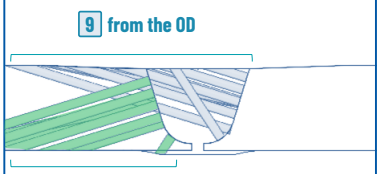
Model-Assisted PoD on Technique #2 is on-going

- Evaluating alignment between experimental PoD and model-assisted PoD

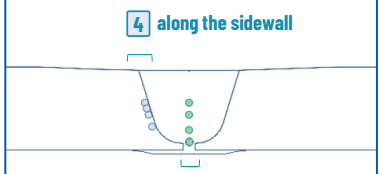
10

Design Features: Reference and Validation Pipe

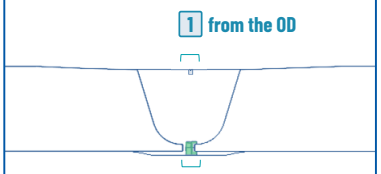
FLAT BOTTOM HOLES 18



SIDE DRILLED HOLES 8



NOTCHES 5



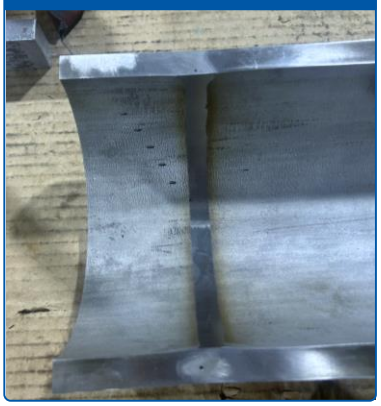
11

Finished Asset: Reference and Validation Pipe

UNIT MARKERS

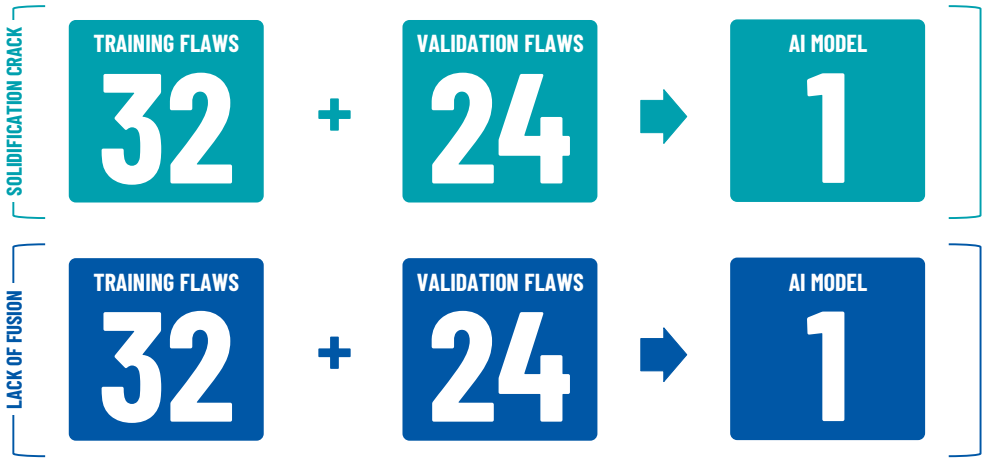
SDHS + ID NOTCHES

FBHS + SDHS



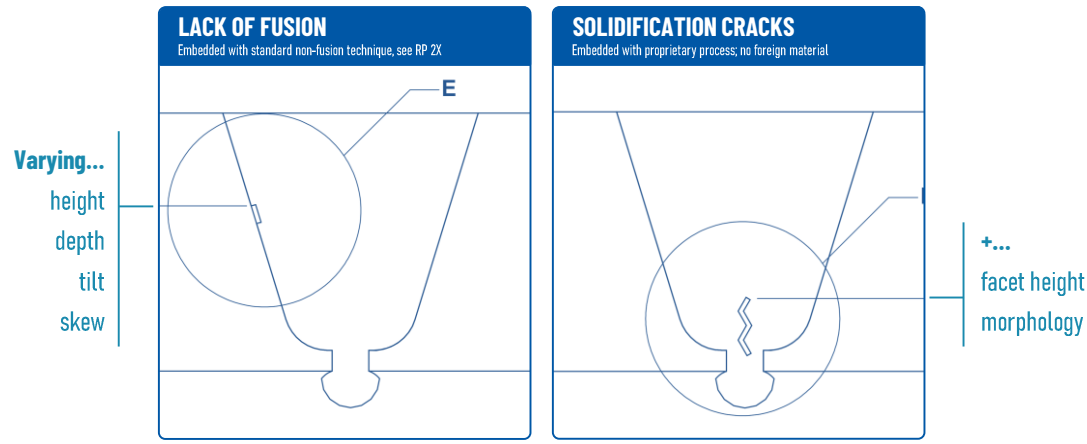
12

Design Features: How Many Flaws?



13

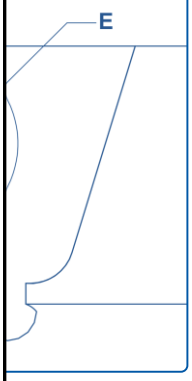
Design Features: Flaw Design



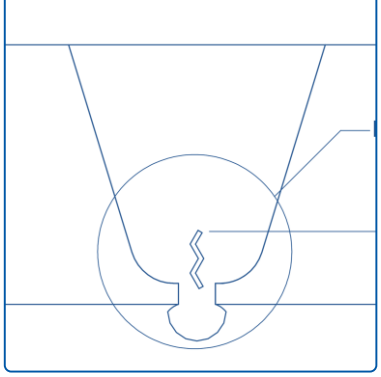
14

Design Features: Flaw Design

echnique, see RP 2X

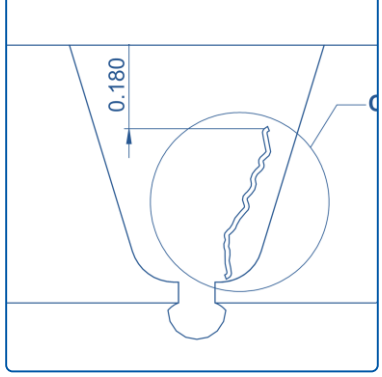


SOLIDIFICATION CRACKS
Embedded with proprietary process; no foreign material



+...
facet height
morphology

SOLIDIFICATION CRACKS
Embedded with proprietary process; no foreign material



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2B Design and Fabricate Mockups

15

15

Finished Assets: Mockups

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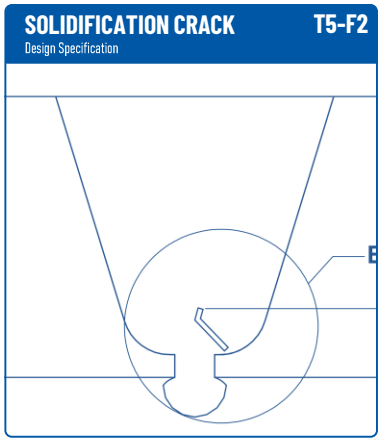
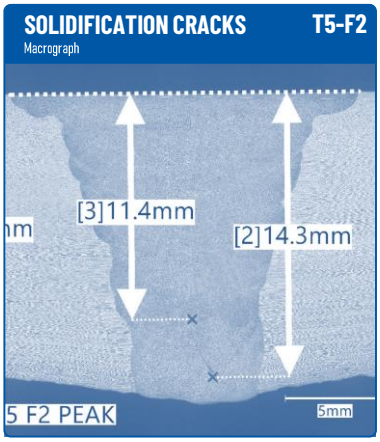
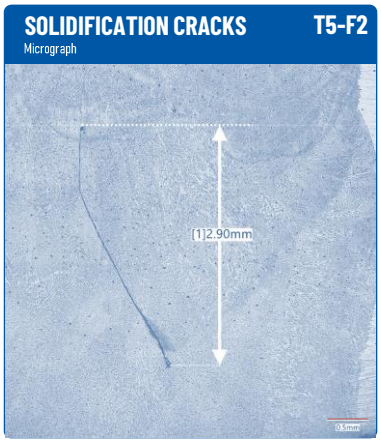
16

16

Finished Assets: Mockups

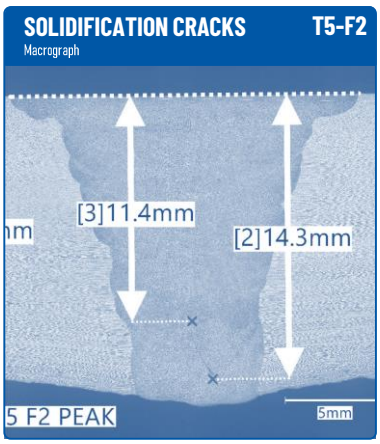


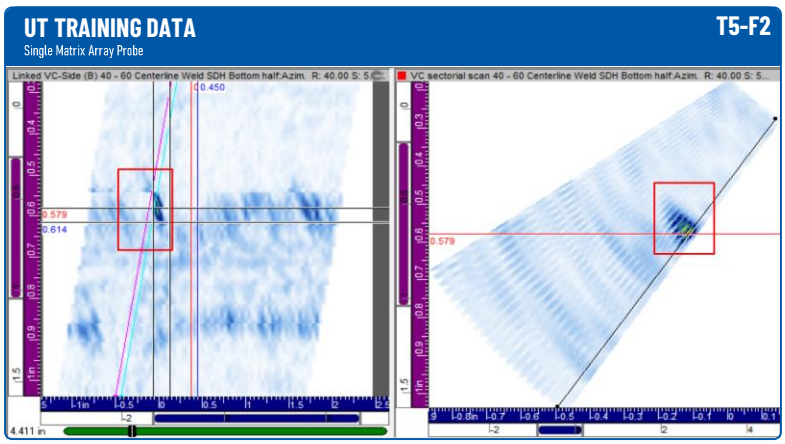




17

Finished Assets: Mockups





18

PAUT Procedure: Description

Technique: PAUT, Angle Beam L-wave; Fully Automated

Equipment and Software: 64:128 PR; 2D-3D Analysis

Probe: 2D Matrix, 5MHz, 63 (9x7) elements, Pitch 1.1mm

Groups: 3; Sectorial Scan (40-60°, 55-75°, 70-89°), Step 1°; Beam Skew, +/- 15°, Step 5°

Calibration: 0.047" diameter SDH; Time Corrected Gain (TCG)

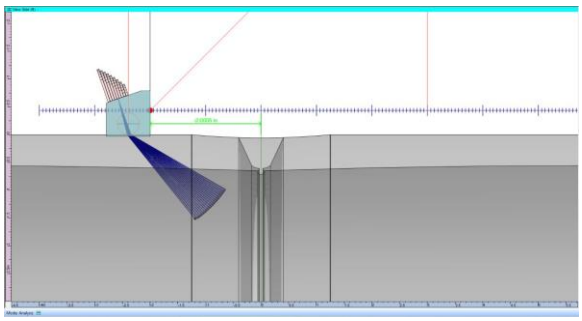
Mechanical Scan: Raster

Data Format: Unrectified (RF mode)

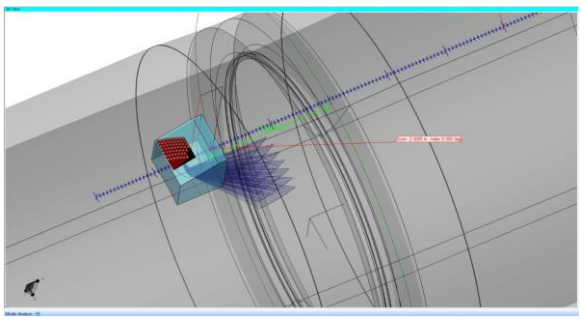
19

PAUT Procedure: Visual Examples

40-60 Group Sectorial Scan



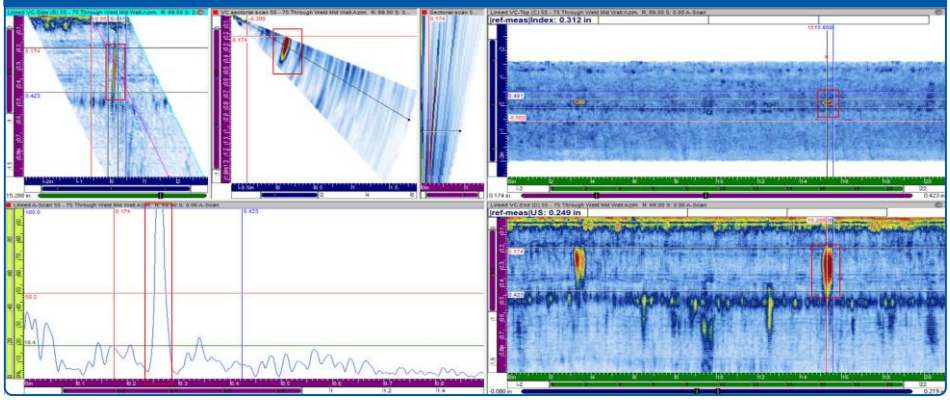
40-60 Group Beam Skew



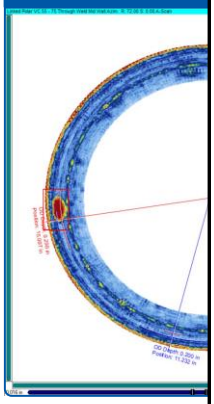
20

PAUT Procedure: Layout Examples

2D LAYOUTS
A-Scan, B-Scan, S-Scan, C-Scan, D-Scan



2D LAYOUTS
Polar Plots



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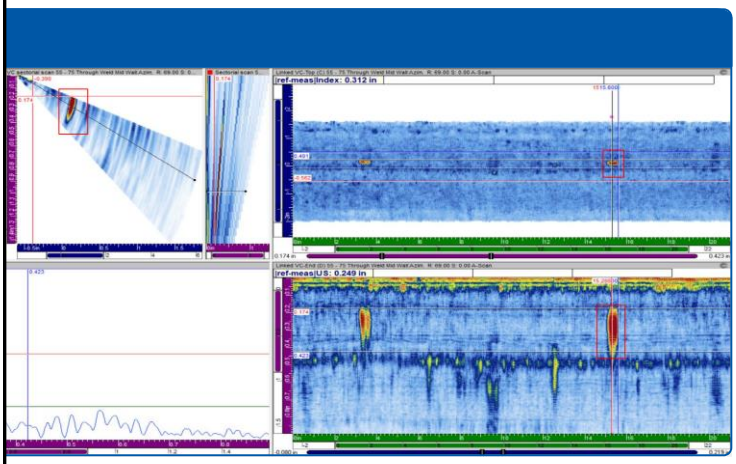
3 Develop, Deploy, Verify PAUT Procedure and Collect Data 21

21

PAUT Procedure: Layout Examples



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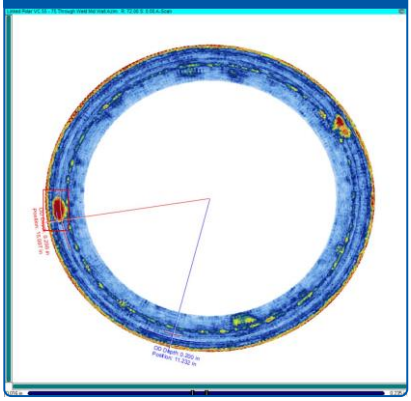

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3 Develop, Deploy, Verify PAUT Procedure and Collect Data 22

22

Collect Data: Acquire + Organize

Acquired on 2 procedures

23

Collect Data: Acquire + Organize

385+ GB of training data

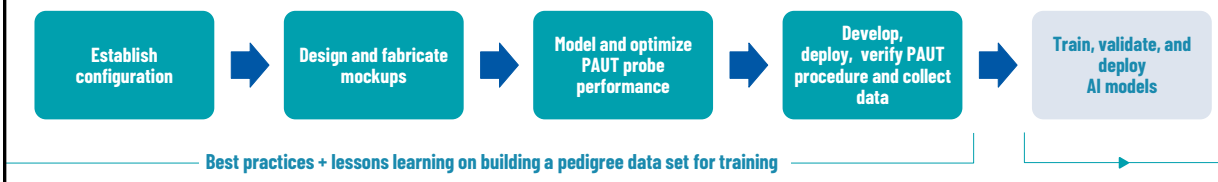
24

Collect Data: Acquire + Organize

230+ GB of validation data

25

AI can help you analyze your PAUT data.



26

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Call us with questions!

27

#1 Include a **welding engineer** in decisions made on inspection configuration

#2 Beam modeling and inspection simulation are **nice-to-haves but not necessary steps** for AI model development

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Key takeaways

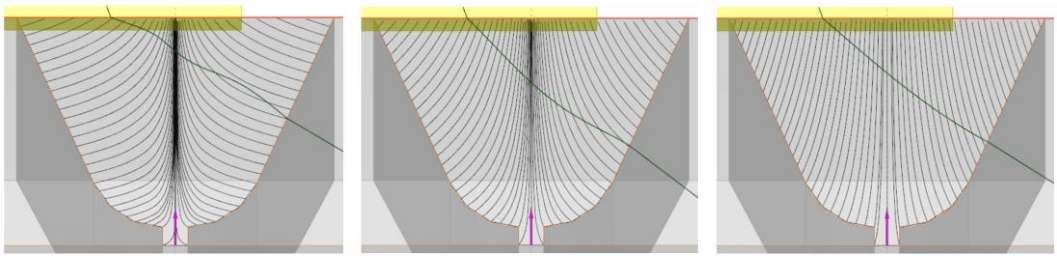
28

Backup Slides

29

Modeling + Simulation: Material Assumptions

Model grain orientation on Ogilvy model



30

Modeling + Simulation: Material Assumptions

Model elastic stiffness on Cij variation

Agreed variation plan and nominal matrix after 12/04/2024 meeting									
	C11	C22	C33	C23	C13	C12	C44	C55	C66
Center value / Nominal Set	240,5	240	232	103	104	106,5	113	114,5	94,5
Extende's variation plan	20%	20%	20%	45%	45%	45%	20%	20%	45%
Deterministics sets added manually to the variation plan									
	C11	C22	C33	C23	C13	C12	C44	C55	C66
ID 6 – AcW***	234	240	220	146	148	118	99	110	95
ID 7 – IndusW***	227	244	218	146	140	109	107	119	80
Manual Arc 2_5*	250	232	243	81	75	73	111	112	113
Manual Arc 5_8*	265	256	258	89	87	74	108	111	114
308 SS**	216	216	216	145	145	145	129	129	129

*Lozev, M. " NDT of Welded Joints of Austenitic Steels", PhD Thesis, Sofia University, 1984 (Table 10, pp76 -in Bulgarian)
*Lozev, M. " Acoustic evaluation of Austenitic Welded Joints", INFORMA, Sofia, 1990 (Table 4, pp25 -in English)
**Ogilvy, J.A., "Ultrasonic beam profiles and beam propagation in an austenitic weld using a theoretical ray tracing model," Ultrasonics 24(6): 337-347 (1986).
***Chassignole's Thesis – 2000: Influence of the metallurgical structure of austenitic stainless steel welds on non-destructive ultrasonic testing
+ Chassignole's Article –2010: Ultrasonic and structural characterization of anisotropic austenitic stainless-steel welds: Towards a higher reliability in ultrasonic non-destructive testing