Total Focusing Method (TFM) for Automated Pipeline Girth Weld Inspections

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NDT in Canada NDTIC 2017 Canada's NDT Conference
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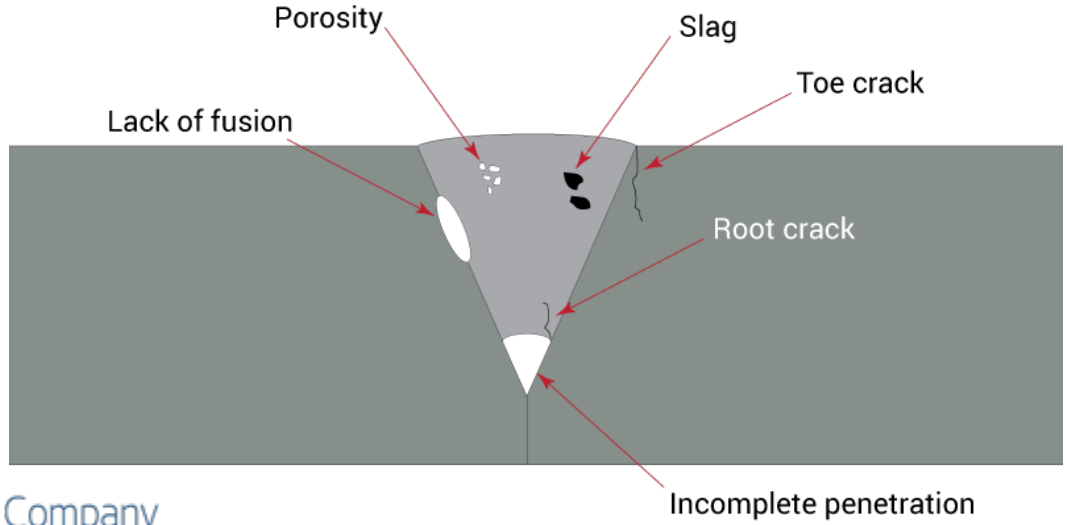
Context

- Inspection of girth welds is crucial in the oil & gas industry
- Weld defects can be tragic for companies and the environment
- Each weld is inspected during new construction
- Automatic Ultrasonic Testing (AUT) is <u>a quite common NDT method and included in standards (ASTM, API, DNV…)</u>

Objective

- Evaluate the Total Focusing Method (TFM) for girth weld inspection
- Obtain flaw sizing results with TFM (flaw, depth and height)
  - The TFM imaging algorithm will be applied to data acquired with the Full Matrix Capture (FMC) technique
- Comparison with (P)AUT and destructive testing (Macrography)
- Practical considerations: Scan speed, etc.

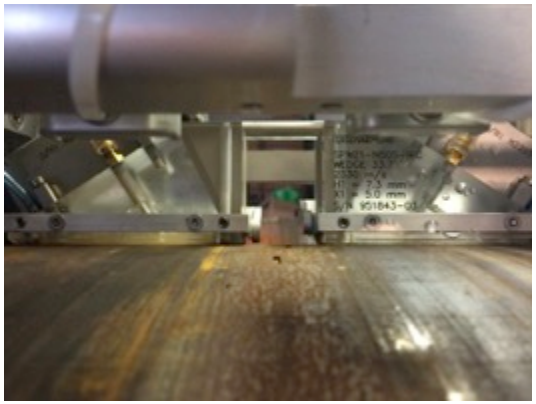


Inspected Parts

- **Carbon Steel Pipes**
- **Diameter** : Ø24in/610 mm
- **Thickness** : 0.75in/19.1 mm
- **Longitudinal Velocity** : 5910 m/s
- **Transversal Velocity** : 3220 m/s

Inspection Setup Details

- **2 Phased array probes** : 60 elements, 1mm Pitch, 7.5 MHz
  - One probe on either side of the weld
- **Wedge angle** = 33.7°
- Shear waves used for defect detection
- Circumferential scanner



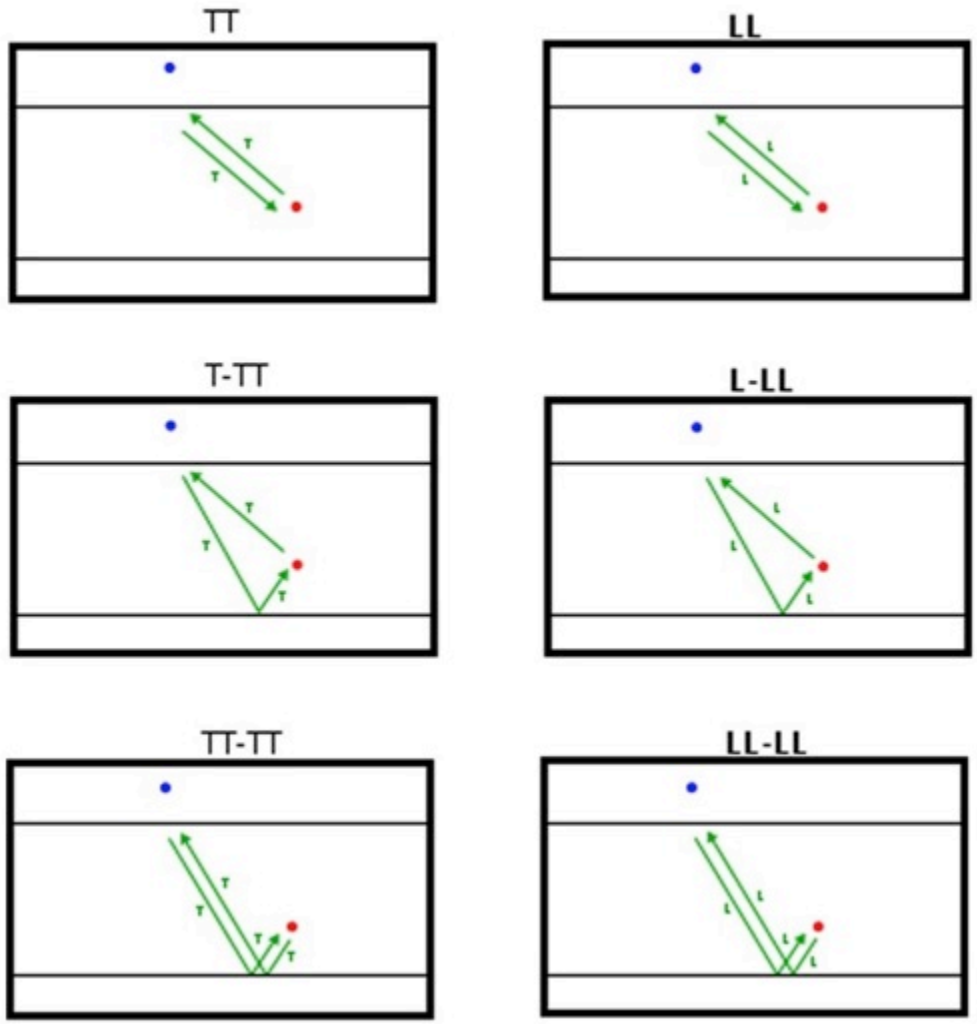
PAUT Instrument AOS OEM-PA 128/128

- **Super Fast Data Rate!**
  - 160 MB/s (for high frame rate)
- **Full-Matrix Capture (FMC)**
- **Total Focusing Method (TFM) (5 Different Styles):**
  - Standard TFM
  - Migration TFM
  - Advanced TFM
  - Adaptive TFM
  - TFMp
- **Utilizes GPU**
  - For faster TFM calculation speed
- **Open!**
  - Access raw data and low level parameters

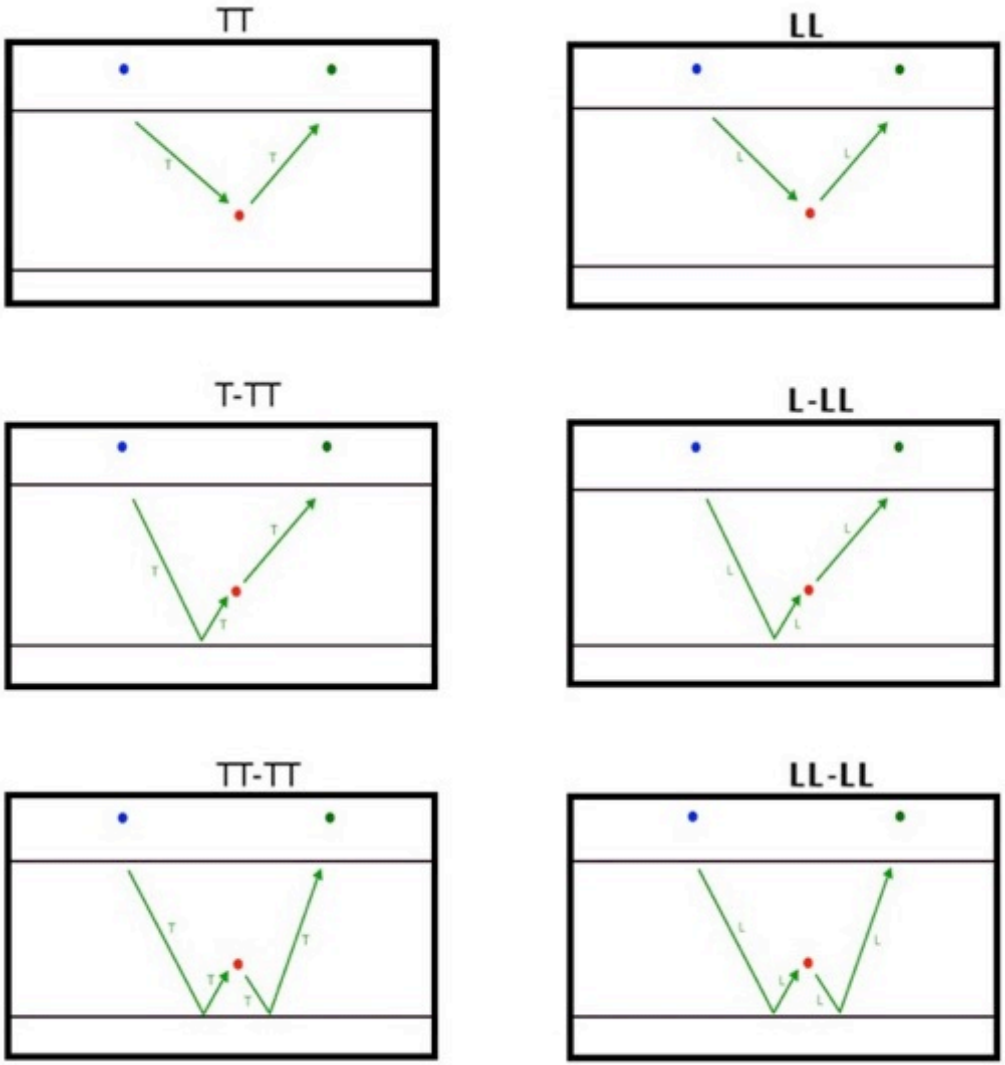
Advanced OEM Solutions

Wave Modes: Pulse/Echo

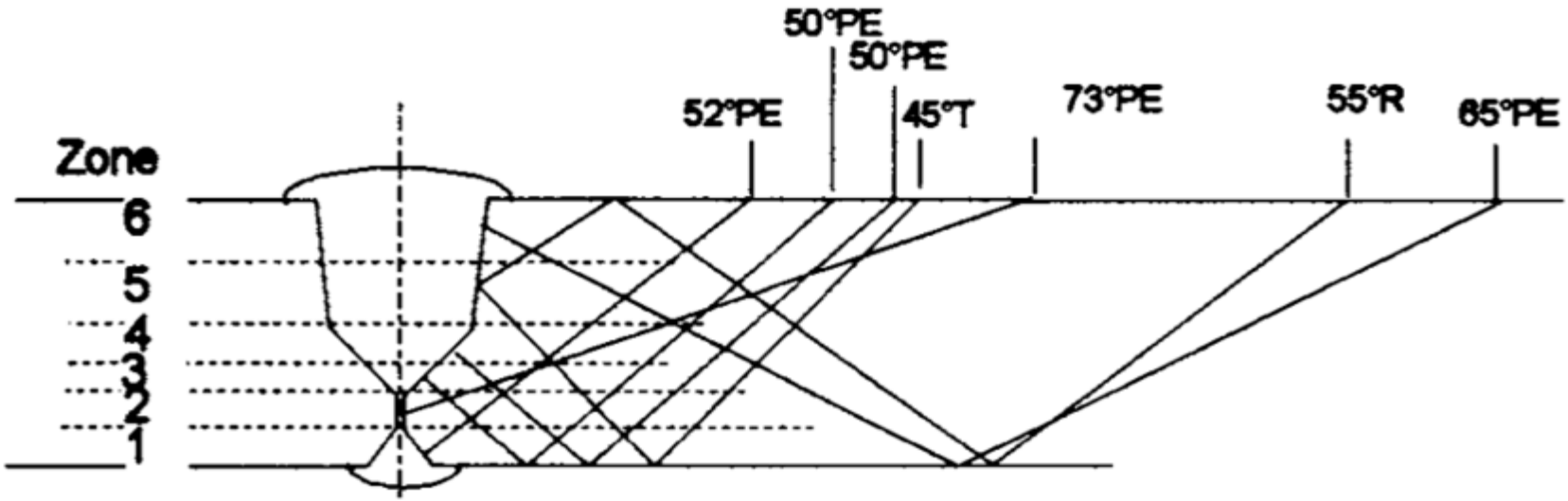
Multiple Wave Modes can be processed in parallel with one FMC acquisition!



Wave Modes: Pitch/Catch

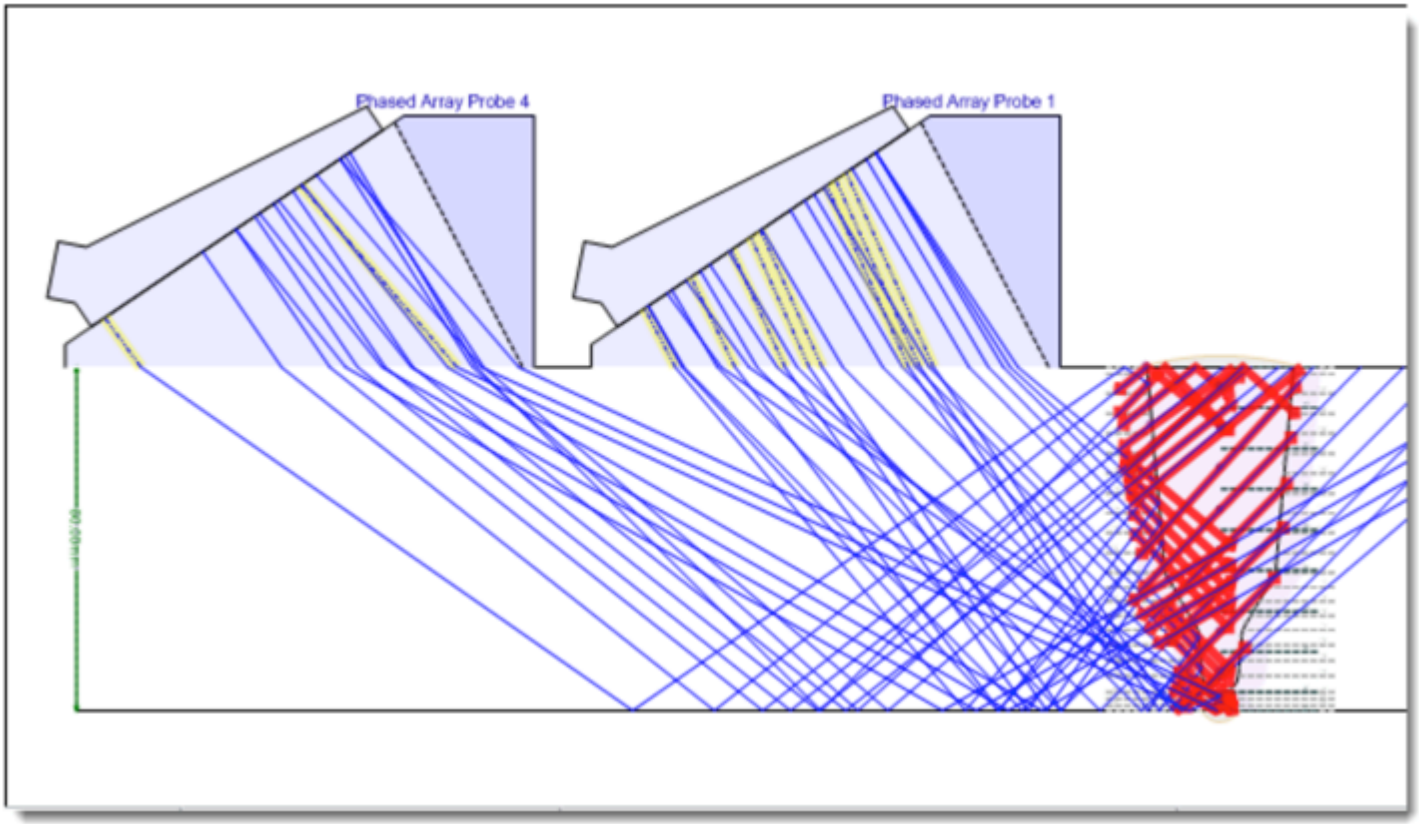


Zonal Discrimination



*Drawing from ASTM E1961-11

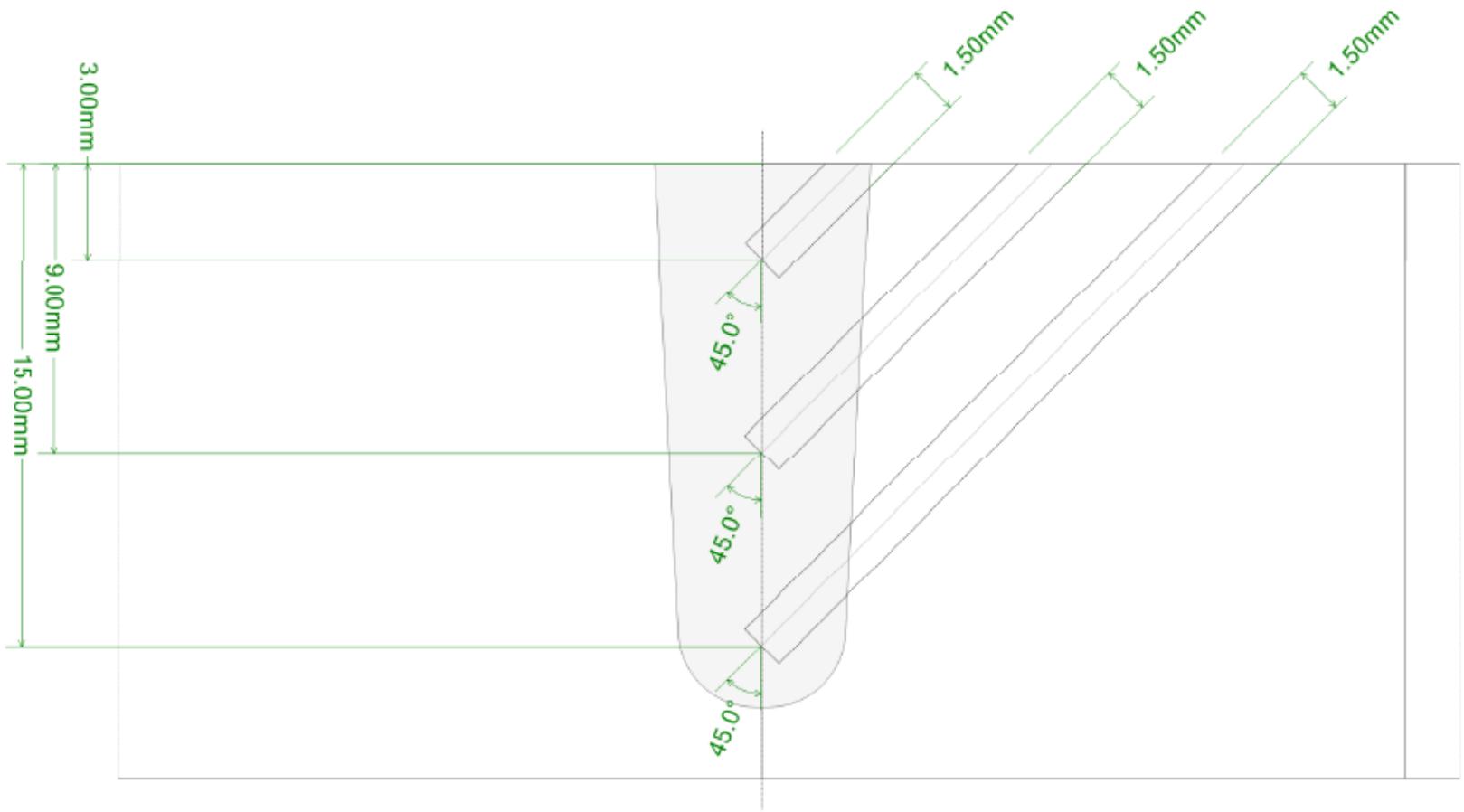
Zonal Discrimination



TFM Benefits vs. Zonal Discrimination

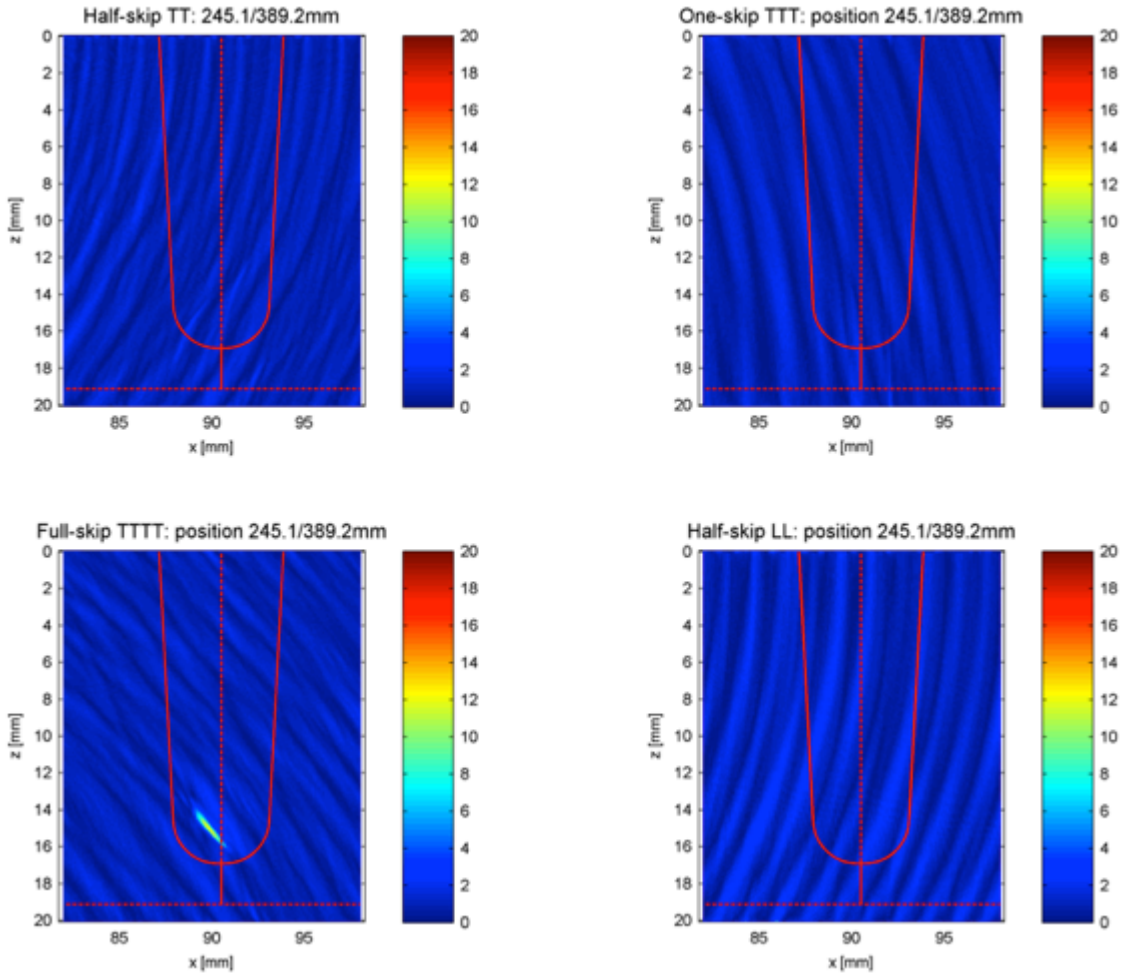
- Any zone of the weld can be imaged, so misalignment of the probe in reference to the weld will not affect scan results.
- The TFM resolution can be defined arbitrarily. In this case, 0.1mm was chosen which provided a good compromise between image resolution and reconstruction complexity.
- Since we have the full data set, we can obtain complimentary views.
- All views are done with one (FMC) data capture.
- With all views, a 6dB drop sizing function can be applied volumetrically (in 3D).
- The data can be reprocessed at any time with a change of parameters. Examples are material velocity and wave modes like TT, LL, TTT…etc..

DNV Cal Block: Volumetric

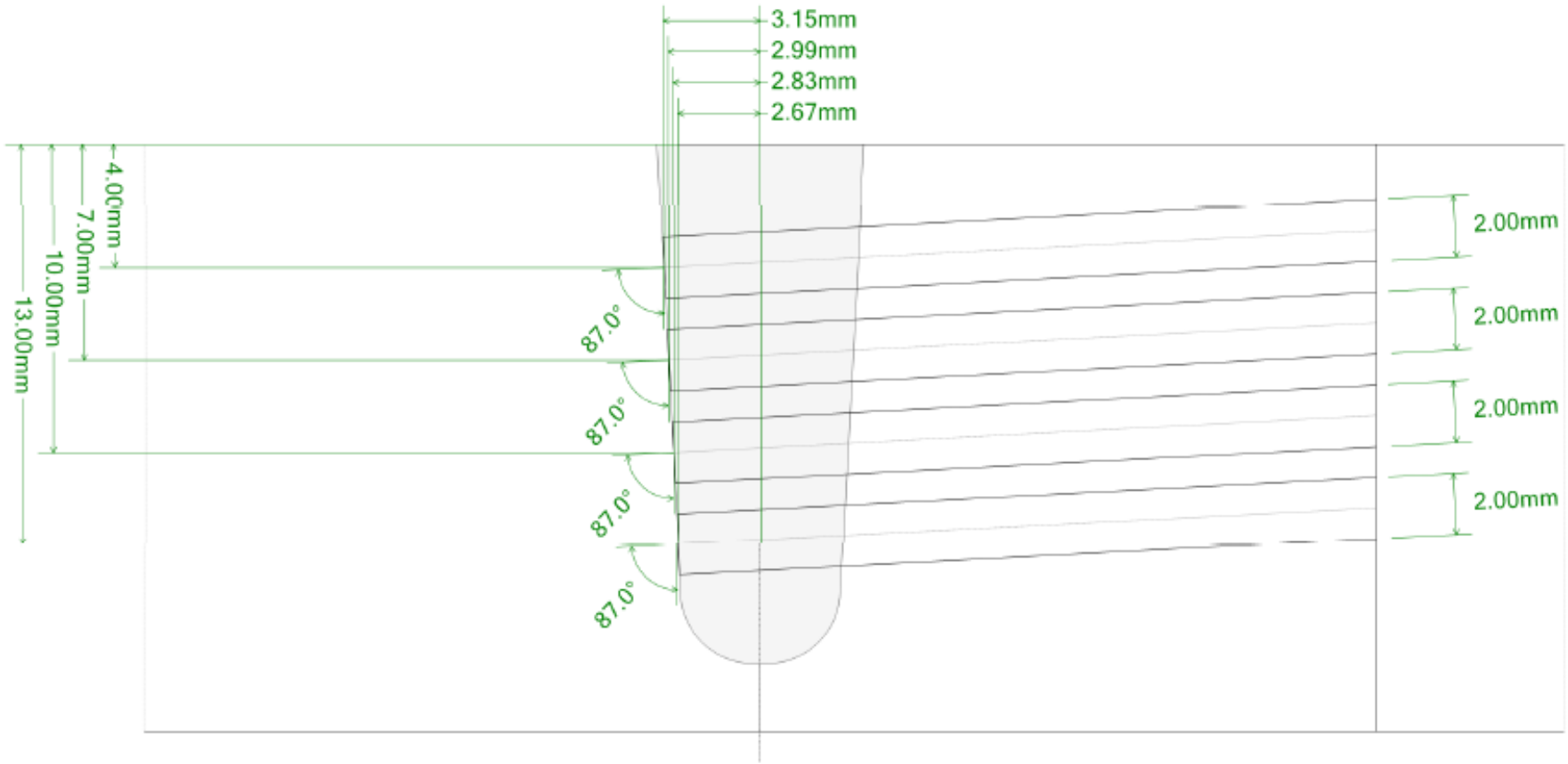


DNV Vol. Cal Block: TFM Results

- **Upstream Side – Pulse/Echo**

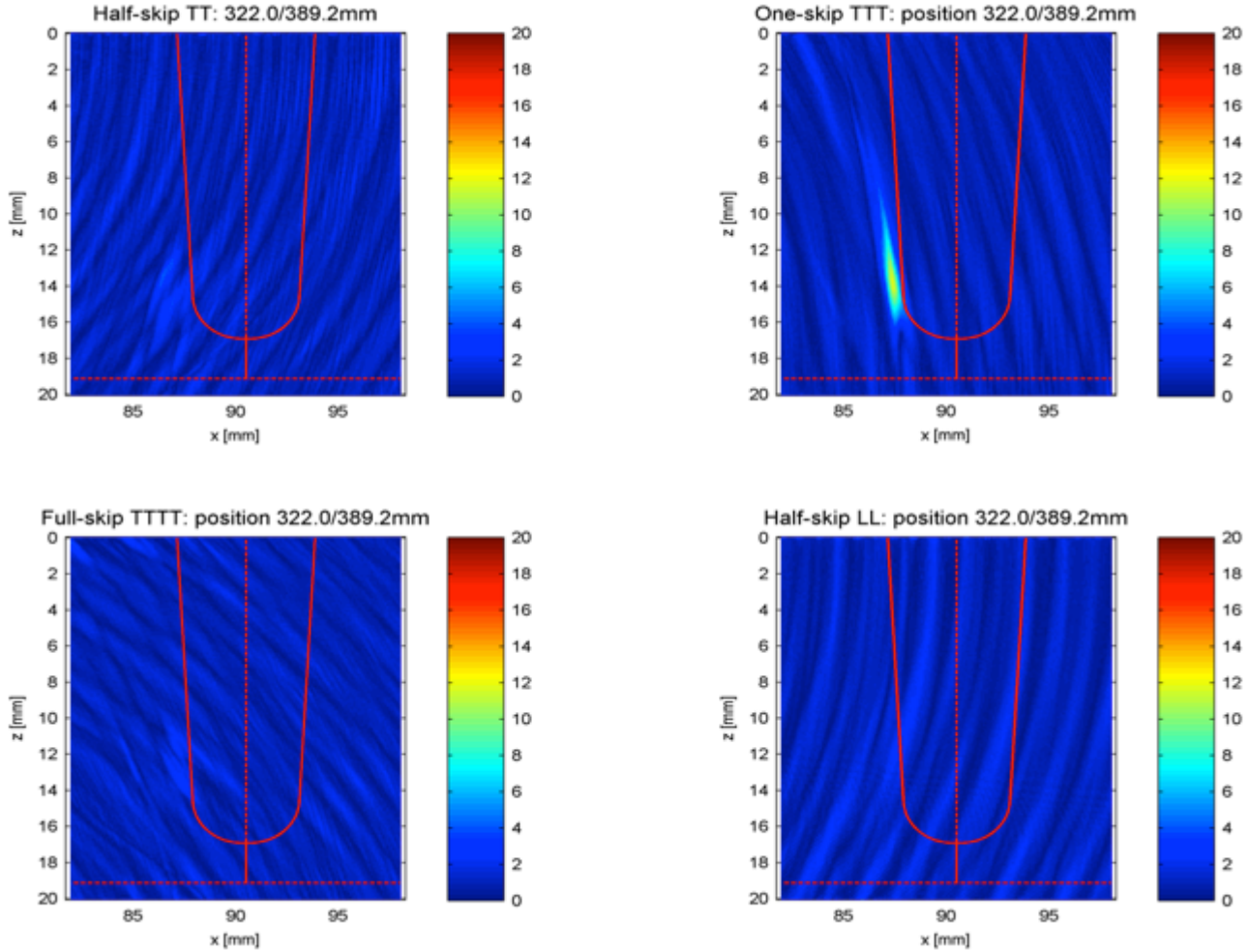


DNV Cal Block: Fusion Line

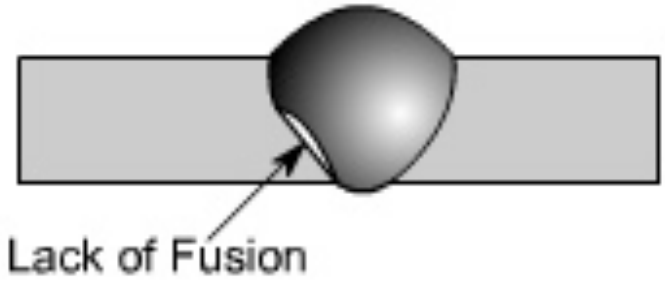


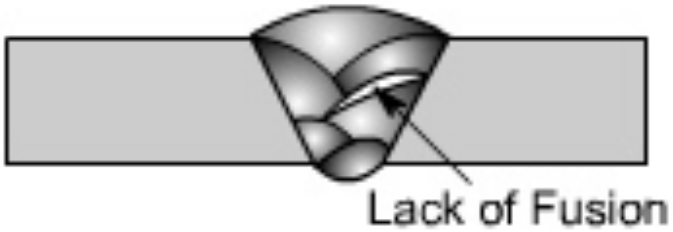
DNV F.L. Cal Block: TFM Results

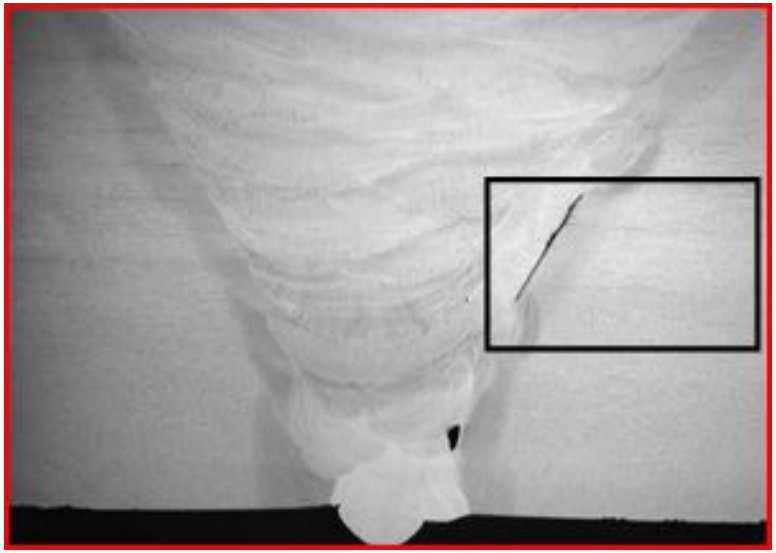
- **Upstream Side – Pulse/Echo**



Lack of Fusion Flaws

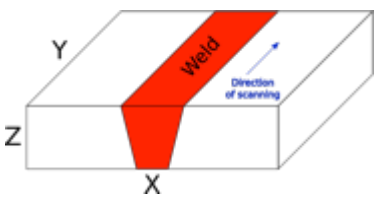


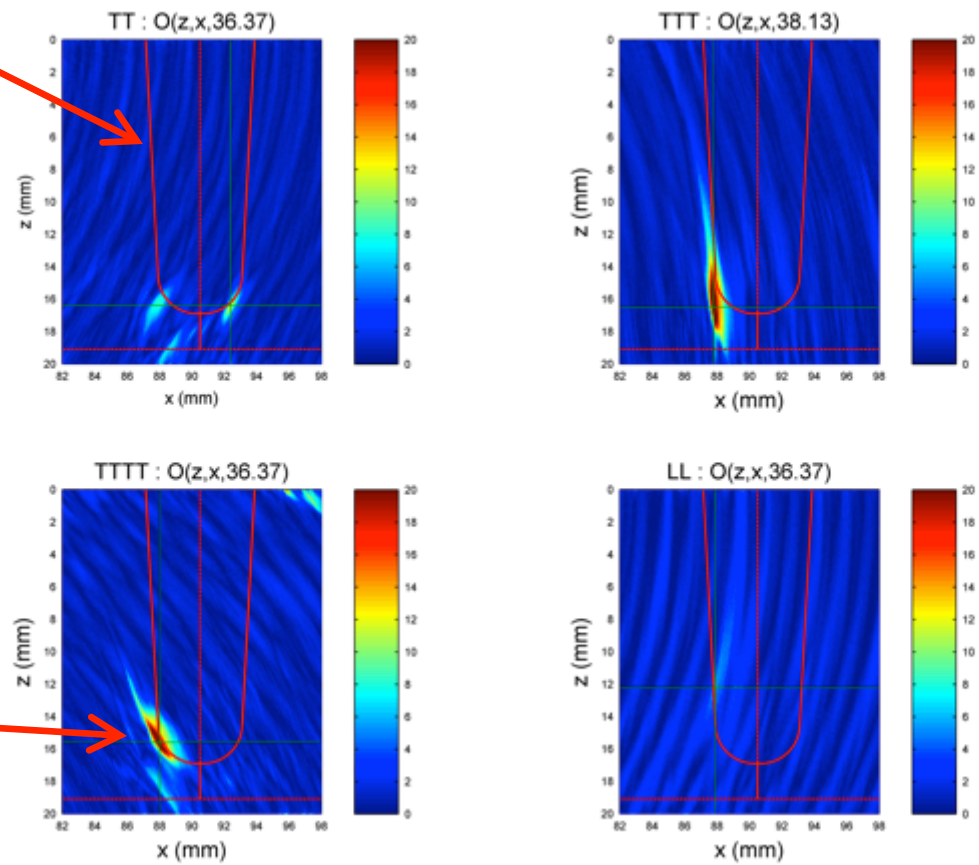




TFM Results C1: XZ View (B-Scan)

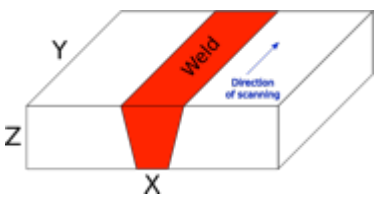
Theoretical weld bevel

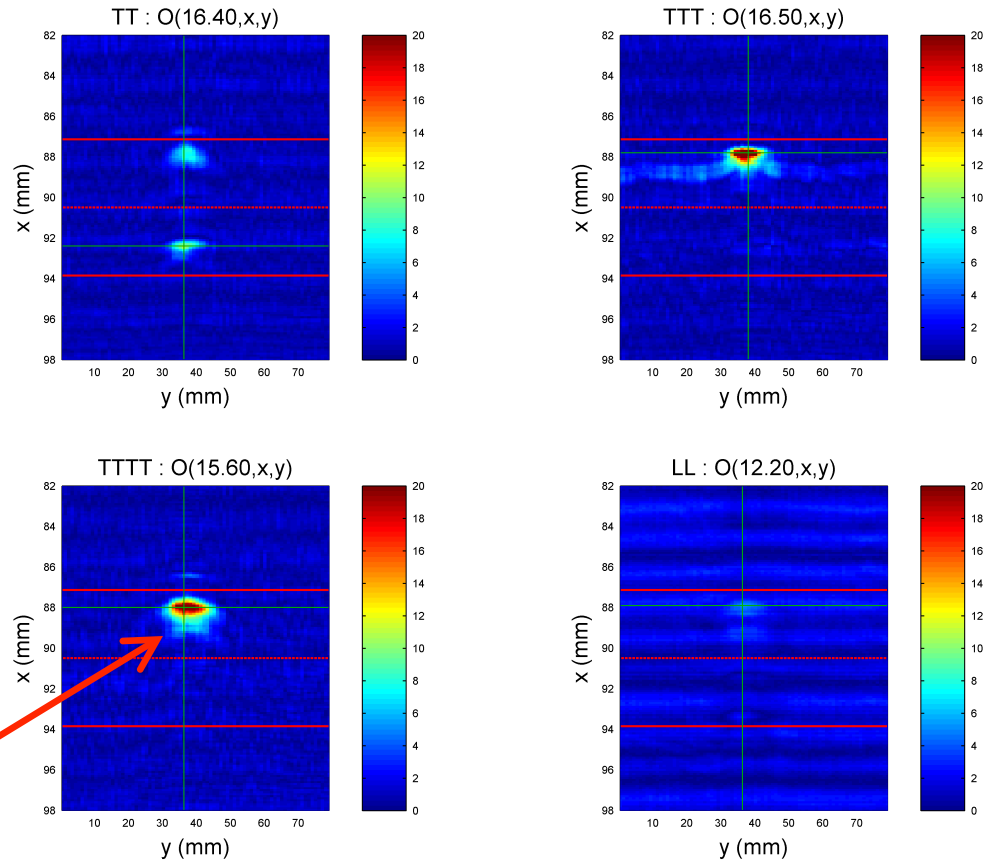




Lack of Fusion

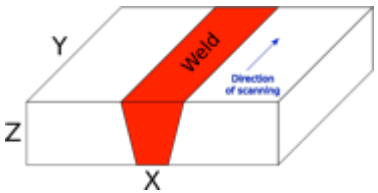
TFM Results C1 : XY View (C-Scan)



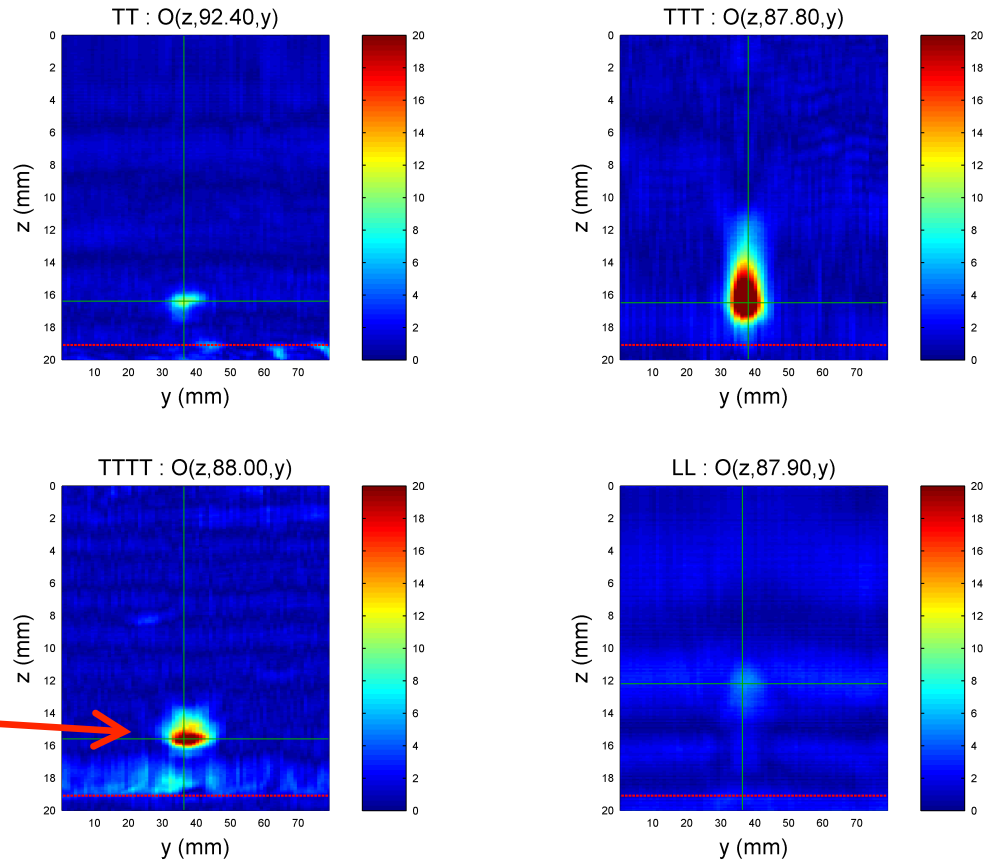


Lack of Fusion

TFM Results C1: YZ View (D-Scan)



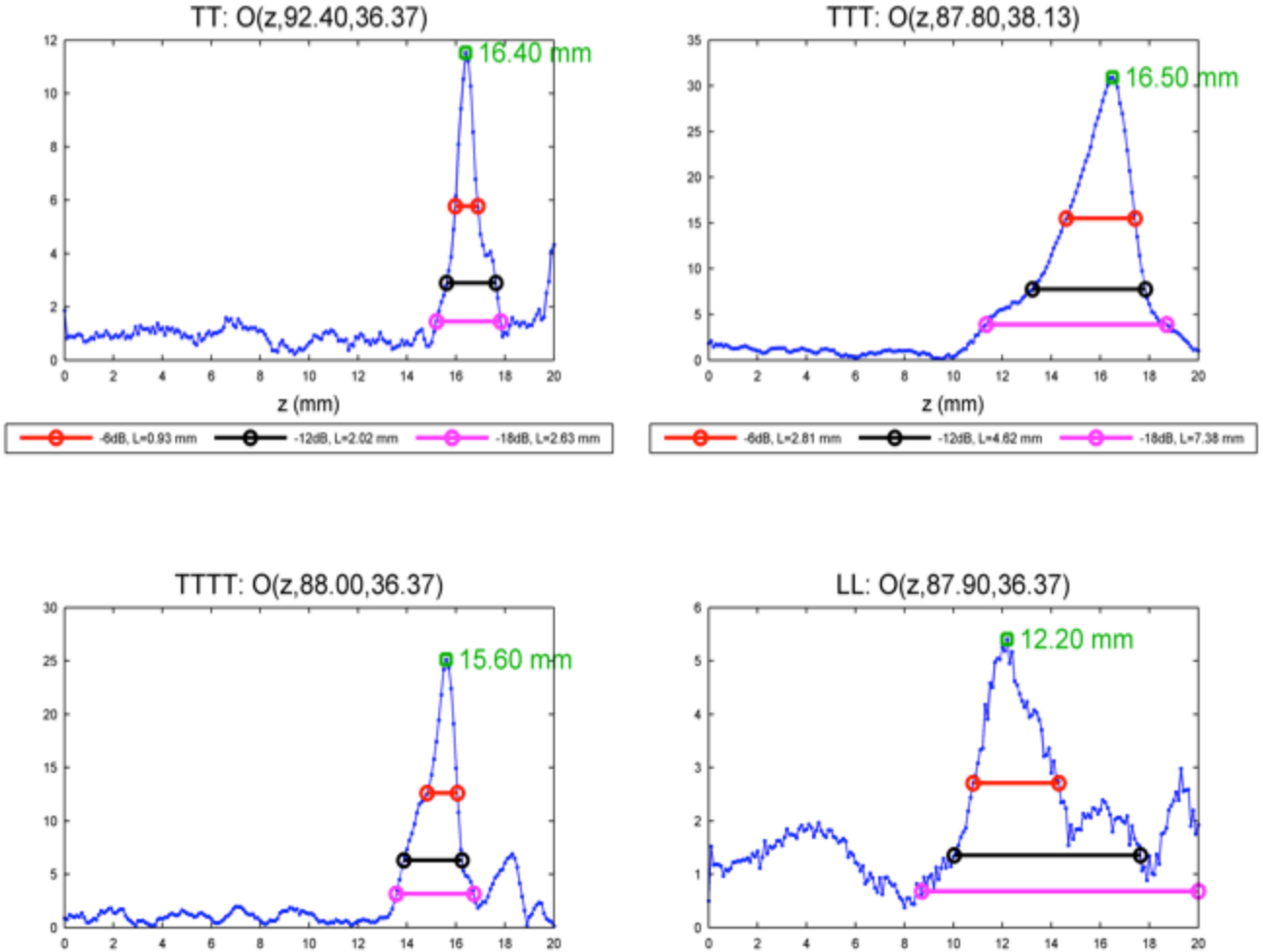
Side view



Lack of Fusion

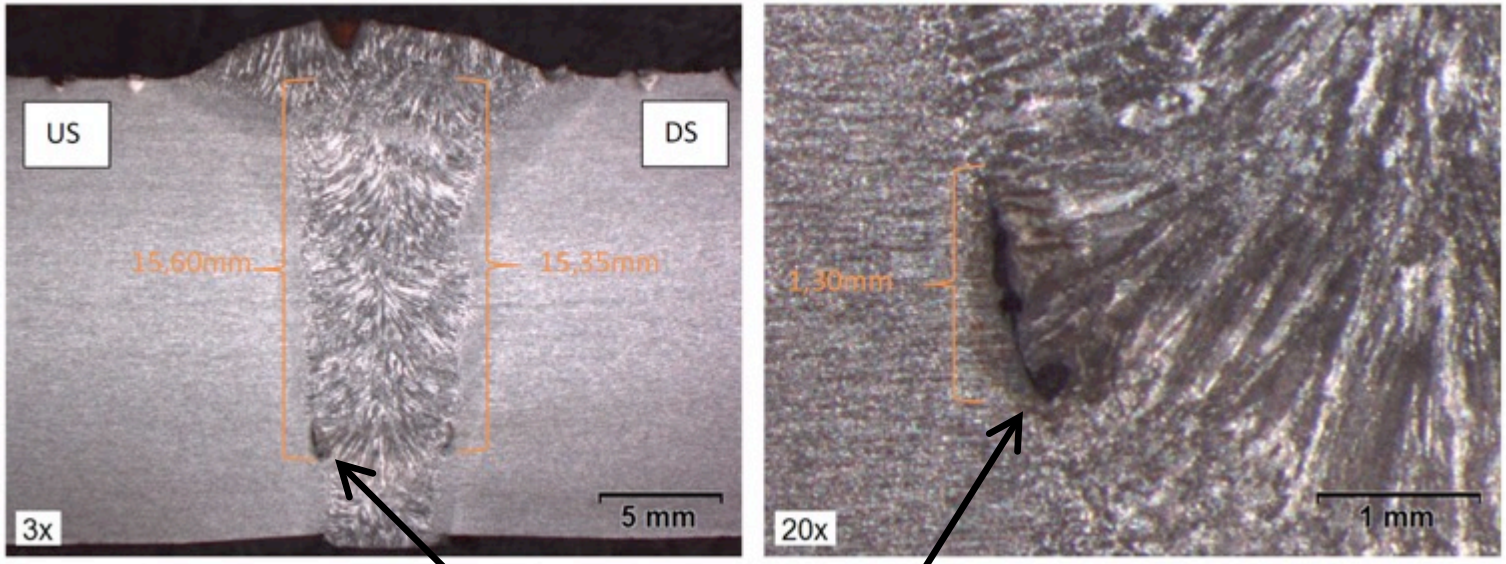
Flaw Sizing from XZ view (B-Scan)

TFM Automated Sizing Results



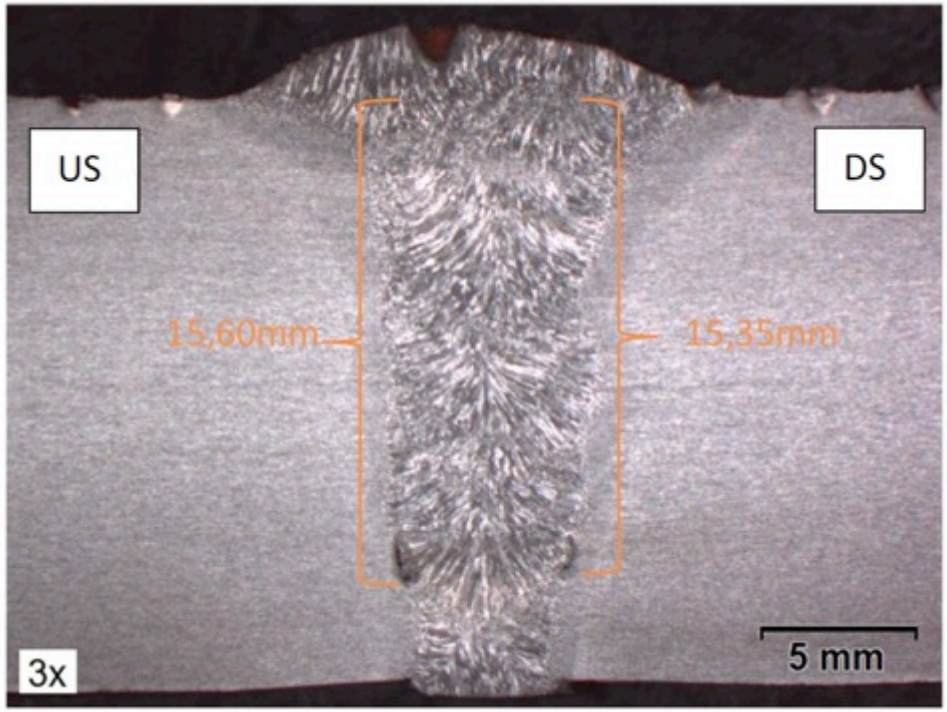
Macrography Results (First Coupon)

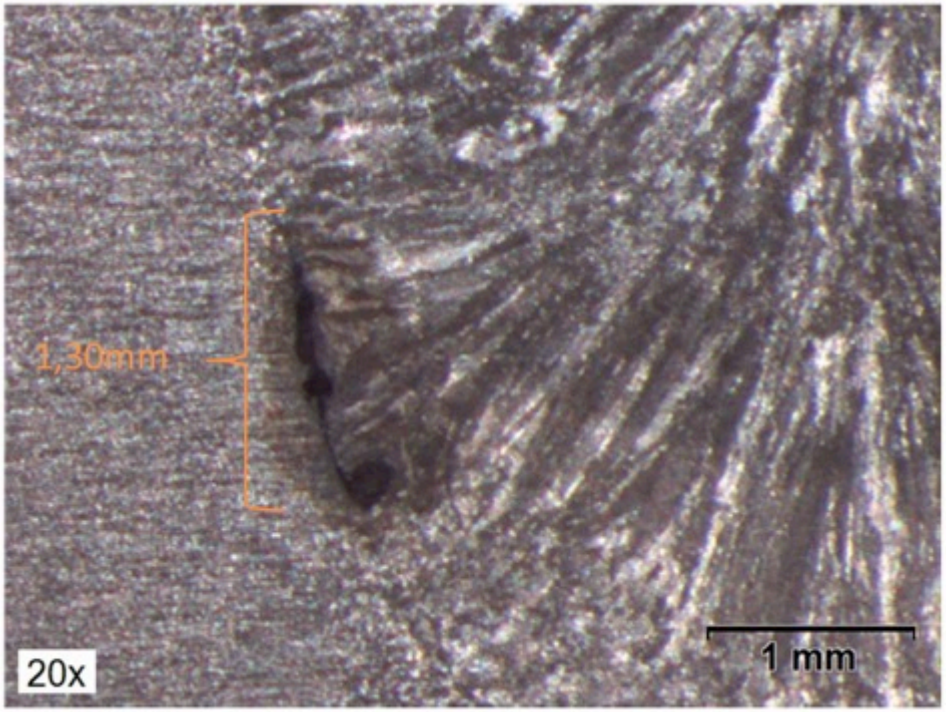
Macrography results of the First Coupon



Lack of Fusion flaws

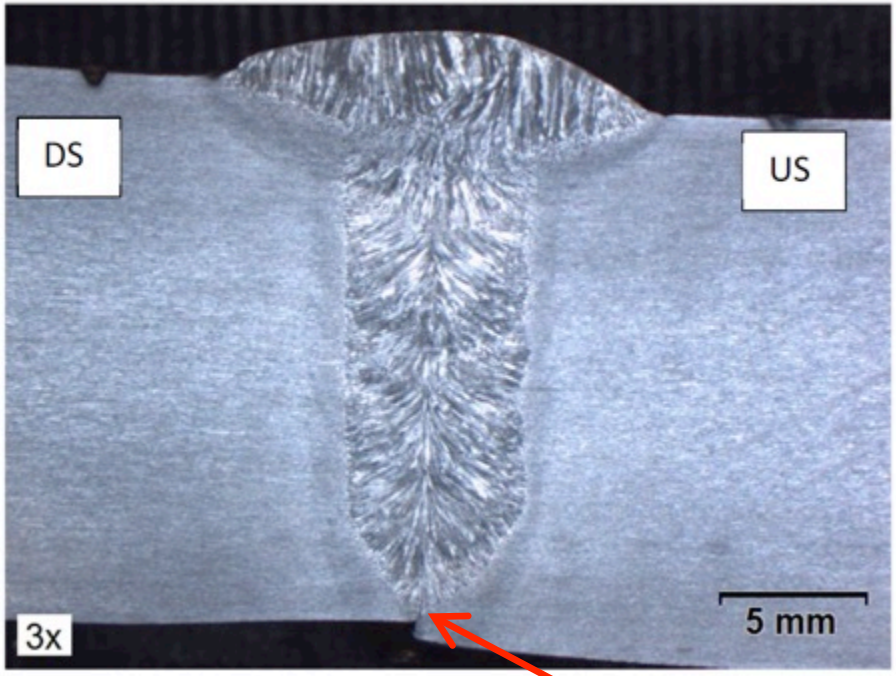
Macrography Results (First Coupon)

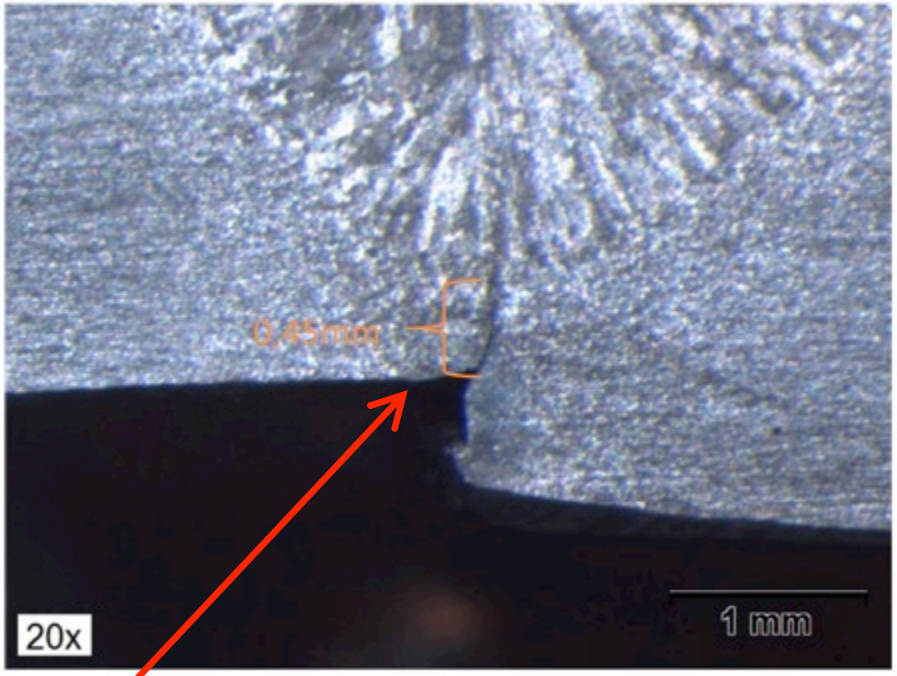




Value	Macrography	AUT	TFM (TTTT)
Depth (mm)	**15.60**	17.0	15.60
Height (mm)	**1.30**	1.6	1.24
Error in height (%)	-	23.1	4.6

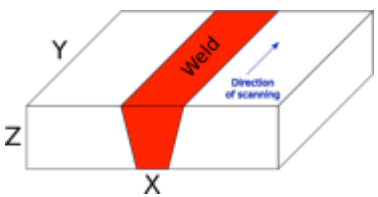
Macrography (Second Coupon)

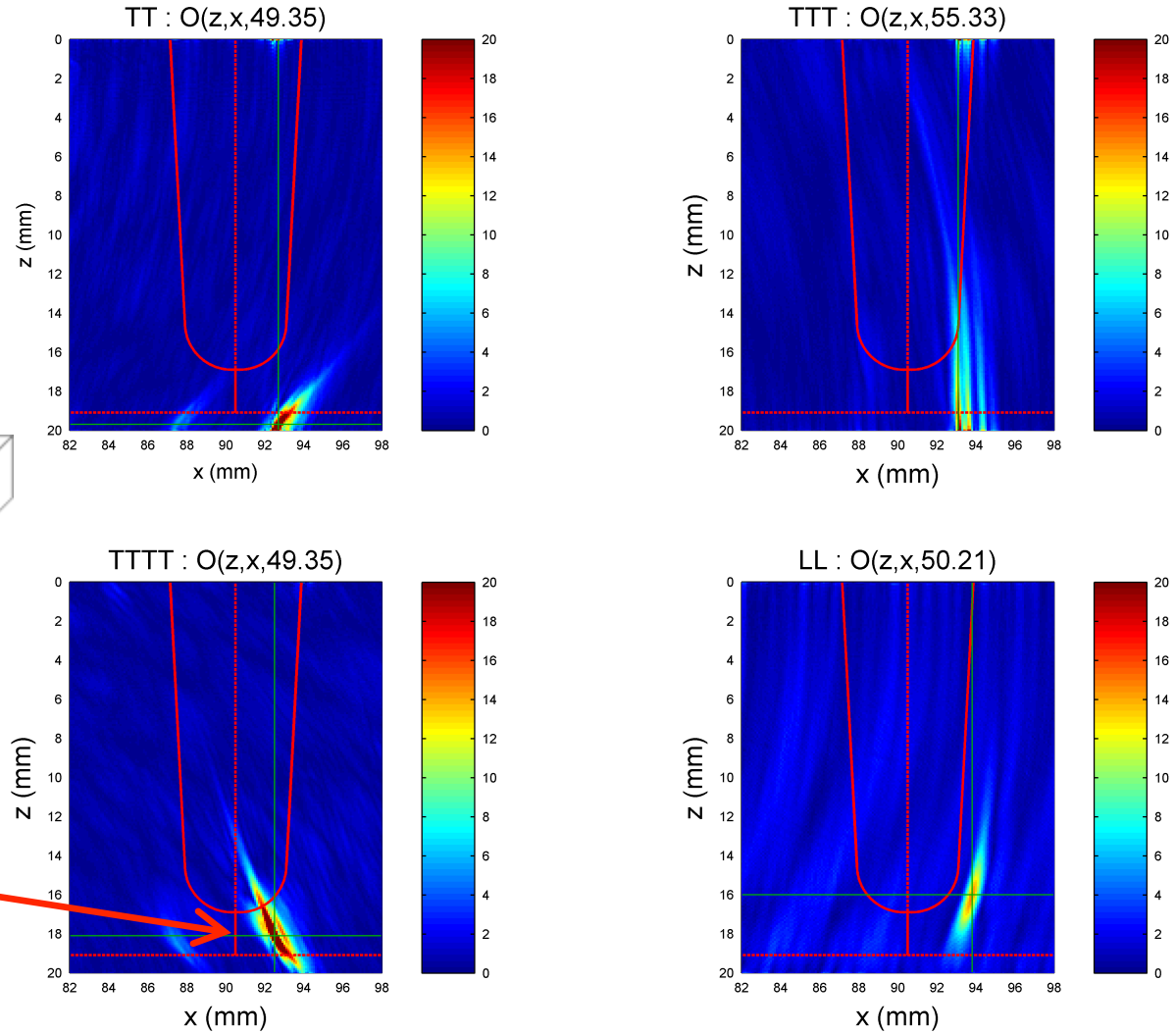




Lack of Fusion (Root Area) with misalignment

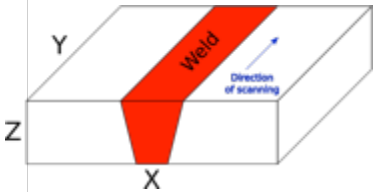
TFM Results C2: XZ View (B-Scan)

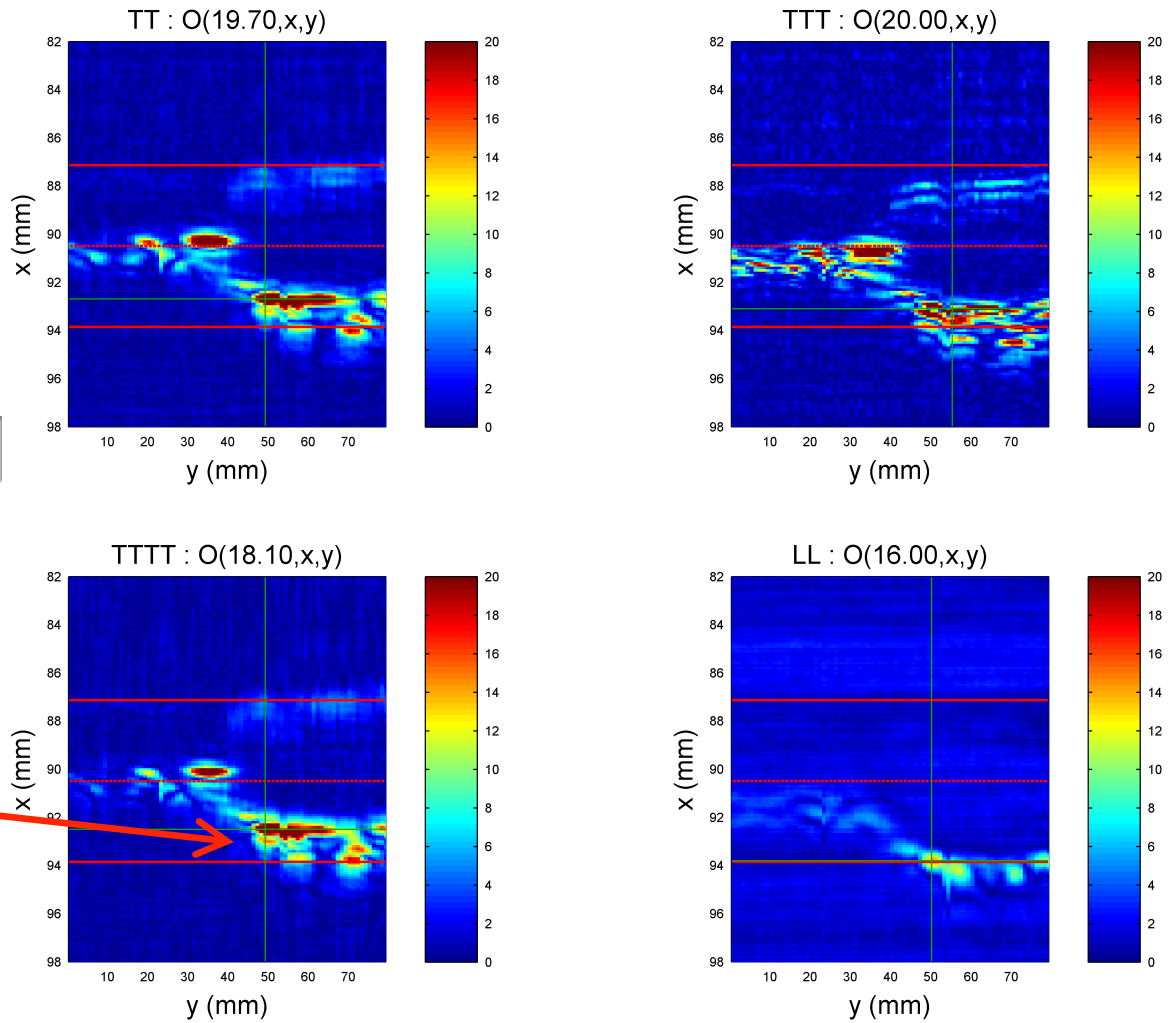




Lack of Fusion (Root Area)

TFM Results C2: XY View (C-Scan)

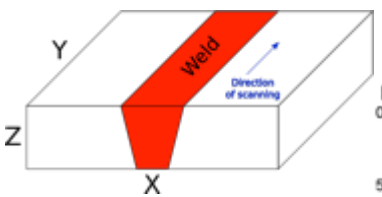


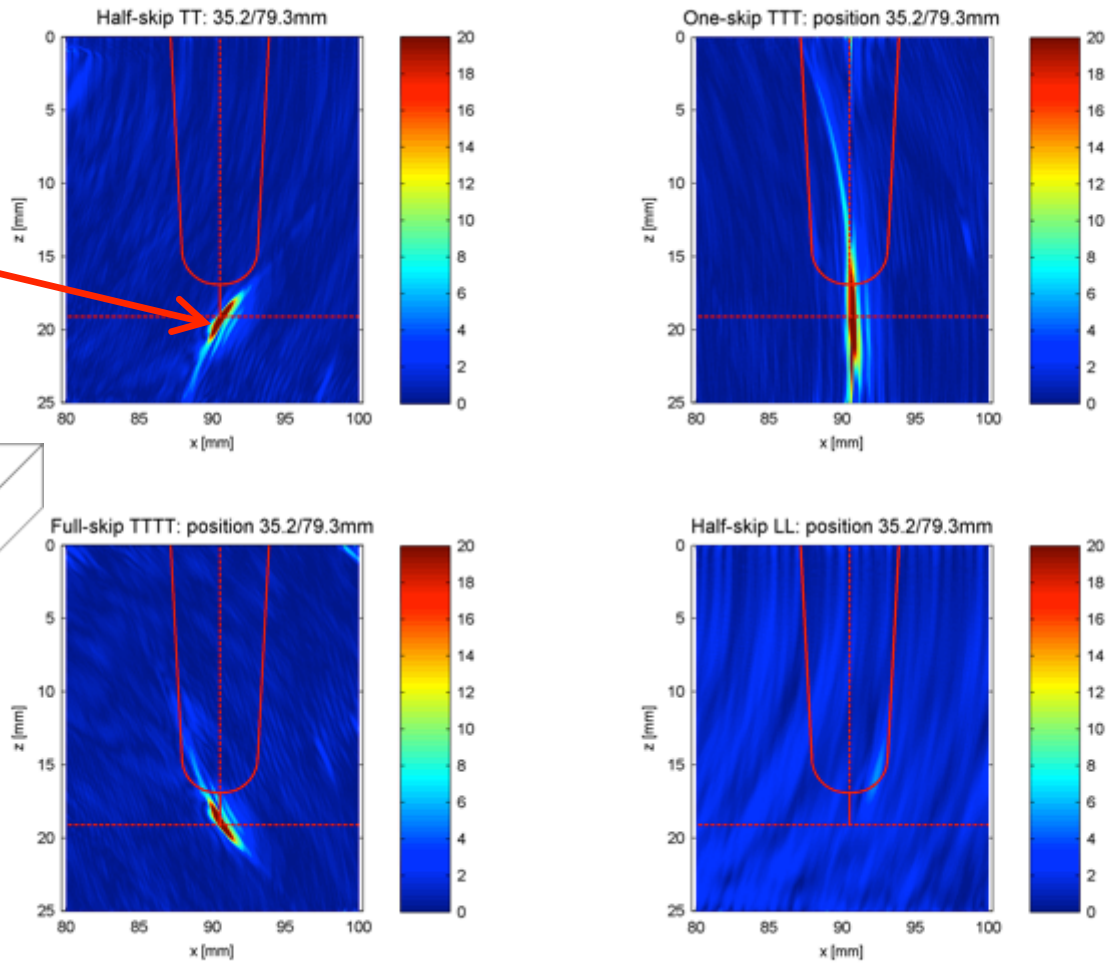


Lack of Fusion (Root Area)

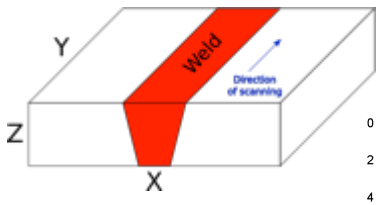
TFM Results C2: XZ View (B-Scan)

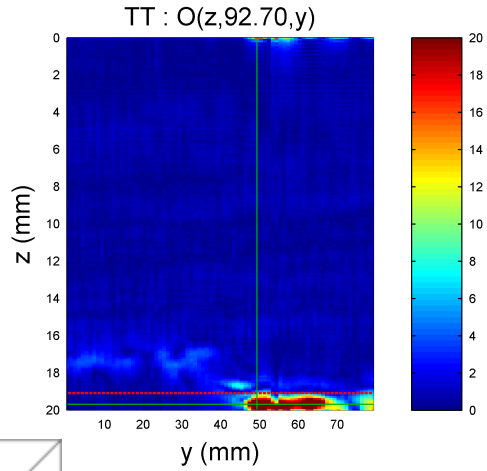
Root Edge

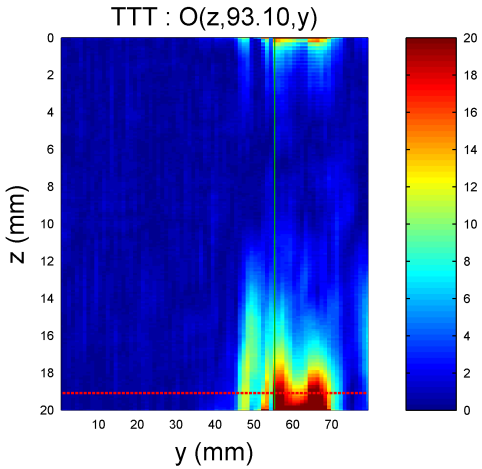


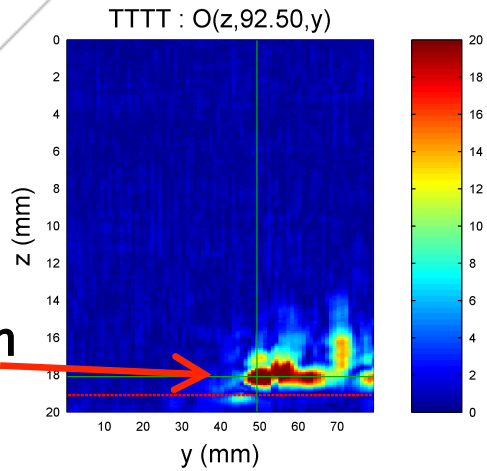


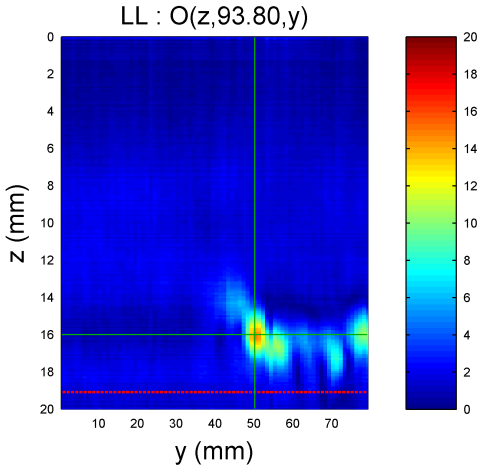
TFM Results C2: YZ View (D-Scan)







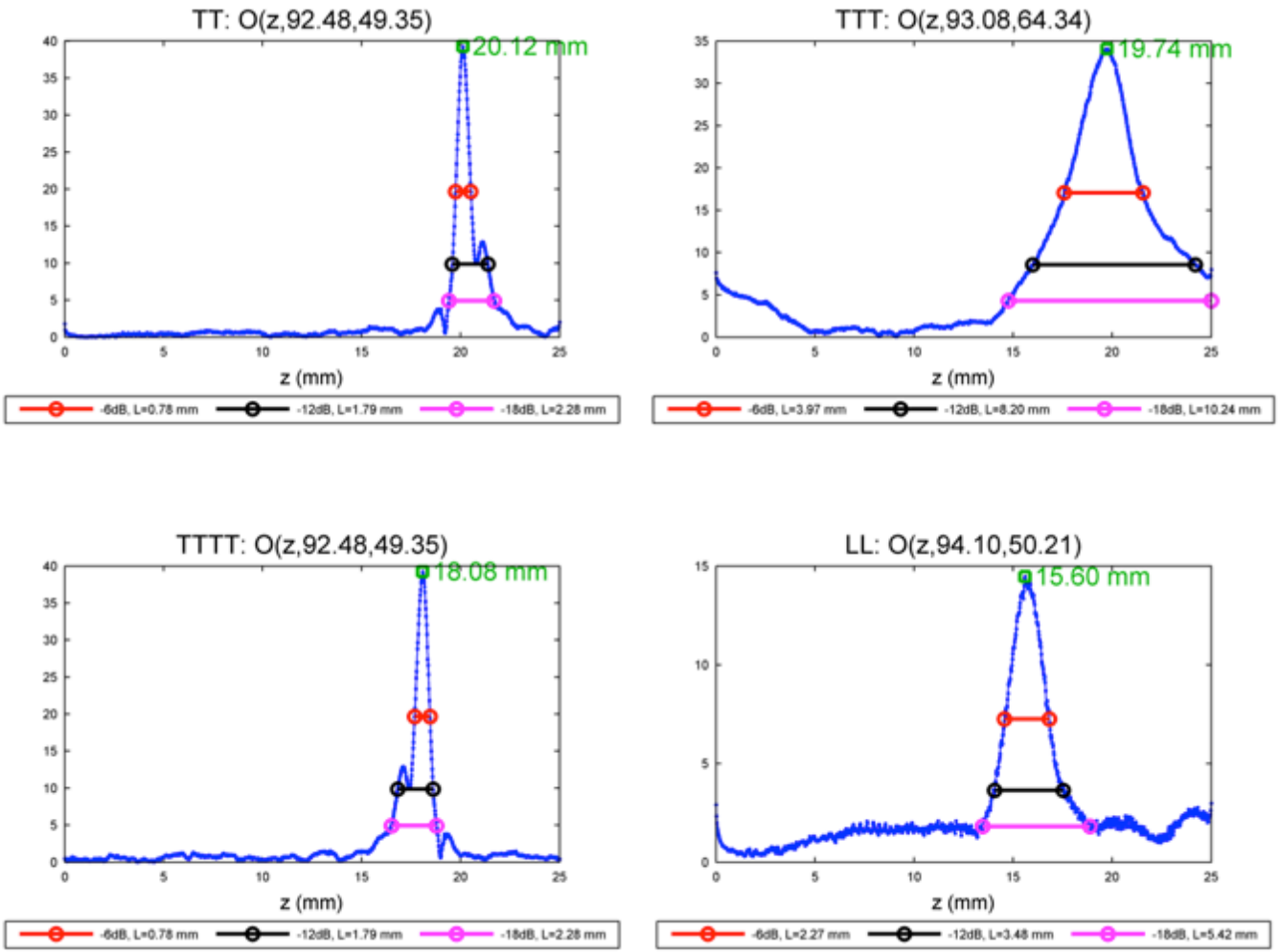




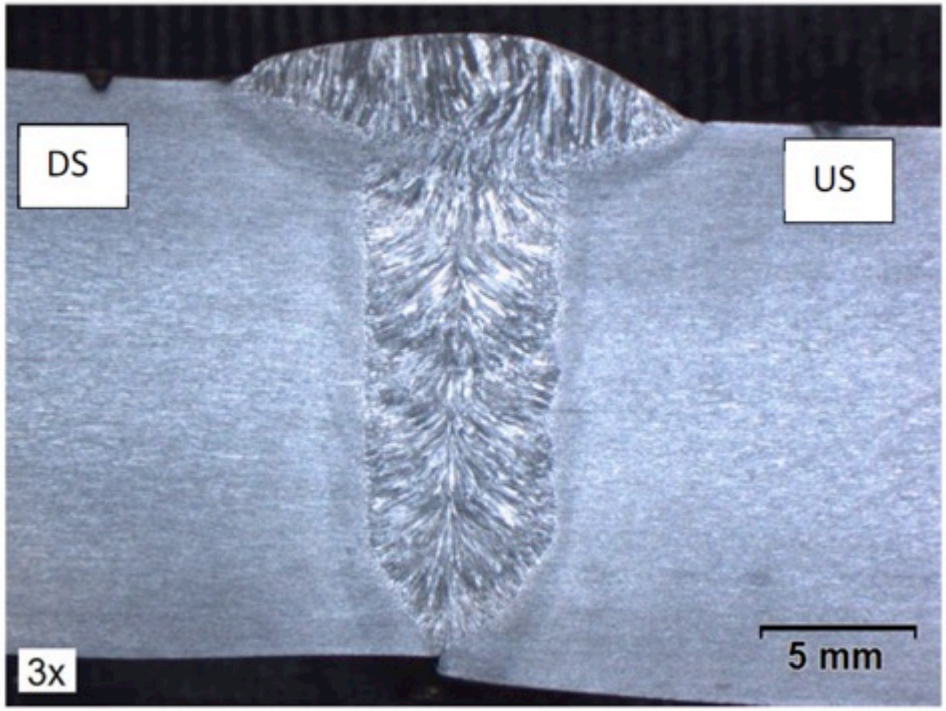
Lack of Fusion (Root Area)

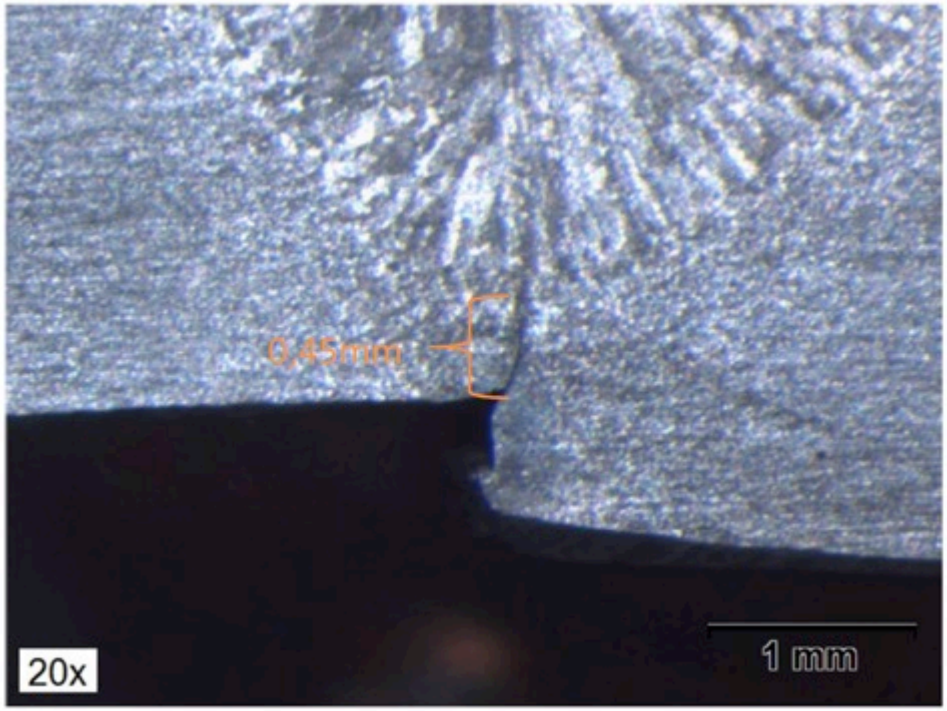
Flaw Sizing from XZ view (B-Scan)

TFM Automated Sizing Results



Macrography Results (Second Coupon)





Value	Macrography	AUT	TFM (TTTT)
Depth (mm)	**root**	19.1	18.10
Height (mm)	**0.45**	2.2	0.77
Error in height (%)	-	388.9	71.1

Flaw Sizing Results Comparison

Lack of Fusion (Volumetric):

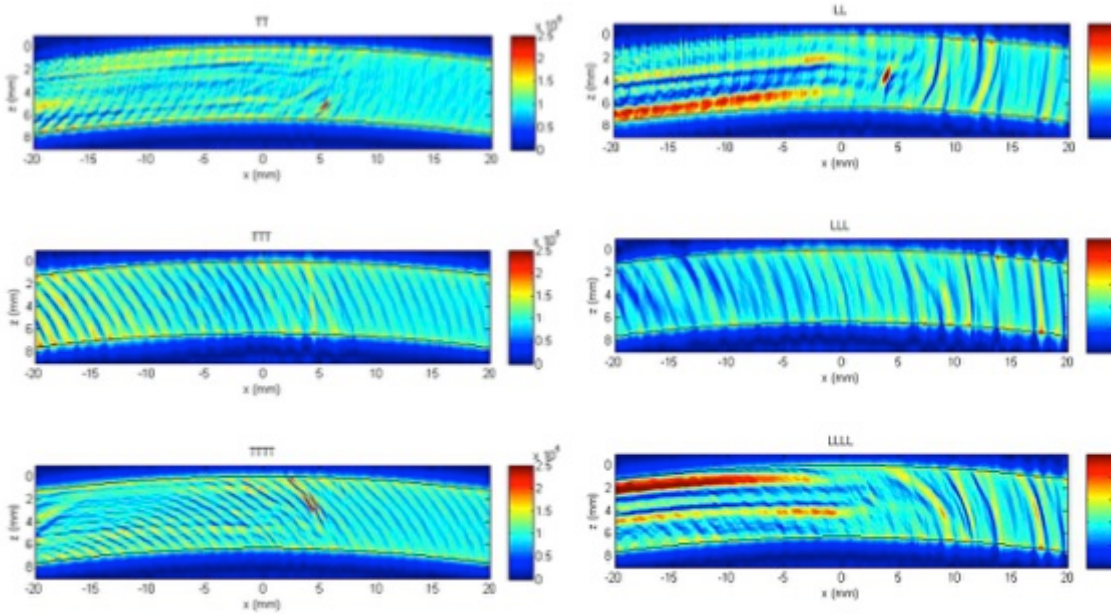
Value	Macrography	AUT	TFM (TTTT)
Depth (mm)	15.60	17.0	15.60
Height (mm)	1.30	1.6	1.24
Error in height (%)	-	23.1	4.6

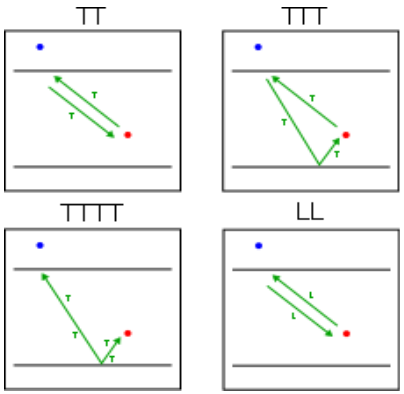
Lack of Fusion (Root) :

Value	Macrography	AUT	TFM (TTTT)
Depth (mm)	root	19.1	18.08
Height (mm)	0.45	2.2	0.78
Error in height (%)	-	388.9	73.3

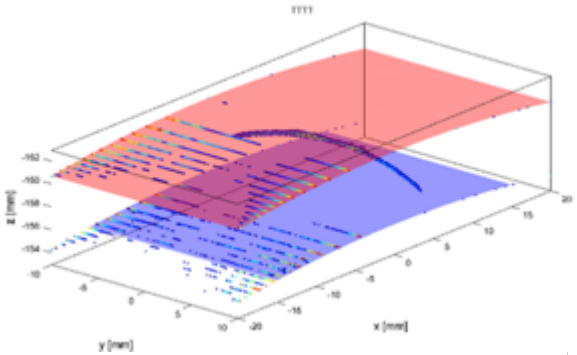
Next Step FMC/TFM

- FMC/TFM Results with Long Seam





[FMC/TFM 3D result]



- <u>Advantages</u>
  - Easy flaw location
  - Multiple Wave Mode analysis & 3D display: easy flaw characterization
  - More reliable data analysis

Summary of Results

- 4 Girth welds were tested with FMC/TFM
- 27 Imaged defects from US and DS
- TFM provided superior flaw height accuracy over AUT
- Flaw detection efficiency was achieved by TFM due to its ability to produce multimodal imaging
- Sizing can be achieved volumetrically/in 3D
- Overall, the results of sizing from TFM proved more precise than with conventional AUT

CONCLUSION

- Based on the results achieved with this study, industry would benefit greatly from implementing an automated FMC/TFM inspection procedure for girth weld inspections.