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New Inspection Approach according to revised API RECOMMENDED PRACTICE 941 by using Olympus HTHA

Presenter: Stéphan COUTURE
Global Product Support Specialist
Olympus NDT Canada

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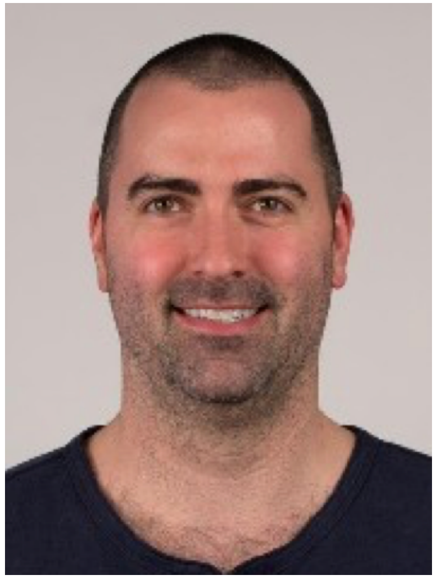


Stéphan Couture

Global Advanced Product Support Specialist

Olympus Scientific Solutions Americas

Agenda

1 HTHA Mechanism

2 New Inspection Approach by revised API 941

3 Olympus HTHA Probes and OmniScan X3

4 Study Case -1 (Plate)

5 Study Case -2 (Weld)

6 Conclusions

8 Live demonstration

8 Q&A

1

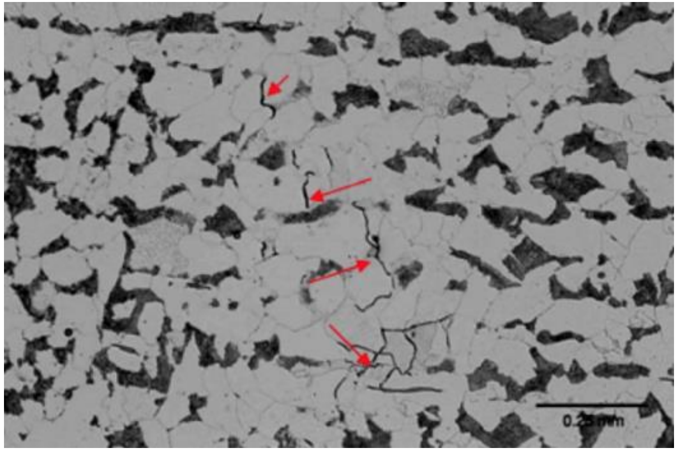
HTHA Mechanism

HTHA Mechanism

High Temperature Hydrogen Attack

- High temperature hydrogen attack (HTHA), also called hot hydrogen attack, is a problem which concerns steels operating at elevated temperatures (typically above 400°C) in hydrogen environments, in refinery, petrochemical and other chemical facilities and, possibly, high pressure steam boilers.

- HTHA is the result of **hydrogen dissociating and dissolving in the steel**, and then reacting with the **carbon** in solution in the steel to form **methane bubbles**. This can result in either surface decarburization, when the reaction mostly occurs at the surface and draws carbon from the material, or internal decarburization when atomic hydrogen penetrates the material and reacts with carbon to form methane, which accumulates at grain boundaries and/or precipitate interfaces and cannot diffuse out of the steel. **This causes the fissures and cracking which are typical of HTHA.**



Microstructural damage caused by HTHA. Red arrows point to micro-fissures formed

HTHA Mechanism

High Temperature Hydrogen Attack

- HTHA results from hydrogen service at elevated temperatures and pressures. The hydrogen reacts with carbides in steel to from methane (CH_4) which cannot diffuse through the steel. The loss of carbide causes an overall loss in strength. Methane pressure builds up, forming micro fissures that may combine to form cracks

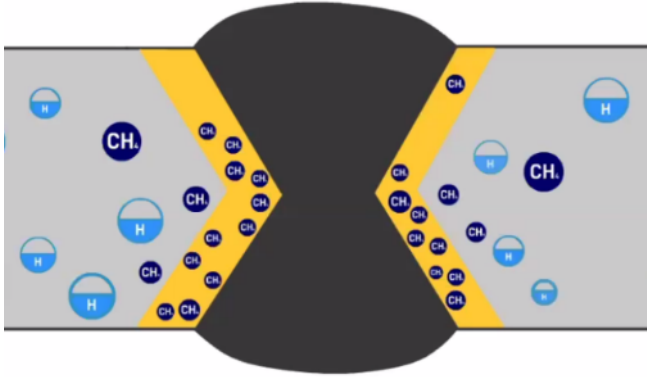


Image : Tim Armitt , Lavender International

Key Factors Leading to HTHA

- Presence of Hydrogen
- Presence of High Pressure
- High Temperature
- Presence of Stress
- Material Composition

HTHA Mechanism

HTHA Stages

The inspector will often provide a “stage” of severity for the damage mechanism.

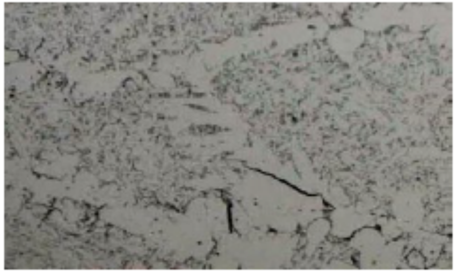
- Stage 1: <50 um (0.05mm) = Voids
- Stage 2: 50 um to 100 um (0.05-0.1 mm) = Micro fissures
- Stage 3: > 100um (0.1mm) = Macro fissures
- Stage 4: Connection of fissures to open larger cracks.

Figure 6. Micrographic sample 200x.

HTHA Mechanism

Industries

- Refinery – Fossil Fuel Processing
- Fertilizer – Ammonia Production



2

New Inspection Approach by revised API 941

New Inspection Approach by revised API 941

Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants

energy API

AMERICAN PETROLEUM INSTITUTE

API RECOMMENDED PRACTICE 941
EIGHTH EDITION, FEBRUARY 2016

ERRATA 1, JUNE 2016
ERRATA 2, JANUARY 2018
ADDENDUM 1, JULY 2020

New Inspection Approach by revised API 941

Historic Ultrasonic Techniques for Characterization

Table E.1c—Historic Ultrasonic Techniques for Characterization

	Velocity Ratio	Attenuation	Longitudinal Spectral Analysis	Angle-beam Spectrum Analysis	Conventional Single Element A-scan Backscatter Pattern Recognition
Description	Ratio of shear and longitudinal wave velocity is measured. HTHA changes the ratio.	Dispersion of ultrasonic longitudinal wave is measured by recording drop in amplitude of multiple echoes. HTHA increases attenuation.	The first backwall signal is analyzed in terms of amplitude versus frequency. HTHA will attenuate high-frequency response more than low frequencies.	The spectrum of any suspect signal from pulse-echo inspection of weld/HAZ is compared with a reference spectrum taken in the pitch-catch mode from the base metal. HTHA causes the pulse-echo spectrum to increase amplitude with increase of frequency.	— Amplitude-based — Pattern Recognition — Spatial Averaging — Directional Dependence — Frequency Dependence
Capability	— A combination of these techniques is historically used to assist in characterizing an indication of HTHA from other flaws. — Reliability and repeatability of angle beam spectrum analysis are very dependent on subjective judgement of personnel during inspection. — Very limited data is collected for monitoring purposes, and the data collection process is time consuming.				

Capability

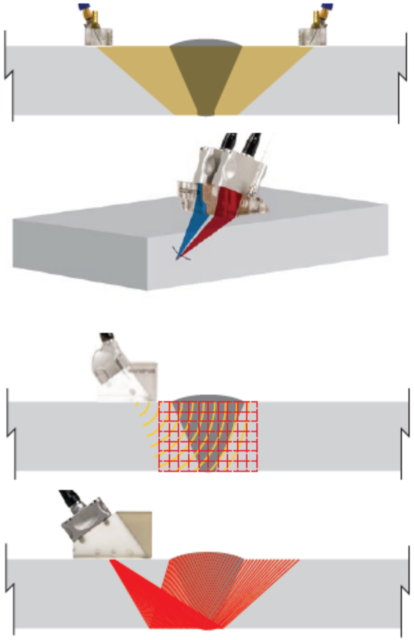
- Reliability and Repeatability are very dependent on personal
- Limited Data Collection for monitoring purposes
- Time Consuming

New Inspection Approach by revised API 941

New Inspection Approach

E.3 New Inspection Approach

While backscattered UT approach may be appropriate for complementary HTHA inspection, TOFD, PAUT (beam forming) and FMC/TFM (i.e. non-beam forming synthetic aperture PAUT techniques) are now the recommended techniques for HTHA inspection—see Table E.1a, Ultrasonic Techniques. More details about these techniques and essential variables can be found in 2019 Edition of ASME *BPV* Code Section V, Articles 1 and 4 and related Appendixes [3] and other publications focused on in-service inspections[4–13]. The use of the highest practical frequency (e.g. 7.5 MHz to 10.0 MHz) is recommended to achieve maximum detection sensitivity for the detection of microdamage. Selection of frequency of equivalent wavelength for the purpose of discriminating HTHA from metallurgical imperfections is recommended. For example, use of 10 MHz 0-degree longitudinal wave to be compared with 5 MHz transverse wave angle beam in order to determine orientation of imperfection. The use of "typical" shear wave frequency in the 3.5 MHz to 5.0 MHz range may also be included to enhance characterization of coalesced or macrocracking associated with adjacent microdamage.



ASME BPV 2019 Edition Code Section V, Articles 1 and 4 and related Appendixes

- TOFD
- PAUT (beam forming)
- FMC/TFM (non-beam forming synthetic aperture PAUT techniques)

New Inspection Approach by revised API 941

Time of Flight Diffraction (TOFD)

E.3.1 Time of Flight Diffraction (TOFD)

— TOFD involves a pair of angled longitudinal wave probes with discrete transmitter and receiver facing towards each other on the same surface of the material being inspected.

— The transmitter emits a broad beam of energy that insonifies the area of interest. Responses from the direct path between the probes (lateral wave), reflected and diffracted energy from features within the material, and reflected energy from the far surface are detected by the receiver.

— The probe pair is scanned with a fixed separation while ultrasonic waveforms are digitized at predetermined intervals. These are used to create real-time B or D-scans typically with grayscale imaging.

New Inspection Approach by revised API 941

Time of Flight Diffraction (TOFD)

Screening Tool

TOFD is used as the first and primary screening tool.
Usually, the inspect will perform a scan on the <u>based material first, and then on the weld</u>.
It is also common to be using **2 TOFD groups**, one at reference dB with the Lateral Wave at about **50% FSH** and the other channel at **100% FSH**. (No filters)

Why TOFD?

Time of Flight Diffraction is a fast and very sensitive method. Looking for small diffracted signals rather than amplitude reflections, this method has been found to be the most sensitive for the small voids that are created by HTHA. Because this is a highly sensitive method, it is used as a screening tool only, and other methods will be used to confirm findings.

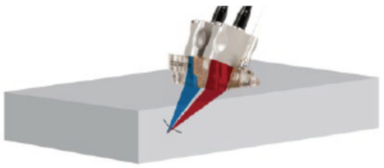
New Inspection Approach by revised API 941

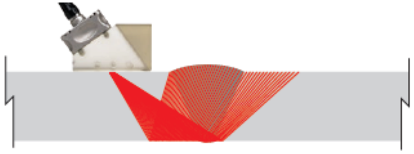
Phased Array Ultrasonic Testing (PAUT)

E.3.2 Phased Array Ultrasonic Testing (PAUT)

— In the 2019 Edition of ASME *BPVC* Section V, *Nonmandatory Appendix E*, E-474 [14], "the UT-phased array technique is a process wherein UT data are generated by controlled incremental variation of the ultrasonic beam angle in the azimuthal or lateral direction while scanning the object under examination."

— This process offers an advantage over processes using conventional search units with fixed beam angles, as it acquires considerably more information by covering a large range of angles (sweep).





New Inspection Approach by revised API 941

Phased Array Ultrasonic Testing (PAUT)

Confirming Tool

Once the initial screening is done with the TOFD scans on both the parent material and the weld, the inspector will confirm findings using **Phased Array Ultrasound** (PAUT).

The PAUT setup should have a carefully selected **focusing at the depth** of the indications found in step 1 with TOFD.

Why PAUT?

Since TOFD is limited when it comes to finding the location on the index position, but provide accurate depth location , PAUT is a useful tool to reexamine the component using the depth information from the TOFD findings to focus the PAUT beam at that given depth.

Having a targeted focused in PAUT will allow for a better resolution and definition of the indication.

New Inspection Approach by revised API 941

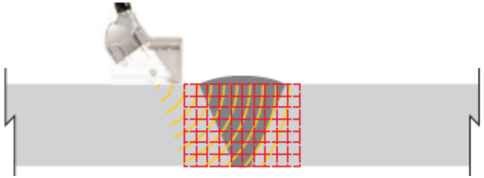
Full Matrix Capture/Total Focusing Method FMC/TFM

E.3.3 Full Matrix Capture/Total Focusing Method (FMC/TFM)

— In the 2019 Edition of ASME *BPVC* Section V: Article 1, *Mandatory Appendix I, Glossary of Terms for Nondestructive Examination* [15], FMC/TFM is an industry term for an examination technique involving the combination of classic FMC data acquisition and TFM data reconstruction.

— Classic FMC: A subset of elementary FMC where the set of transmitting elements is identical to the set of receiving elements.

— Total focusing method (TFM): A method of image reconstruction where the value of each constituent datum of the image results from focused ultrasound. TFM may also be understood as a broad term encompassing a family of processing techniques for image reconstruction from FMC. It is possible that equipment of different manufacture may legitimately generate very different TFM images using the same collected data.



New Inspection Approach by revised API 941

Full Matrix Capture/Total Focusing Method FMC/TFM

Confirming Tool

Total Focusing Method (TFM) can also be used as a confirmation tool like PAUT. Here the 64 element probes are recommended to allow maximum focus. The advantage of the **OmniScan X3** is that it has a TFM 64 effective aperture. This means that it will have the focusing capability of a 64 pulser in TFM mode without needed the purchase of a more expensive pulser-receiver combo.

The multiple views as well as the simultaneous 4 groups/waves sets features can also help the user in visualizing the indication with the optimal mode.

To complete it's HTHA offering, Olympus also developed 10 MHz dual 64-element arrays probes (TFM optimized probe A31 and A32) with special design to allow higher gain with fewer adverse echoes to detect smaller HTHA voids.

New Inspection Approach by revised API 941

Ultrasonic Techniques (Recommended)

Table E.1a - Ultrasonic Techniques (Recommended)

	TOFD	PAUT	FMC/TFM
Description	Diffraction and time-based. Longitudinal-longitudinal diffraction mode setup of pair transducers. B- and D-grayscale 2D image of the digitized A-scan. Higher frequencies increase capability for detection of HTHA at weldments.	Reflective and diffraction-based. Longitudinal and shear waves. Linear, 2-D matrix and annular arrays. A-, B-, C-, D-, S- scan 2D imaging. Pulse-echo scheme (using higher frequency sound) increases capability for detection of HTHA in base material and weldments/HAZ.	Reflective, diffraction and scatter-based. Longitudinal and waves. Linear and 2-D matrix arrays. A-, B-, C-, D- scan 2/3D imaging. FMC data acquisition scheme that involves the collection of all possible combinations of sources and receivers in an array, and TFM imaging scheme that involves computation of a focused image on every point of an imaged region (using high-frequency sound) to increase the capability for better detection and sizing of HTHA in base material and weldments/HAZ.
Detection Capability Effectiveness [a]	Usually Effective: Can detect HTHA in base metal, weld HAZ, and at weldments.	Usually Effective: Can detect HTHA in base metal, weld HAZ, and at weldments.	Usually effective: Can detect HTHA: in base metal, weld HAZ, and at weldments.
Sizing Effectiveness	Usually effective for length and depth (location) and height sizing. Not effective for precise location and sizing (width) perpendicular to the scanning direction.	Usually effective for length and depth (location), height and width sizing when appropriate inspection setup is used.	Usually effective for length and depth (location), height and width sizing. When appropriate inspection setup is used, better effectiveness can be achieved than PAUT.
Characterization Capability	— With a combination of these techniques, proper characterization between HTHA damage and large fabrication flaws (e.g. lamination in base metal, LOP, LOF, slag, isolated porosity, and inclusion) can be effective through indication location and pattern recognition — Difficult to distinguish early-stage HTHA from inclusions/impurities. — Difficult to distinguish HTHA-induced cracking versus cracks induced with potentially other damage mechanisms from one inspection data set. — Encoded data storage makes it possible to perform more reliable monitoring of indication from multiple inspections than conventional methods. — The fundamental principles of historical characterization techniques (backscatter signal pattern recognition, frequency spectrum analysis, and velocity ratio) are still applicable to further assist in indication characterization. These techniques can be applied on data collected from new techniques (TOFD, PAUT, and TFM) to improve capability and confidence for characterization between HTHA and other damage mechanisms.		
Comments	— Higher inspection speed for a parallel scan and lower inspection speed for combined parallel and nonparallel scans. — Consideration is to be given to the blind zone created by the leading edge of the ID response masking low amplitude responses from adjacent flaws and/or flaws located in the shadow zone caused by the ID geometry. Similarly, inspections from the ID will create a near-surface blind zone due to the lateral wave. Supplemental techniques such as PAUT or FMC/TFM should be considered where damage within the blind zones is a concern.	Greatest effectiveness achieved in near field of the transducer used. (Typ. minimum of 32 elements for thickness ≤1 in. and 64 for > 1 in.). Lower inspection speed.	Greatest effectiveness achieved in near field of the transducer used and using high-density reconstruction grid. (typ. minimum of 64 elements for a typical 10 MHz transducer). Lower inspection speed.

New Inspection Approach by revised API 941

Ultrasonic Techniques (Recommended)

TOFD	PAUT	FMC/TFM
▪ Higher frequencies increase capability for detection of HTHA at weldments. ▪ Detection Capability Usually Effective ▪ Can detect HTHA in base metal, weld HAZ, and at weldments ▪ Usually effective for length and depth (location) and height sizing. Not effective for precise location and sizing (width) perpendicular to the scanning direction.	• Longitudinal and shear waves. Linear, 2-D matrix and annular arrays. • Pulse-echo scheme (using higher frequency sound) increases capability for detection of HTHA in base material and weldments/HAZ. • Detection Capability Usually Effective • Can detect HTHA in base metal, weld HAZ, and at weldments • Usually effective for length and depth (location), height and width sizing when appropriate inspection setup is used.	• TFM imaging scheme that involves computation of a focused image on every point of an imaged region (using high frequency sound) to increase the capability for better detection and sizing of HTHA in base material and weldments/HAZ. • Detection Capability Usually Effective • Can detect HTHA in base metal, weld HAZ, and at weldments • Usually effective for length and depth (location), height and width sizing. When appropriate inspection setup is used, better effectiveness can be achieved than PAUT.

New Inspection Approach by revised API 941

Ultrasonic Techniques (Recommended)

TOFD	PAUT	FMC/TFM
• Higher inspection speed for a parallel scan and lower inspection speed for combined parallel and nonparallel scans. • Consideration is to be given to the blind zone created by the leading edge of the ID response masking low amplitude responses from adjacent flaws and/or flaws located in the shadow zone caused by the ID geometry. Similarly, inspections from the ID will create a near-surface blind zone due to the lateral wave. • Supplemental techniques such as PAUT or FMC/TFM should be considered where damage within the blind zones is a concern.	• Greatest effectiveness achieved in near field of the transducer used. • (Typ. minimum of 32 elements for thickness ≤1 in. and 64 for > 1 in.) • **Lower inspection speed.**	• Greatest effectiveness achieved in near field of the transducer used and using high-density reconstruction grid. (typ. minimum of 64 elements for a typical 10 MHz transducer). • **Lower inspection speed.**

New Inspection Approach by revised API 941

Ultrasonic Techniques (Recommended)

Characterization Capability

- With a combination of these techniques, proper characterization between HTHA damage and large fabrication flaws (e.g. lamination in base metal, LOP, LOF, slag, isolated porosity, and inclusion) can be effective through indication location and pattern recognition
- Difficult to distinguish early-stage HTHA from inclusions/impurities.
- Difficult to distinguish HTHA-induced cracking versus cracks induced with potentially other damage mechanisms from one inspection data set.
- Encoded data storage makes it possible to perform more reliable monitoring of indication from multiple inspections than conventional methods.
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3

Olympus HTHA Probes and OmniScan X3

Olympus HTHA Probes and OmniScan X3

Detect HTHA damage at an earlier stage

Olympus HTHA Probes and OmniScan X3

Dual Linear Array™ (DLA) and Total Focusing Method (TFM) Probes

Greater detection capability

- DLA technology → Higher gain can be used
- Smaller elements → Greater focusing
- High frequency → Increased resolution

Efficient

- Smaller elements improve steering for greater coverage of the weld and HAZ
- REX1 wide beam for larger surface coverage
- Wide range of thickness and diameters

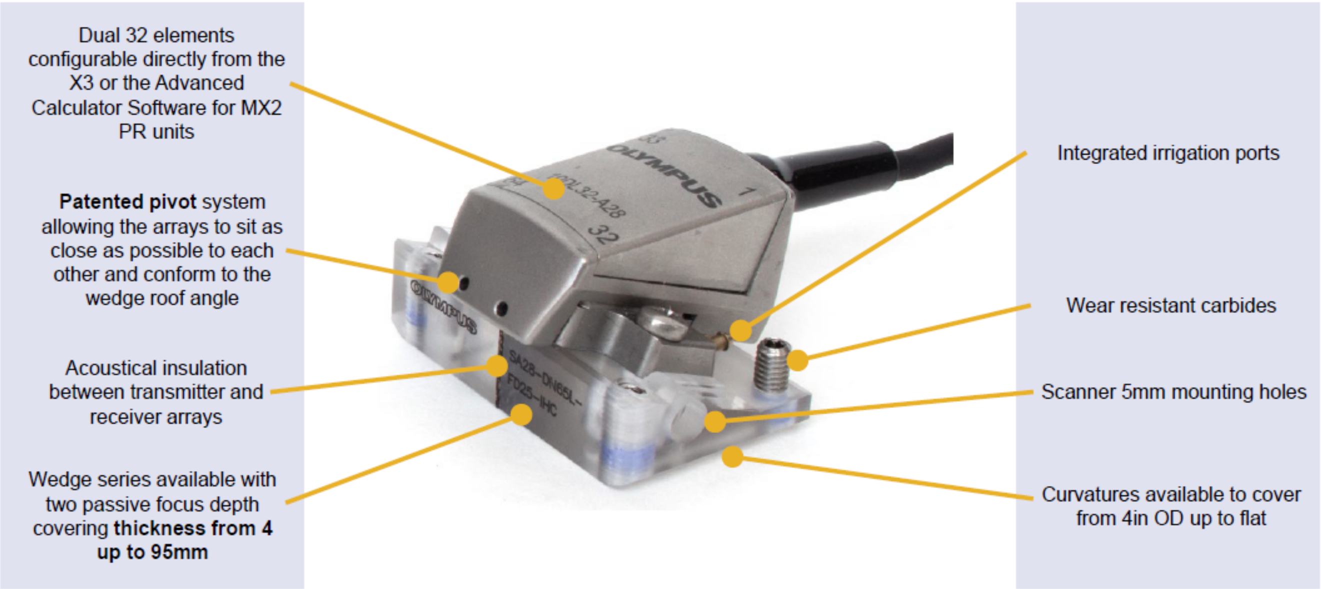
Comprehensive and easy-to-use

- Higher POD using multi-technology approach
- Easily configurable directly on the X3

Olympus HTHA Probes and OmniScan X3

Dual Array (A28) -Weld

- Pitch catch techniques allows higher gain to be used without adverse echo
- High steering capability for greater coverage of the weld and HAZ



Olympus HTHA Probes and OmniScan X3

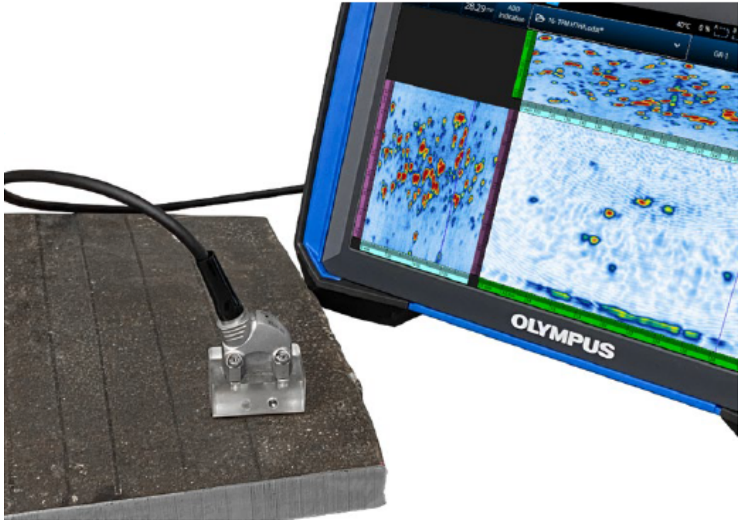
Dual Array (REX1) –0 degrees

- Pitch catch techniques allows higher gain to be used without adverse echo
- 30mm wide coverage for fast C-Scan mapping
- Dual 64 element arrays allow for multiple choices of focusing level
- Combination of passive and electronic focusing increase the usable range of thickness

Olympus HTHA Probes and OmniScan X3

Dual Array (REX1) –0 degrees

- 64 small elements allow greater focusing for clearer TFM imaging of HTHA across the volume
- High frequency further improves sensitivity to small HTHA voids



Olympus HTHA Probes and OmniScan X3

Probe Specifications

Description	Frequency (Mhz)	Element Configuration	Number of Elements	Pitch (mm)	Active Aperture (mm)	Elevation (mm)	Roof Angle (deg)	Thickness Range
10DL32-9.6X5-A28	10	Dual 32	64	0.31	9.6	5	Set by Wedge	Set by Wedge
10DL64-32X5-1DEG-REX1-PR	10	Dual 64	128	0.5	32	5	1	30-95
10DL64-32X5-5DEG-REX1-PR	10	Dual 64	128	0.5	32	10	5	4-30
10L64-19.84X10-A31	10	Linear	64	0.31	19.84	10	N/A	3-60
10L64-32X10-A32	10	Linear	64	0.5	32	10	N/A	8-95

Wedges Specifications

SA28-N65L-FD25: Optimized for part thicknesses ranging from 4 mm to 45 mm
SA28-N65L-FD60: Optimized for part thicknesses ranging from 45 mm to 95 mm

Olympus HTHA Probes and OmniScan X3

OmniScan X3

Improved Phased Array

- 3X as fast as the OmniScan MX2 flaw detector (max pulse repetition frequency)
- Single TOFD menu for accelerated workflow
- Improved fast phased array calibration minimizes frustration
- 800% high amplitude range reduces the need to rescan
- Onboard Dual Linear Array™ and Dual Matrix Array™ probe support accelerates setup creation

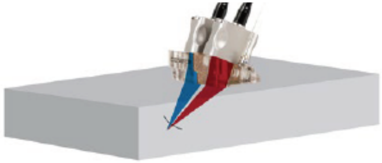
Innovative TFM

- Better flaw imaging brings clarity and resolution to smaller defects
- Image early-stage high-temperature hydrogen attack (HTHA) to detect it when it matters most
- Onboard acoustic influence map (AIM) reflectivity simulator helps you
- Visualize TFM sensitivity and adjust accordingly
- Up to four TFM modes facilitates flaw interpretation and sizing

4

Study Case-1 (Plate)

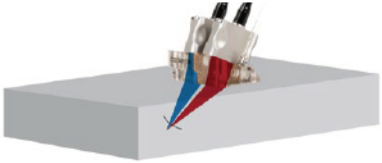
Study Case-1 (Plate)



Inspection of 48mm thick base material

- **Sample:** Artificially cooked HTHA samples
- **Type of defect:** Multiple Hydrogen Cracks near block back surface. Multiple Hydrogen Cracks in first 22 mm from surface.
- **Position:** Located in macrographic sample according to micrographic 1 and micrographic 2.
- **Dimensions of defect:** Several cracks: lengths from: 3µm-50µm

Study Case-1 (Plate)



Inspection of 48mm thick base material

Micrographic 1 : Cracks type 1 : Located near surface. Unetched

Figure 4. Micrographic sample 200x.

Micrographic 2 : Cracks type 1 : Located near surface. Etched

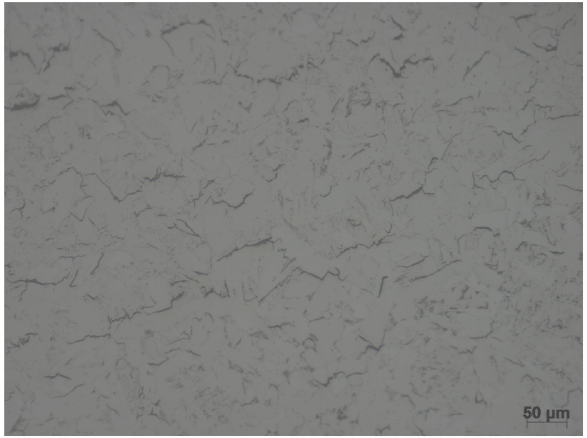
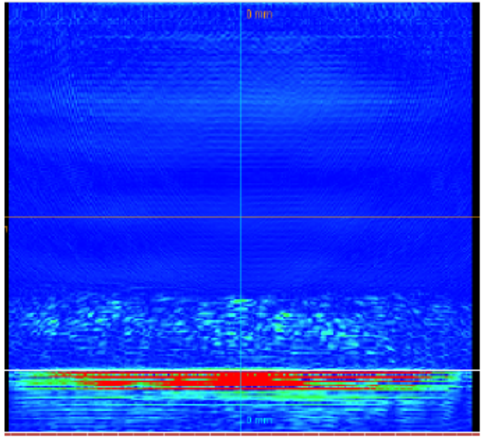


Figure 5. Micrographic sample 200x.



The test specimen was sectioned to expose HTHA cracks near block surface. The specimen was metallographically ground and polished using procedures given in Practice ASTM E3-01(2007)e1 Standard Guide for Preparation of Metallographic Specimens.

Study Case-1 (Plate)

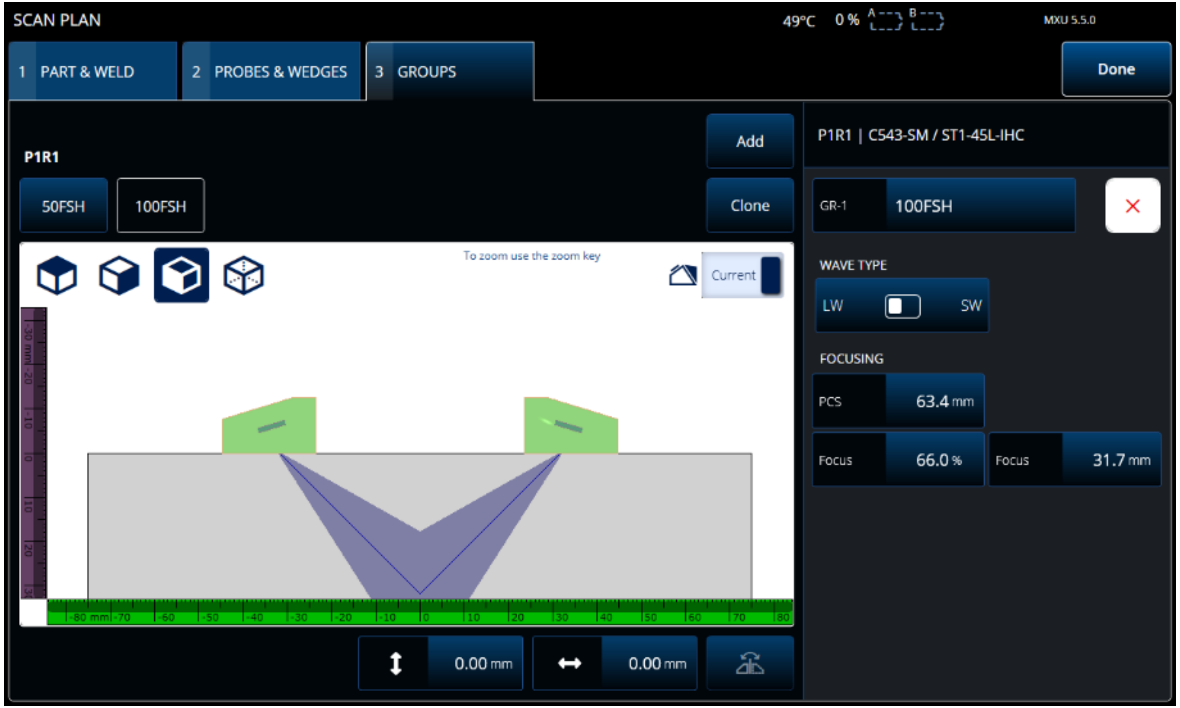
TOFD

- **Probes :** C543-SM (5Mhz ,6mm)
- **Wedges :** ST1-45L-IHC
- **Scan Type :** Raster
- **Scanner** : HST-X04
- **Part Thickness :** 48mm

Study Case-1 (Plate)

TOFD

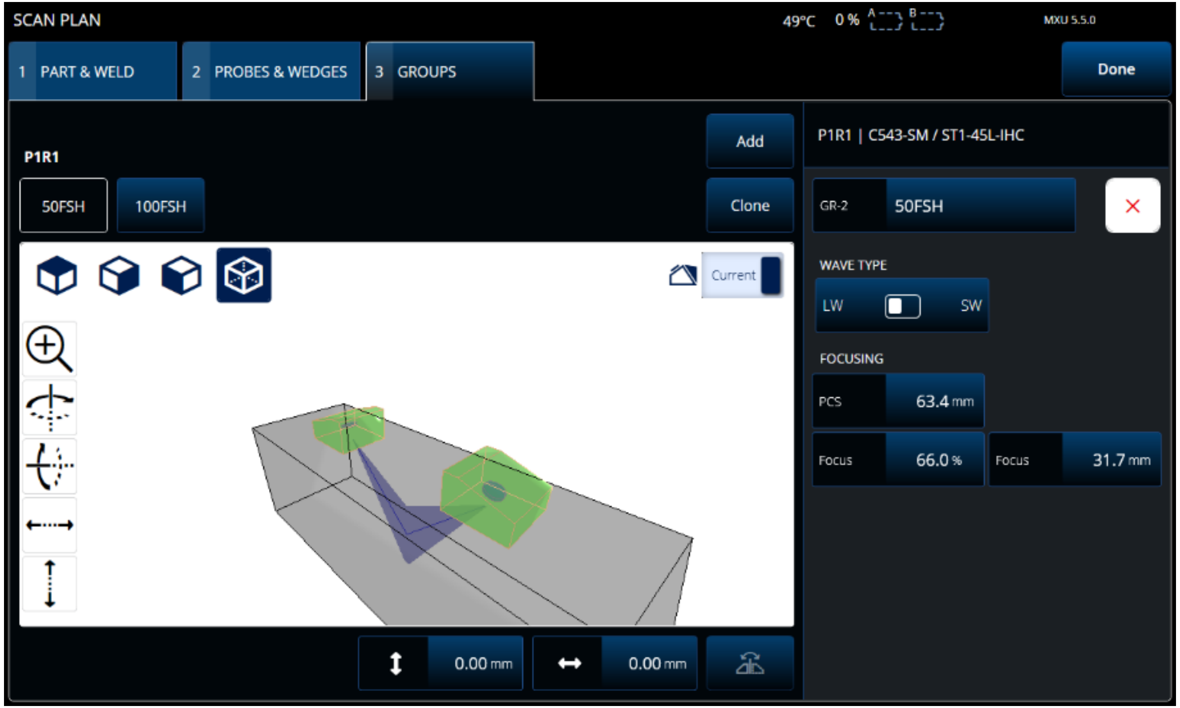
- **Probes :** C543-SM (5Mhz ,6mm)
- **Wedges :** ST1-45L-IHC
- **Scan Type :** Raster
- **Scanner :** HST-X04



Study Case-1 (Plate)

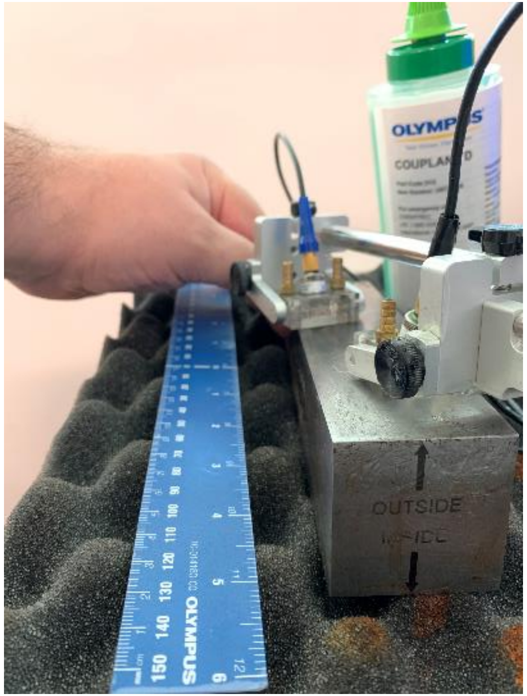
TOFD

- **Probes :** C543-SM (5Mhz ,6mm)
- **Wedges :** ST1-45L-IHC
- **Scan Type :** Raster
- **Scanner** : HST-X04



Study Case-1 (Plate)

TOFD



SCAN from OUTSIDE FACE

Study Case-1 (Plate)

TOFD (from outside face)

%20 FSH Lateral Wave , 57dB

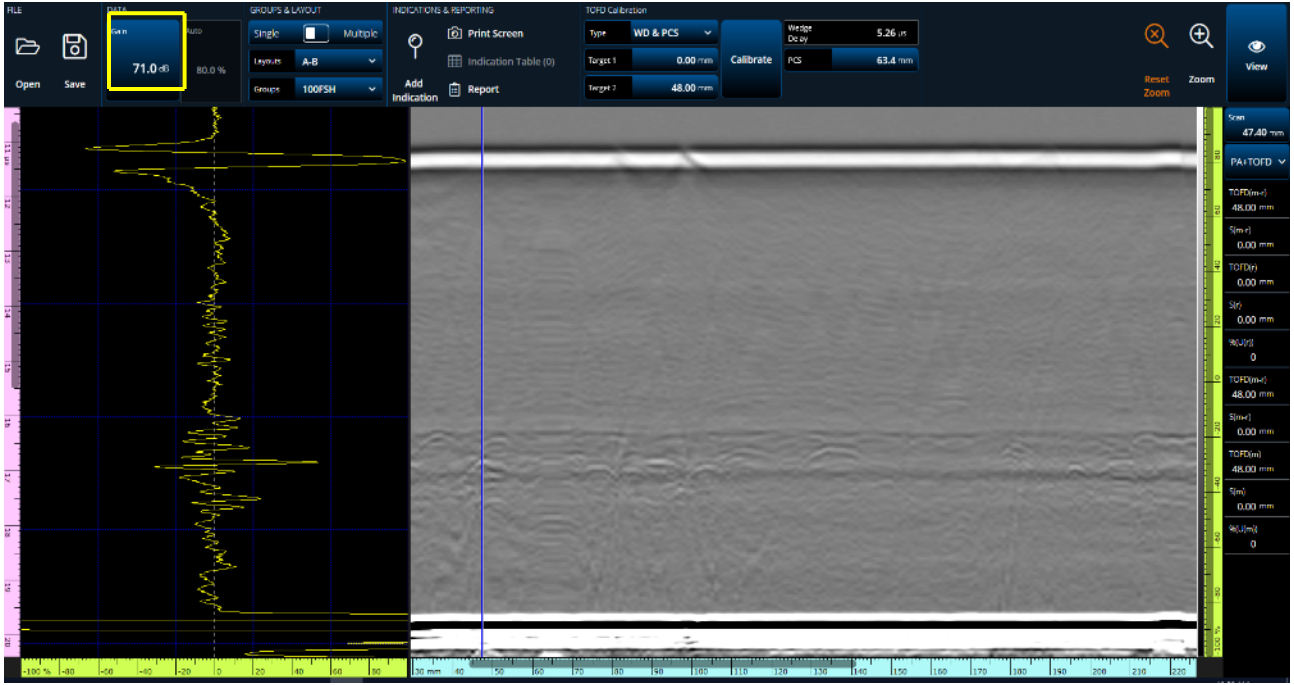
Study Case-1 (Plate)

TOFD (from outside face)

%50 FSH Lateral Wave , 65dB

Study Case-1 (Plate)

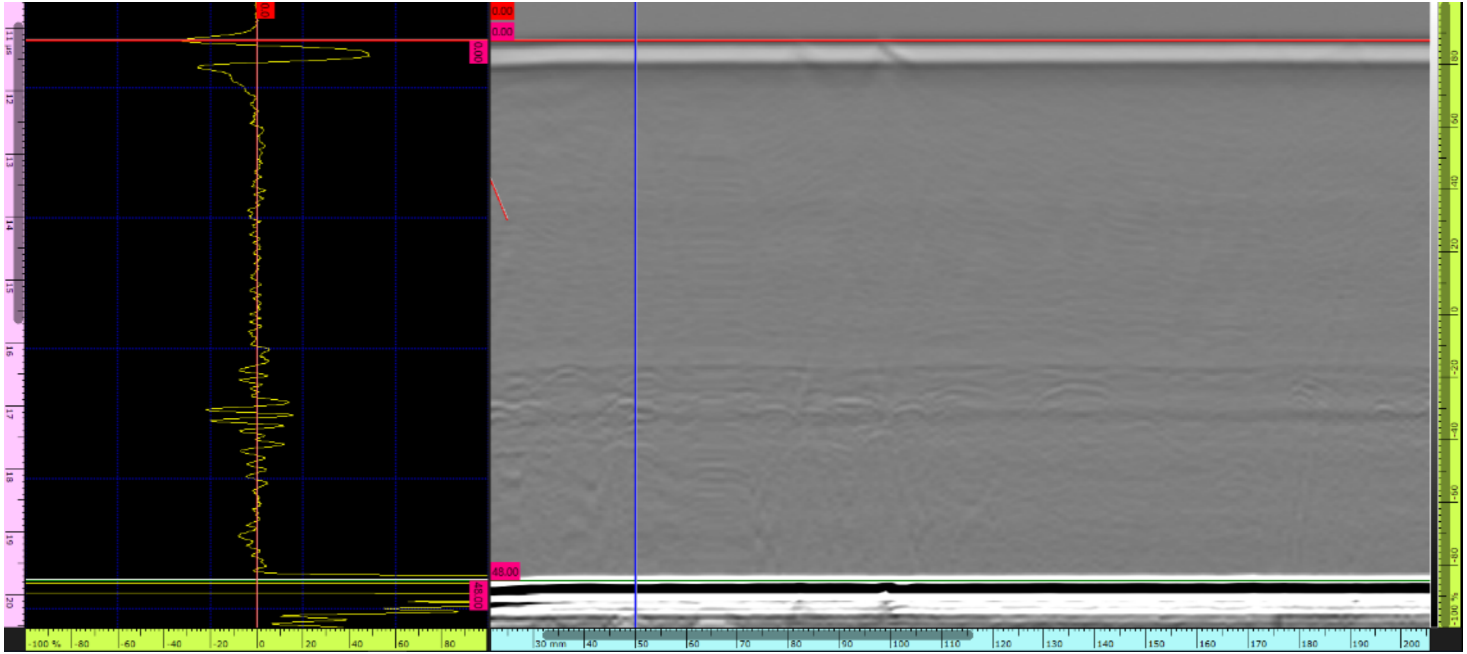
TOFD (from outside face)



%100 FSH Lateral Wave , 71dB

Study Case-1 (Plate)

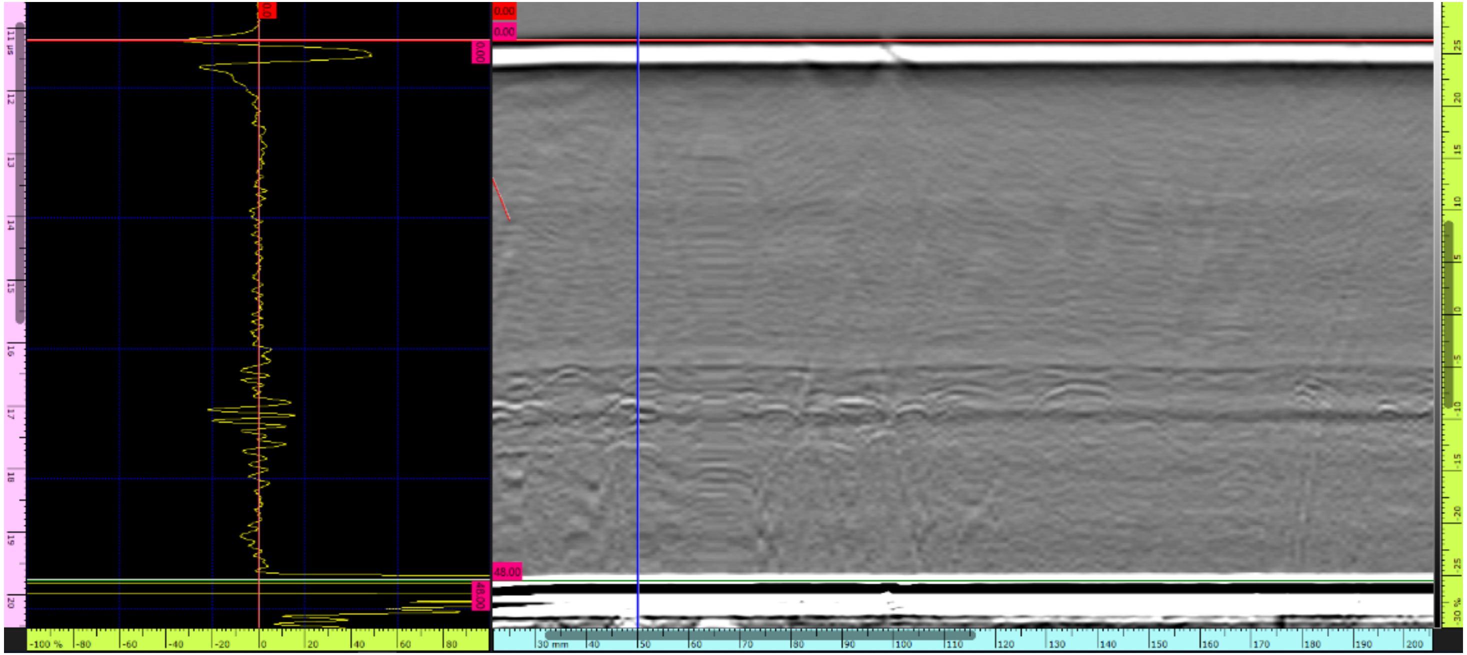
TOFD (from outside face)



%50 FSH Lateral Wave , No Filter

Study Case-1 (Plate)

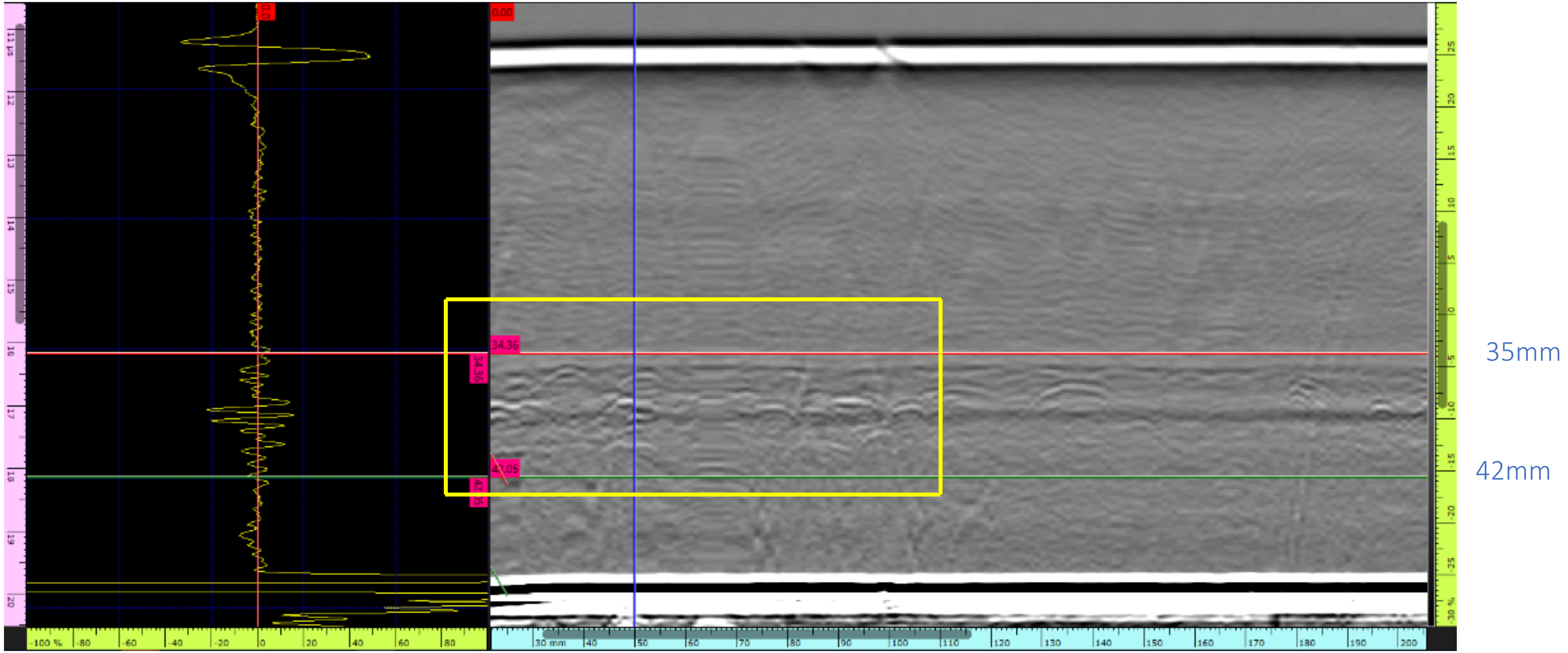
TOFD (from outside face)



%50 FSH Lateral Wave , No Filter, %60 Contrast Palette

Study Case-1 (Plate)

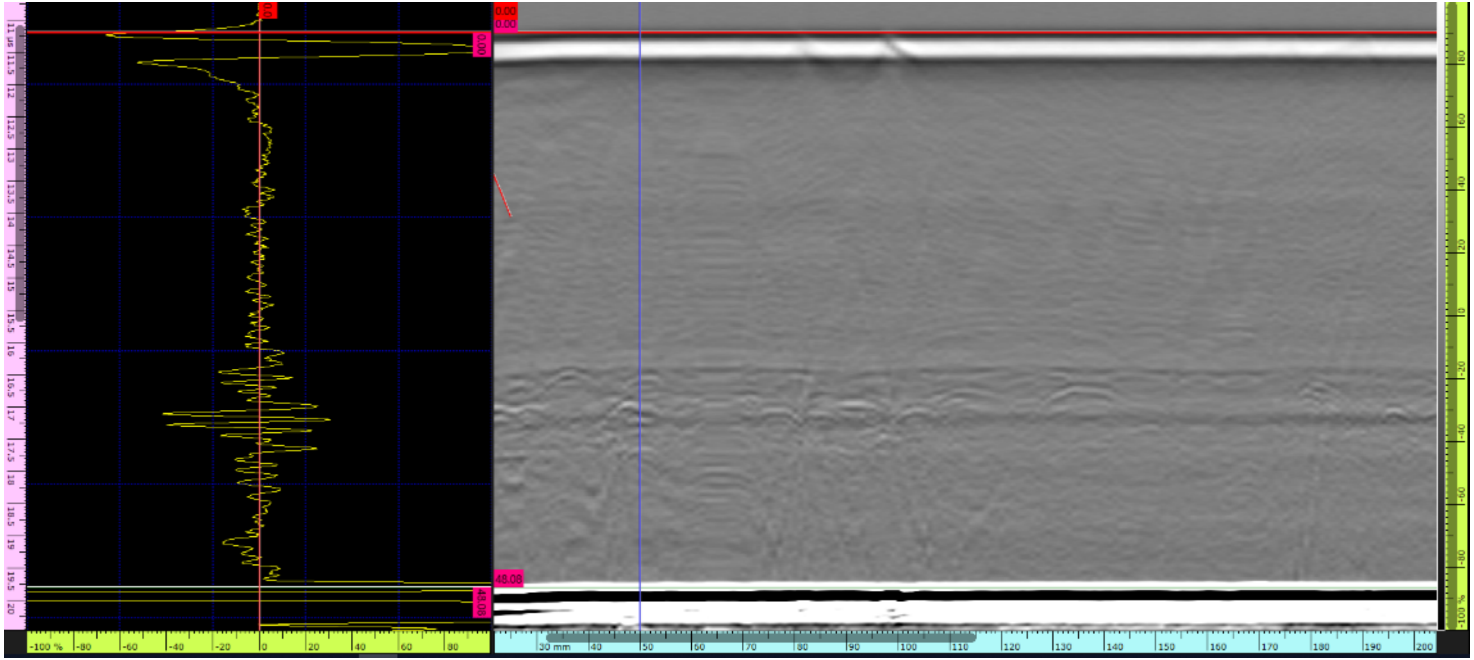
TOFD (from outside face)



%50 FSH Lateral Wave , No Filter, %60 Contrast Palette

Study Case-1 (Plate)

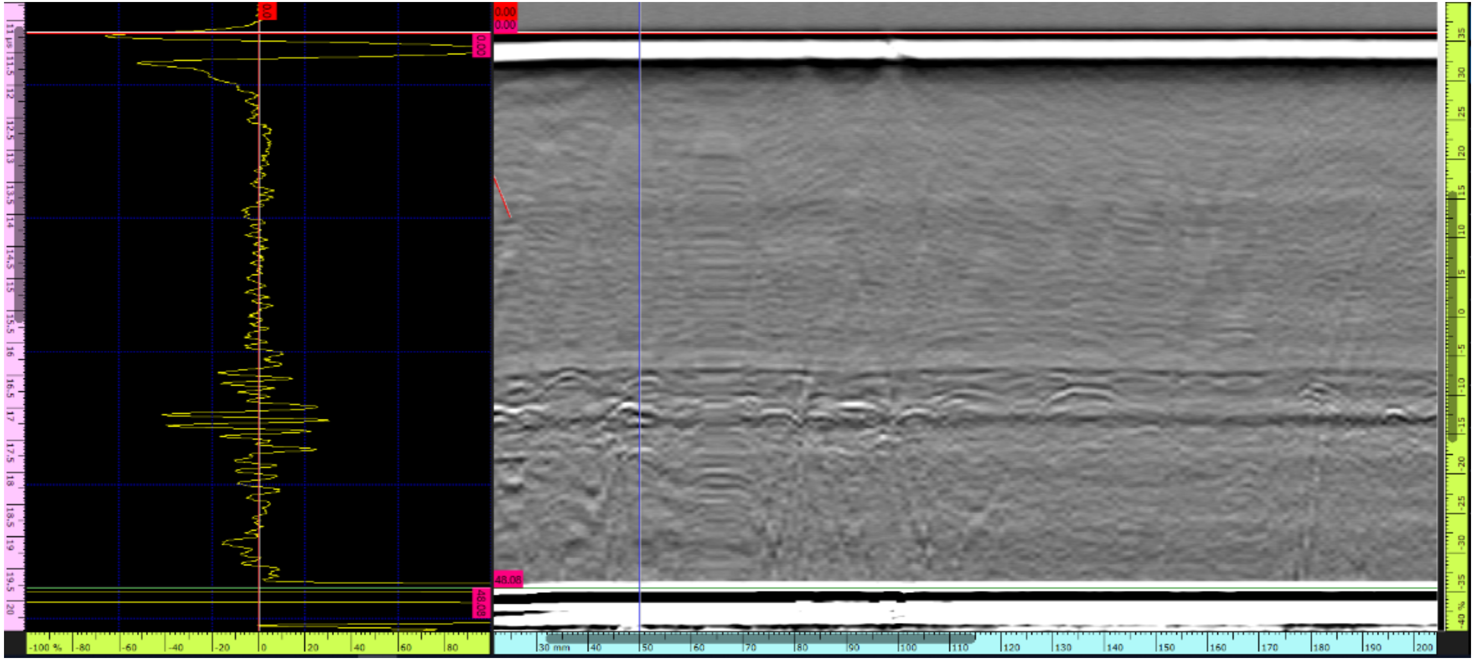
TOFD (from outside face)



%100 FSH Lateral Wave , No Filter

Study Case-1 (Plate)

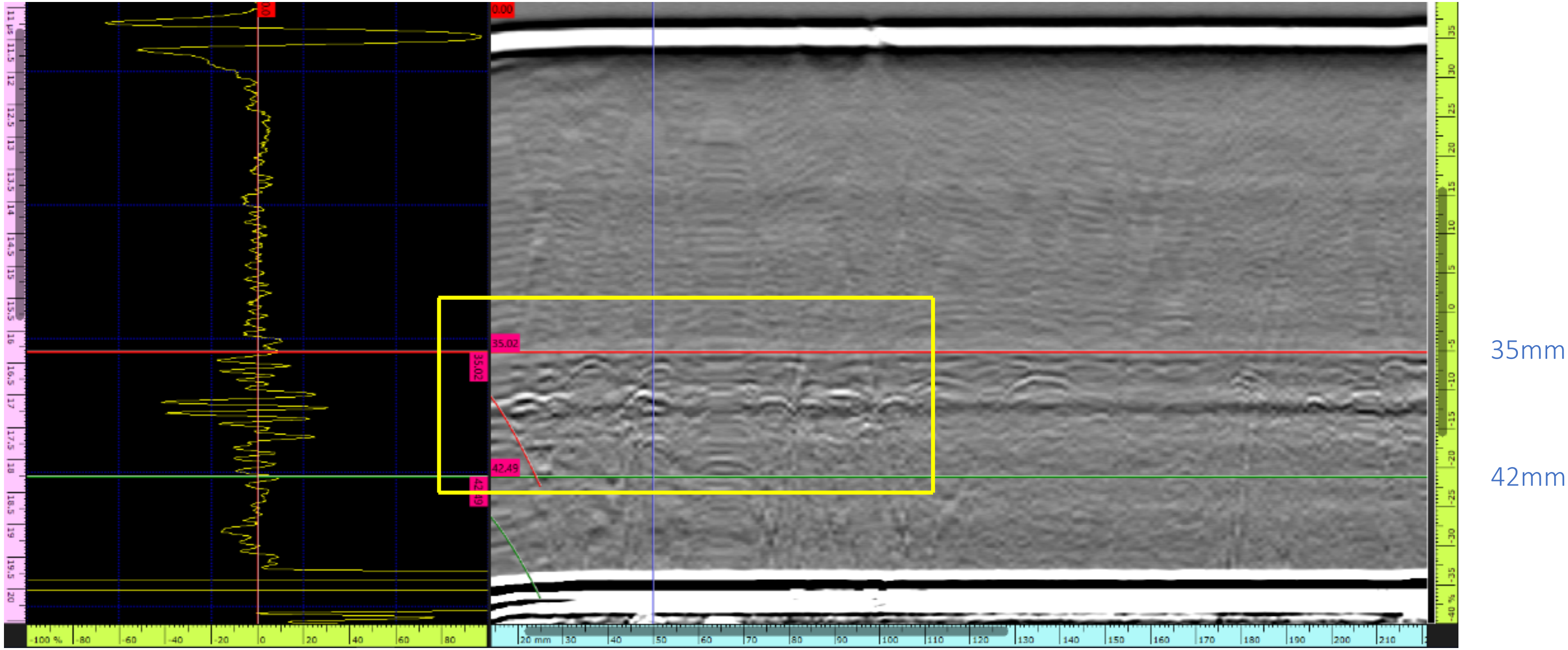
TOFD (from outside face)



%100 FSH Lateral Wave , No Filter, %60 Contrast Palette

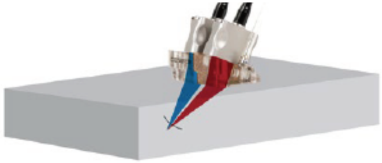
Study Case-1 (Plate)

TOFD (from outside face)



%100 FSH Lateral Wave , No Filter, %60 Contrast Palette

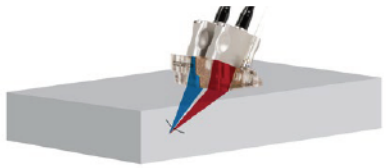
Study Case-1 (Plate)



PAUT – DLA

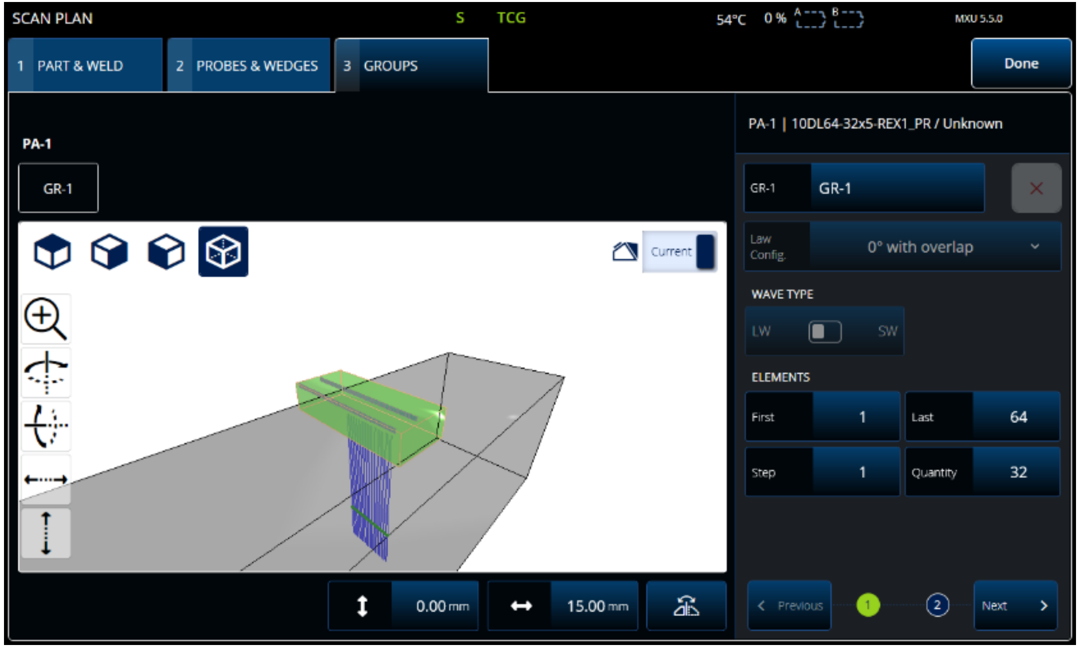
- **Probes** : 10DL64-32X5-1DEG-REX1-PR (10Mhz, 0.5mm Pitch)
- **Wedges** : Integrated
- **Scan Type** : Encoded
- **Scanner** : Versa Mouse

Study Case-1 (Plate)

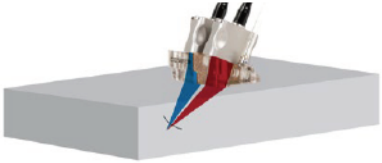


PAUT – DLA

- **Probes :** 10DL64-32X5-1DEG-REX1-PR (10Mhz, 0.5mm Pitch)
- **Wedges :** Integrated
- **Scan Type :** Encoded
- **Scanner** : Versa Mouse

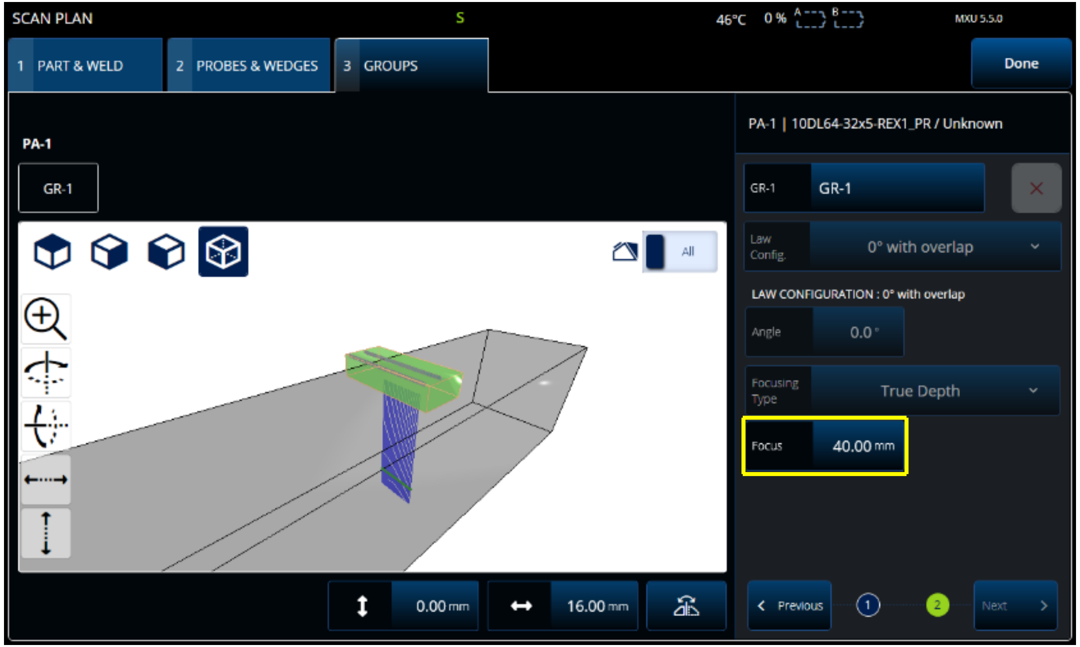


Study Case-1 (Plate)



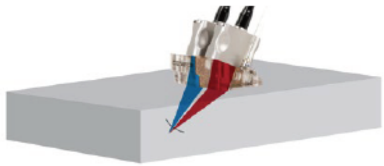
PAUT – DLA

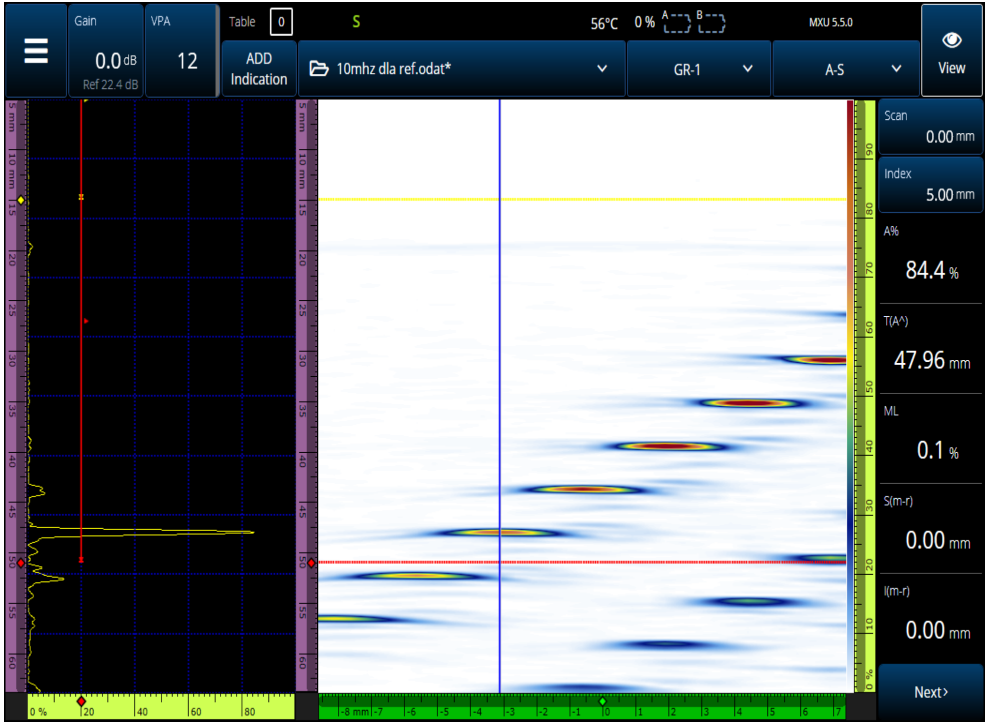
- **Probes :** 10DL64-32X5-1DEG-REX1-PR (10Mhz, 0.5mm Pitch)
- **Wedges :** Integrated
- **Scan Type :** Encoded
- **Scanner** : Versa Mouse

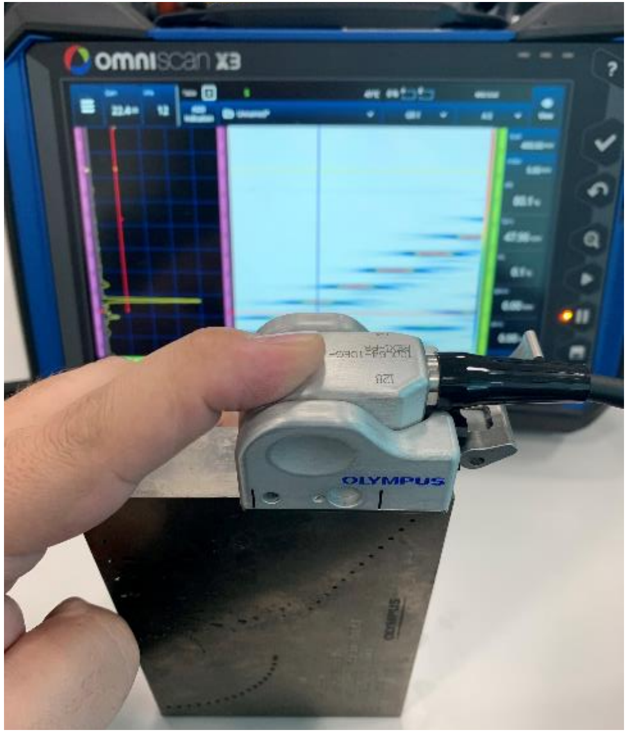


Study Case-1 (Plate)

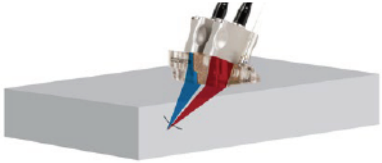
PAUT – DLA





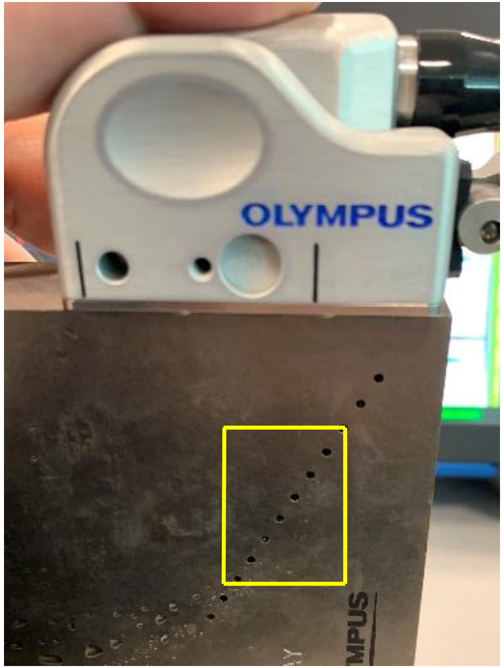


Study Case-1 (Plate)

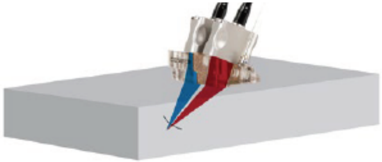


PAUT – DLA

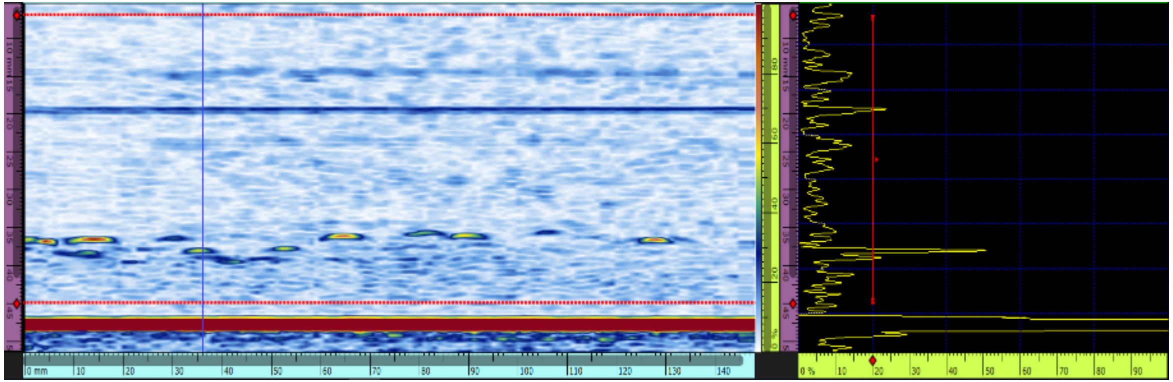
- **Sizing Block :** ASTM E2491 Sensitivity Block
- **Reflector :** Angled row of 12 holes at 1/16" (0.0625) diameter with 0.200" of separation between holes
- **Sensitivity :** %80 FSH
- **Reference Gain :** 22.4dB
- **Scanning Sensitivity :** 22.4dB+ 24dB

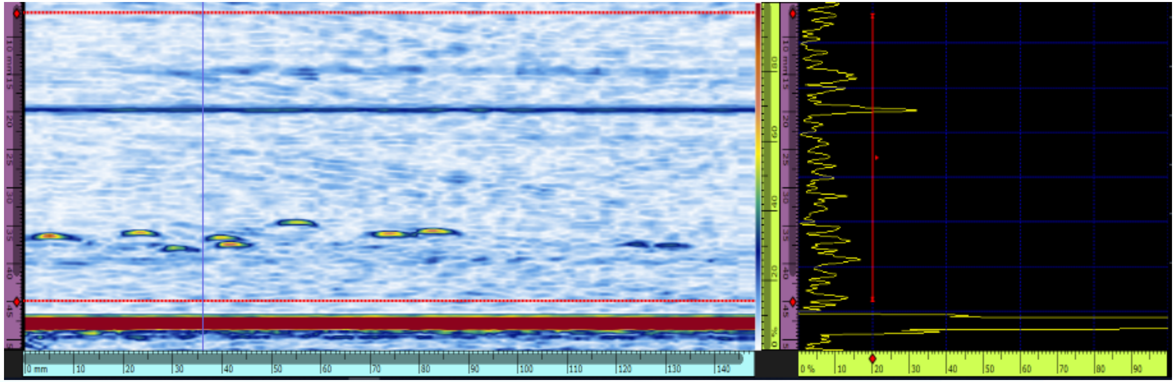


Study Case-1 (Plate)

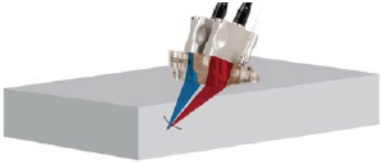


PAUT , B-Scan

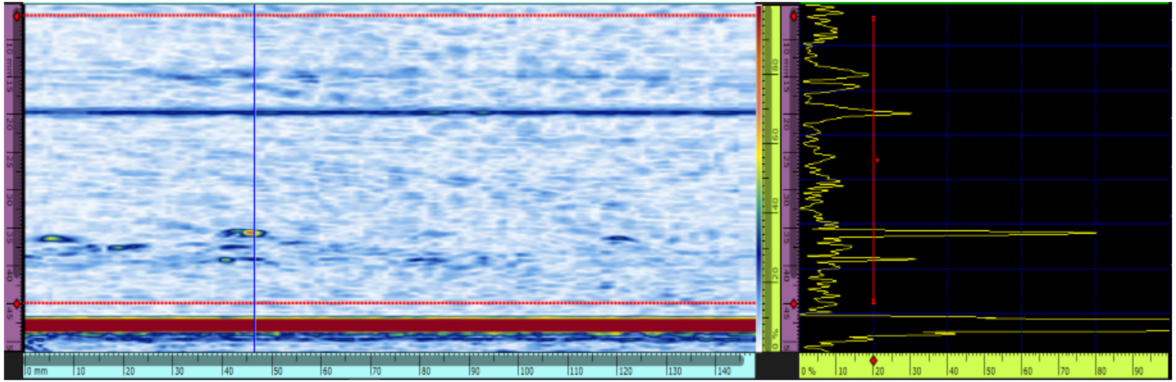


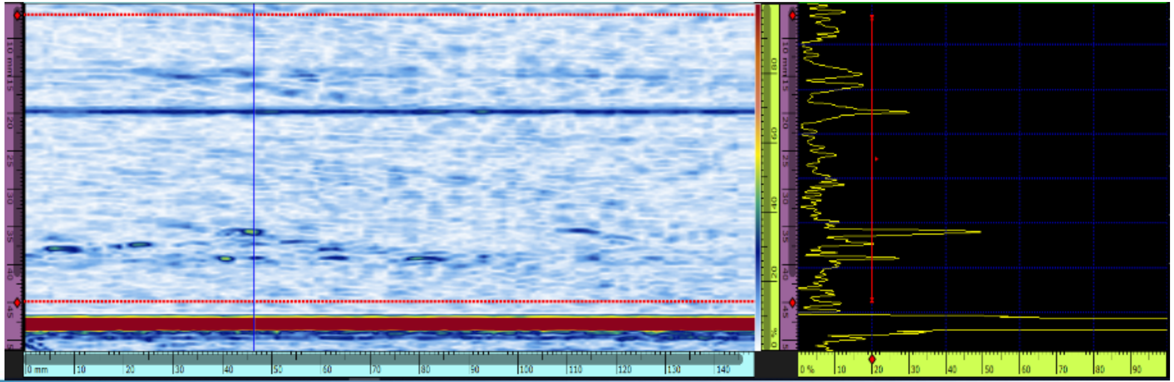


Study Case-1 (Plate)



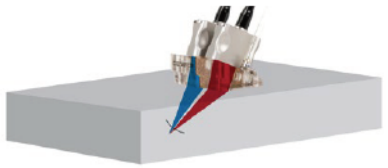
PAUT , B-Scan

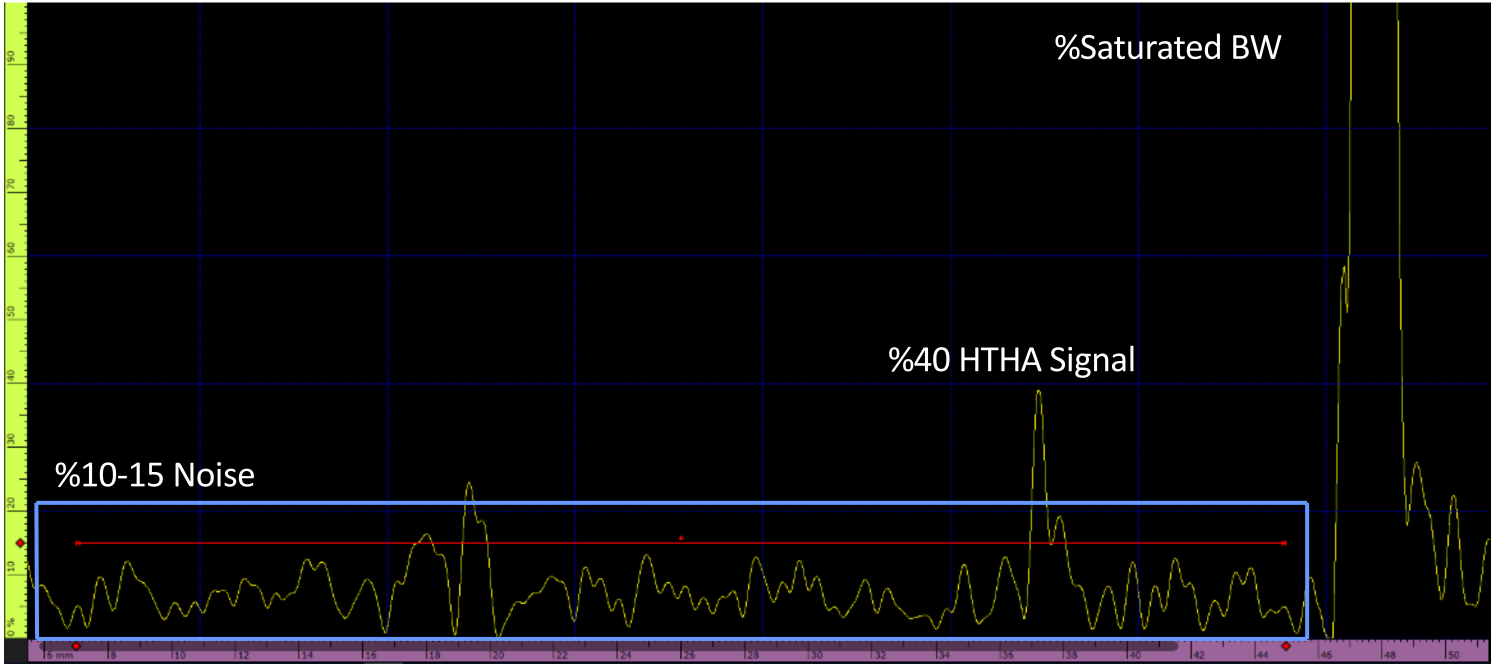




Study Case-1 (Plate)

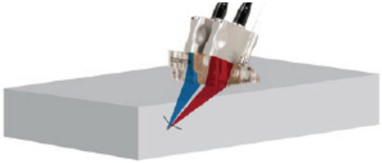
PAUT , S/N ratio

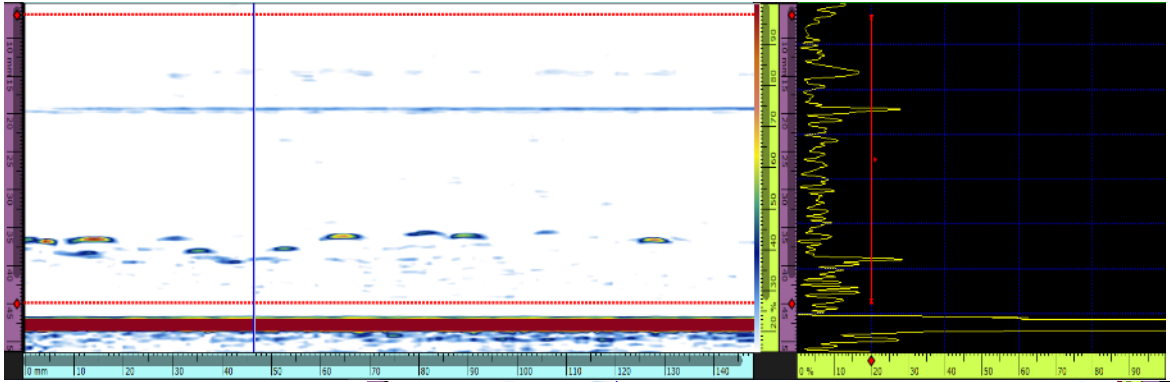


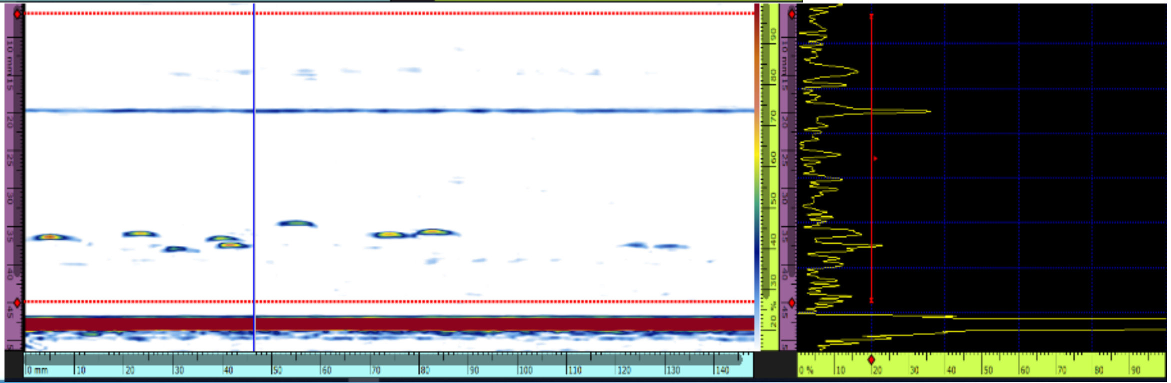


Study Case-1 (Plate)

PAUT , B-Scan

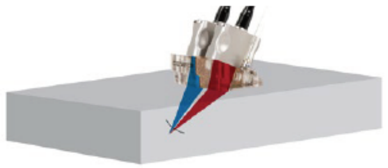


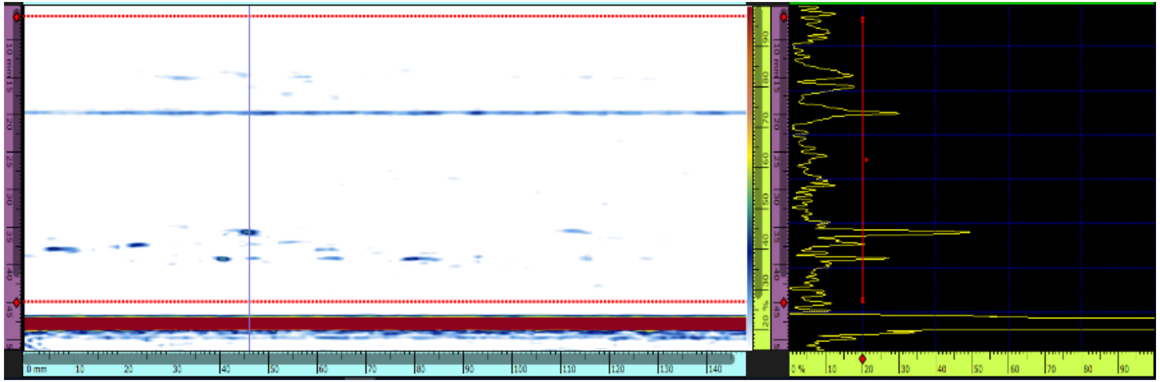


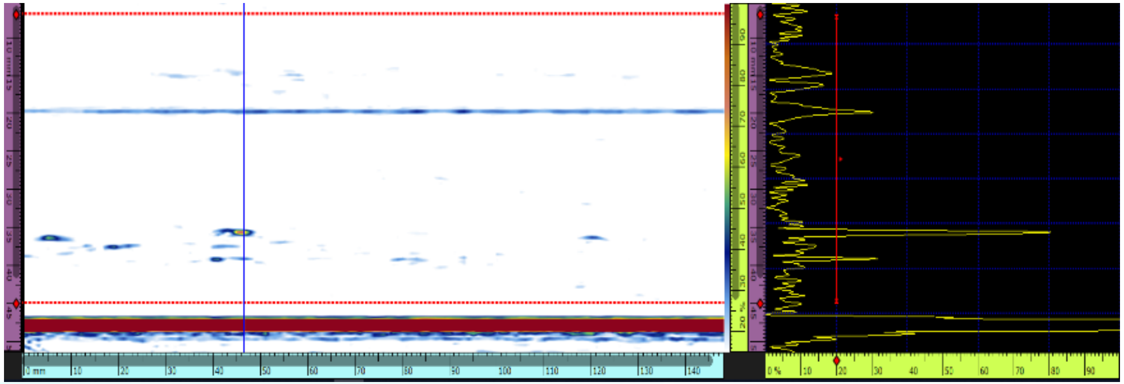


Study Case-1 (Plate)

PAUT , B-Scan

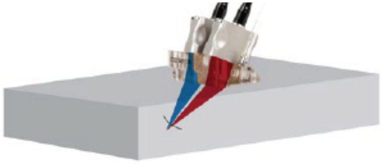


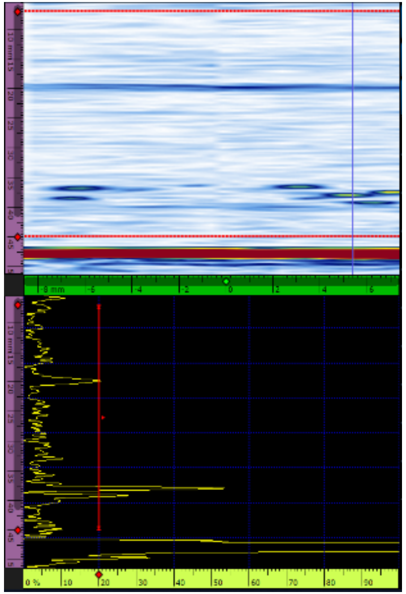


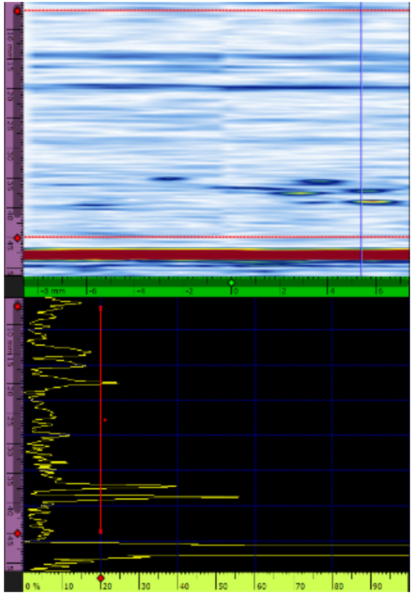


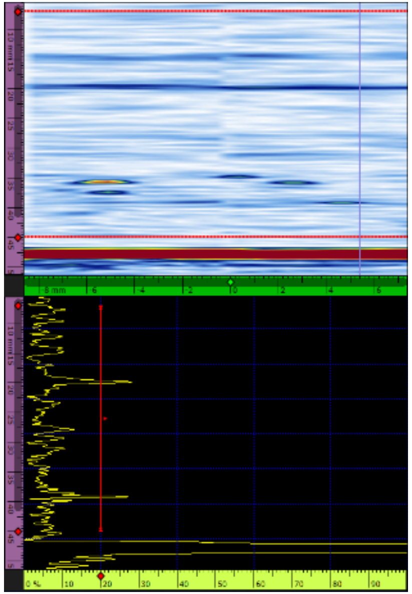
Study Case-1 (Plate)

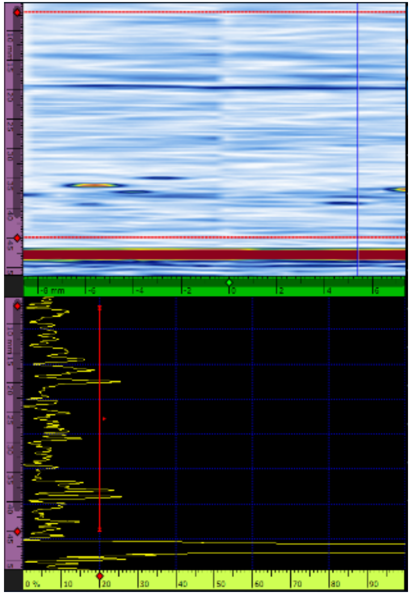
PAUT , D-Scan





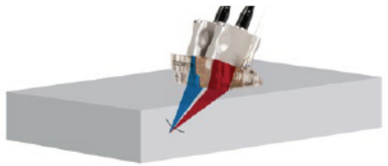


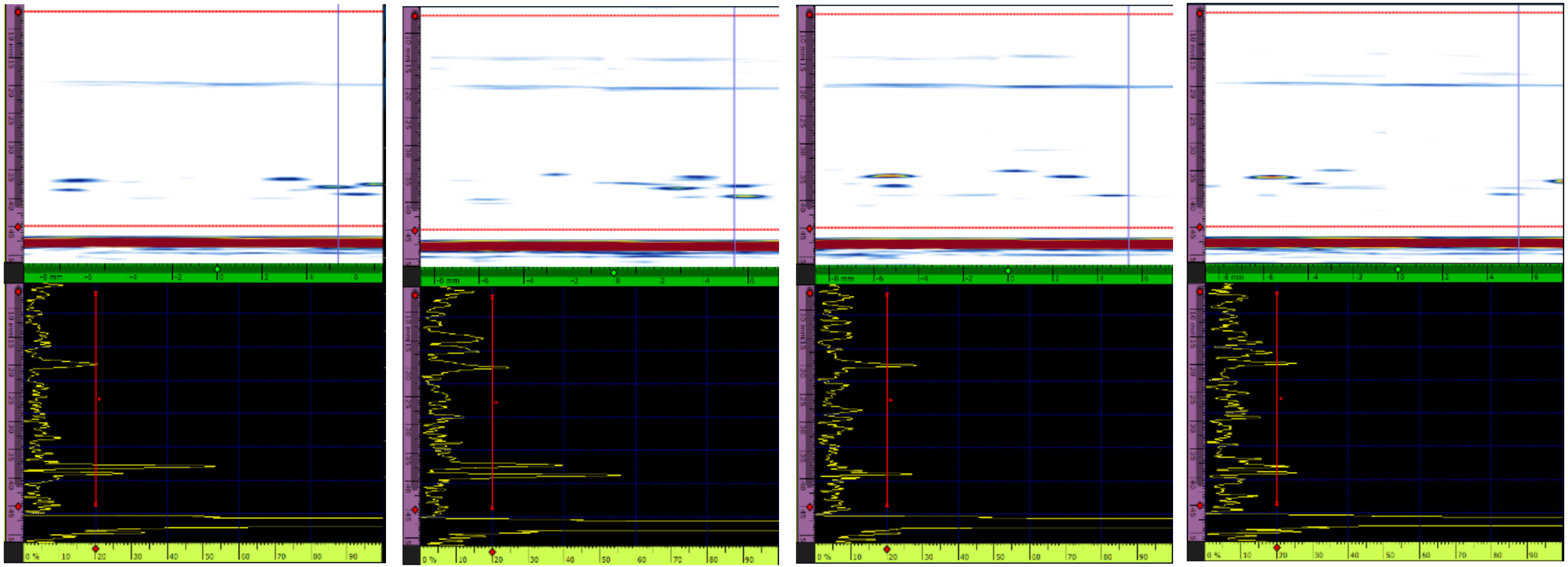




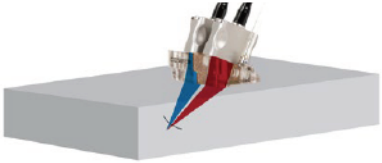
Study Case-1 (Plate)

PAUT , D-Scan

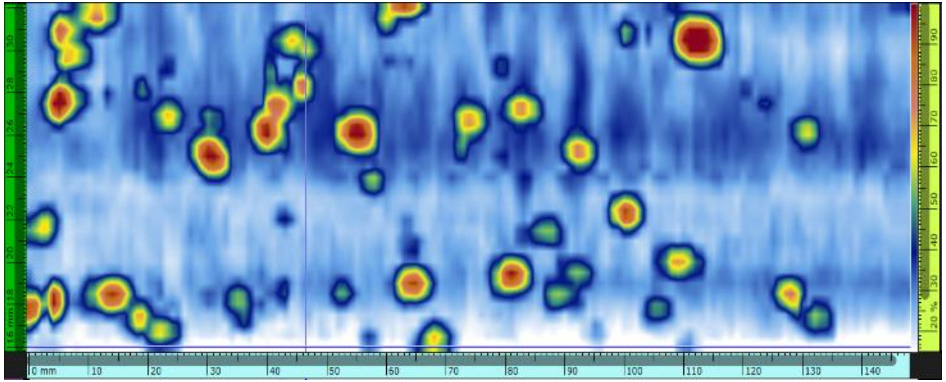


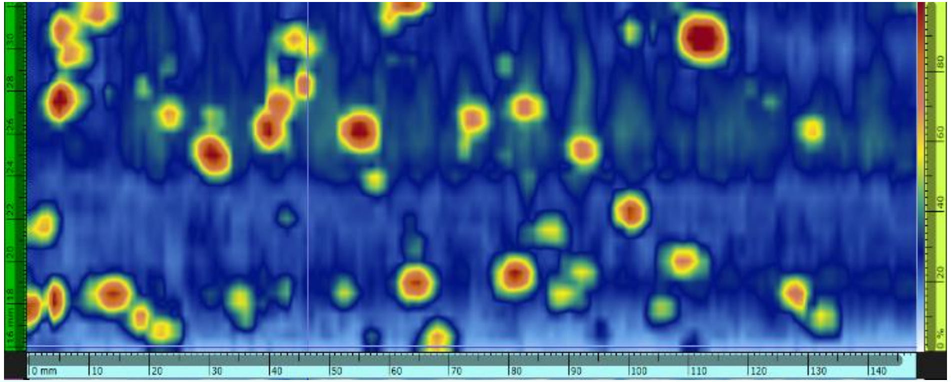


Study Case-1 (Plate)



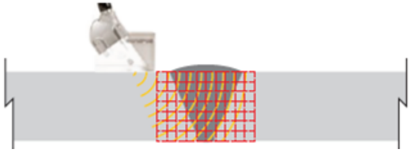
PAUT , C-Scan



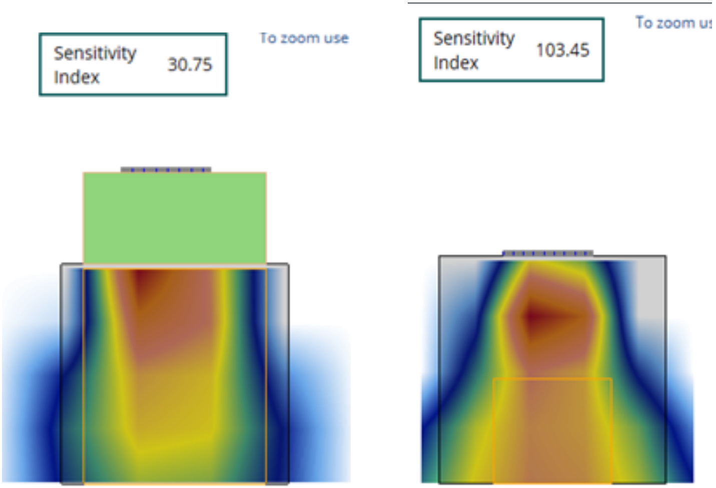


Study Case-1 (Plate)

FMC/TFM



- **Probes :** 10L64-19.84X10-A31 (10Mhz, 0.31mm Pitch)
- **Wedges :** Contact
- **Scan Type :** Raster

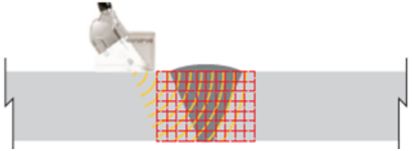


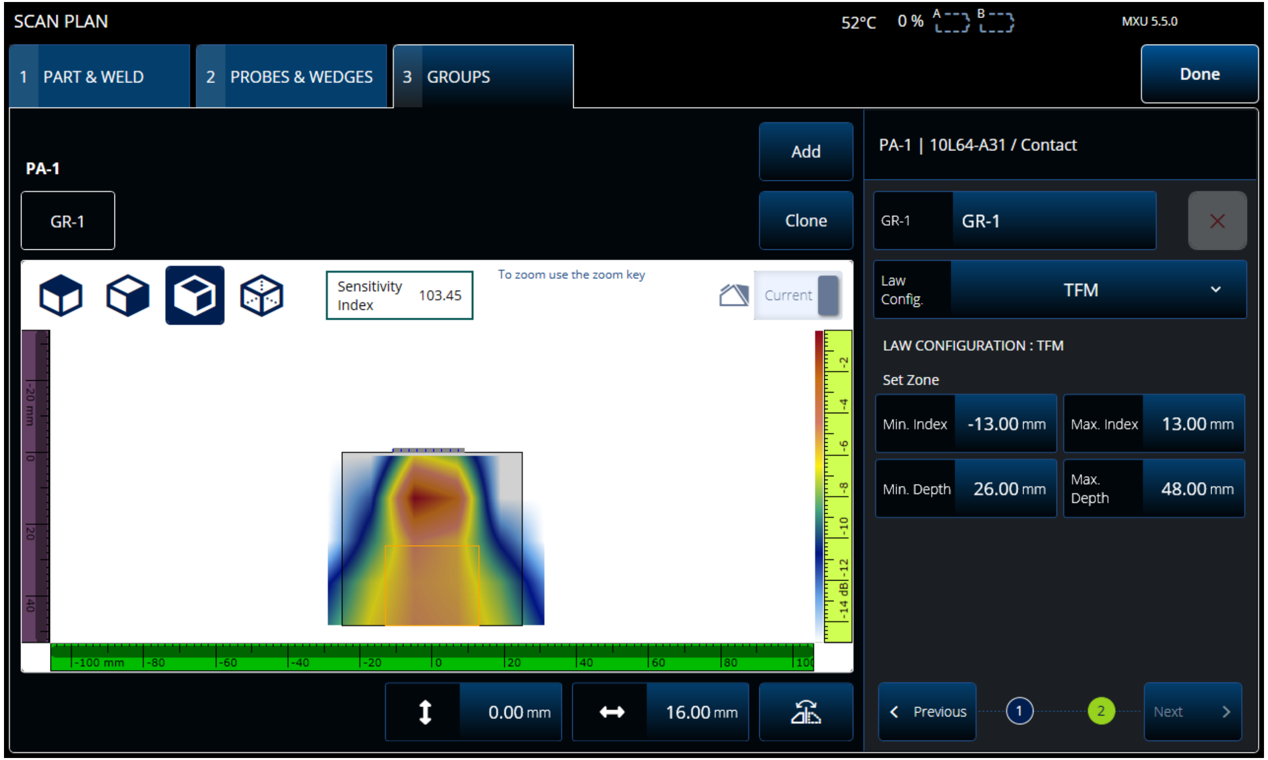
Wedge

Contact

Study Case-1 (Plate)

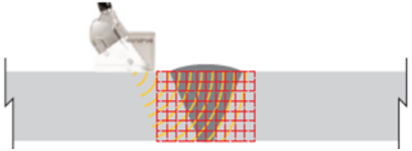
FMC/TFM

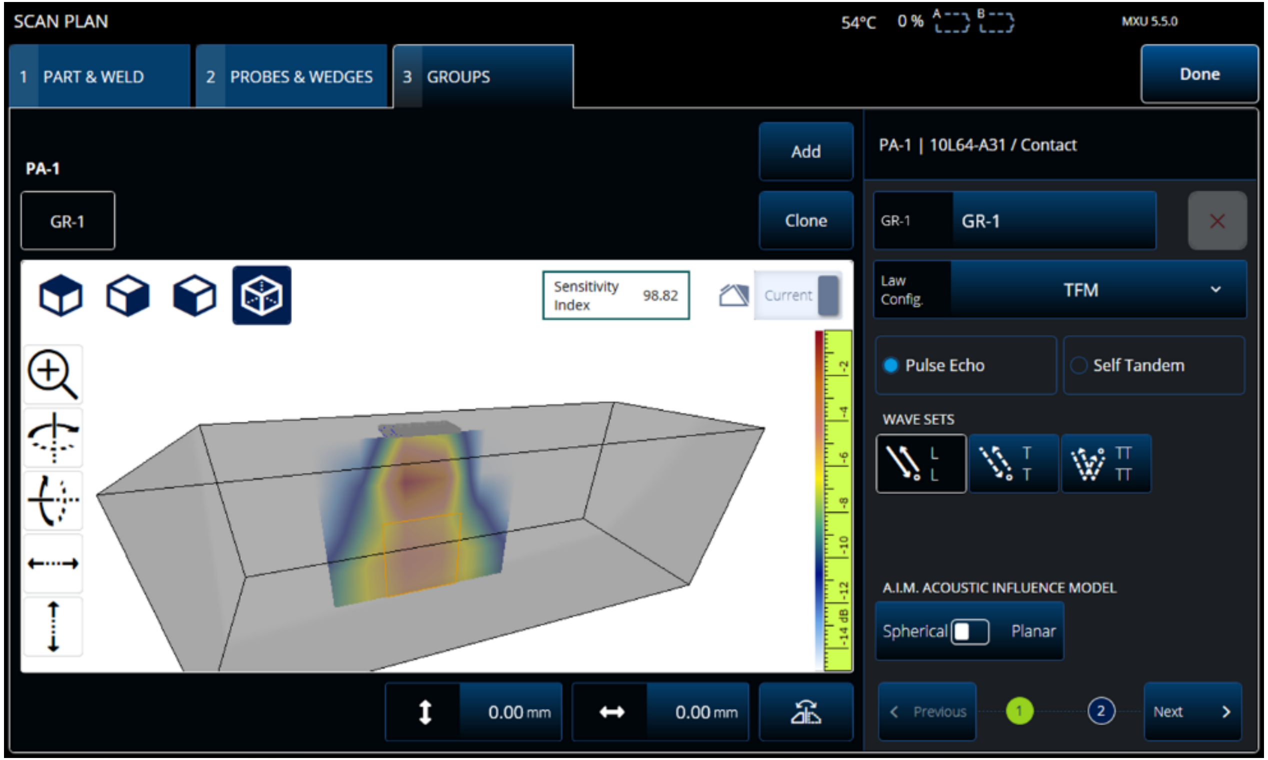




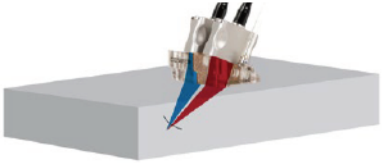
Study Case-1 (Plate)

FMC/TFM





Study Case-1 (Plate)

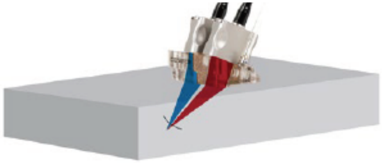


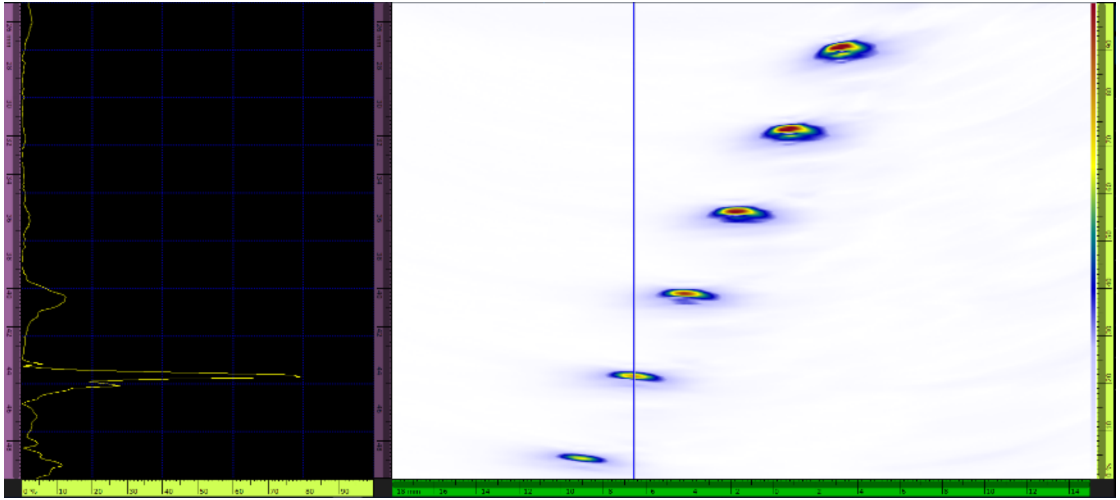
FMC/TFM

- **Sizing Block :** ASTM E2491 Sensitivity Block
- **Reflector :** Angled row of 12 holes at 1/16" (0.0625) diameter with 0.200" of separation between holes
- **Sensitivity :** %80 FSH
- **Reference Gain :** 21dB
- **Scanning Sensitivity :** 21dB+ 25dB

Study Case-1 (Plate)

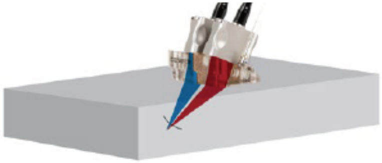
FMC/TFM

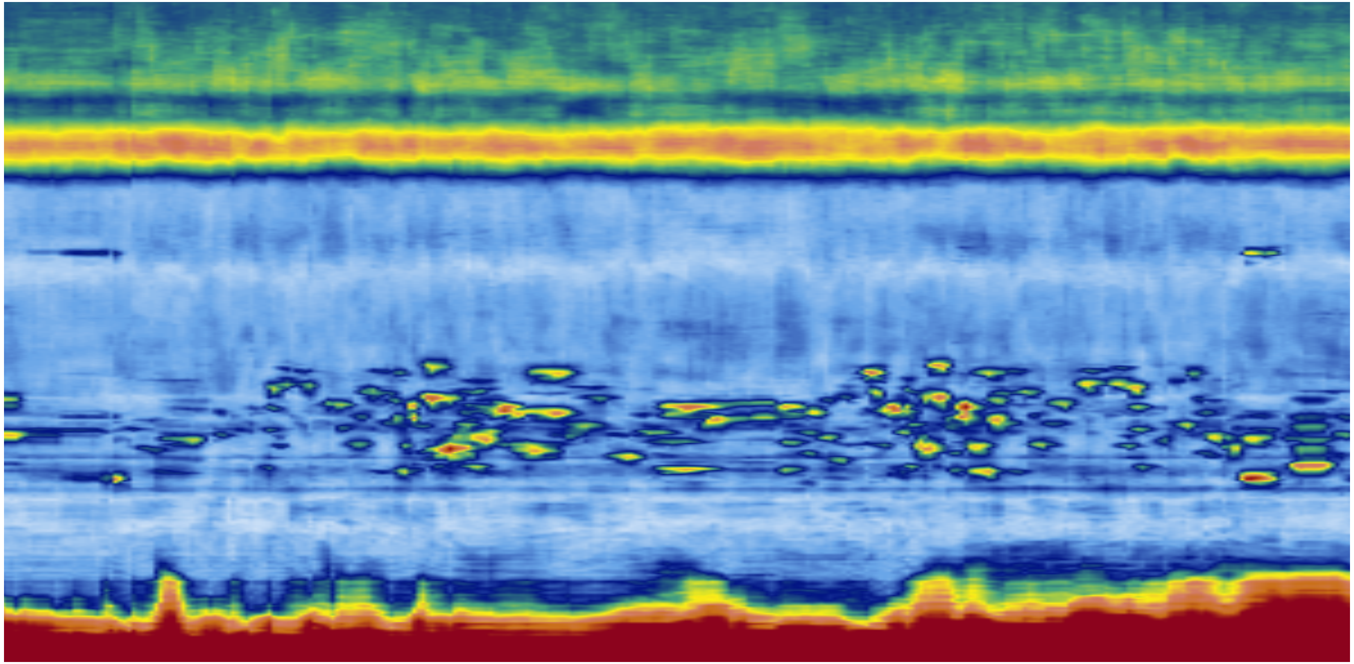




Study Case-1 (Plate)

FMC/TFM

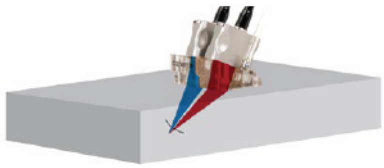


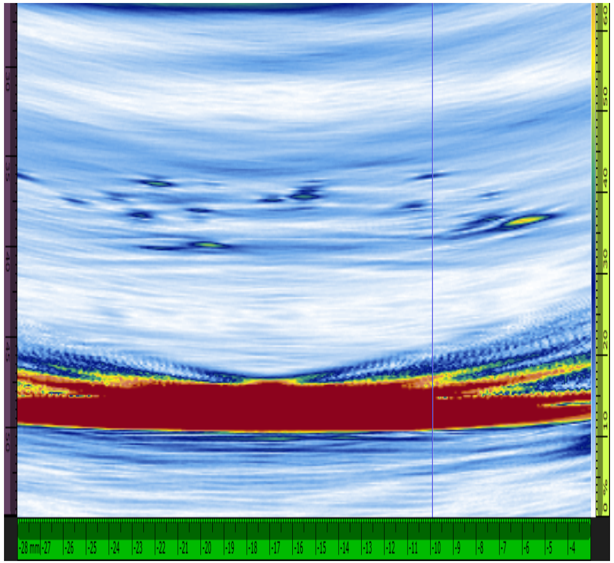


TFM , Side View

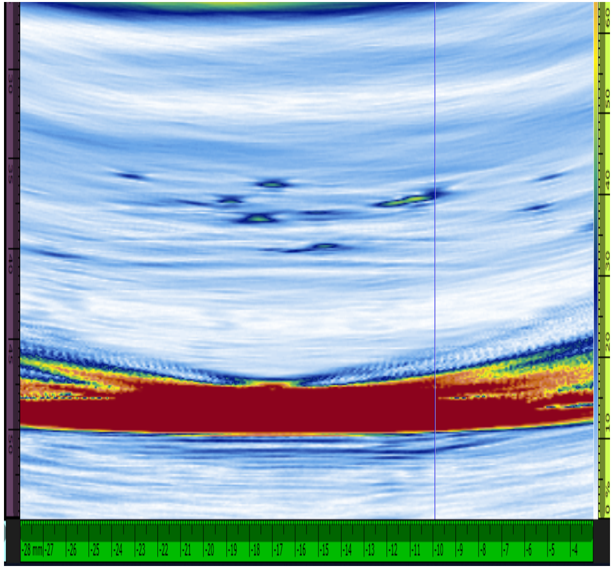
Study Case-1 (Plate)

FMC/TFM

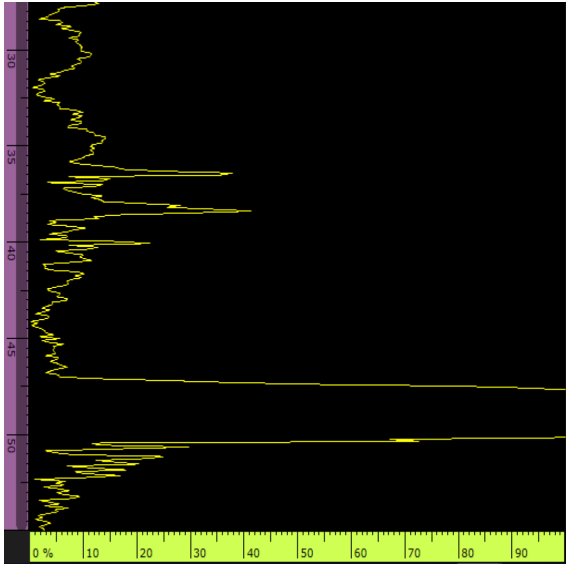




TFM , End View

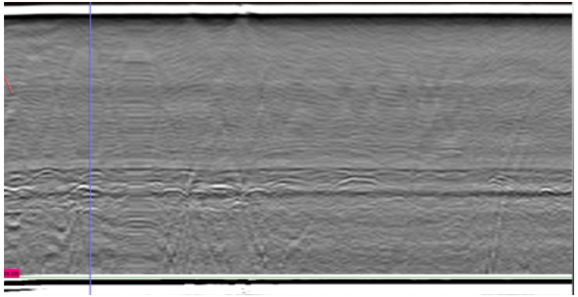


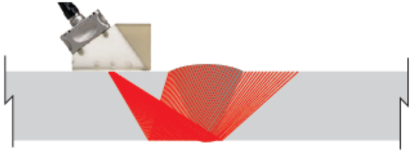
TFM , End View

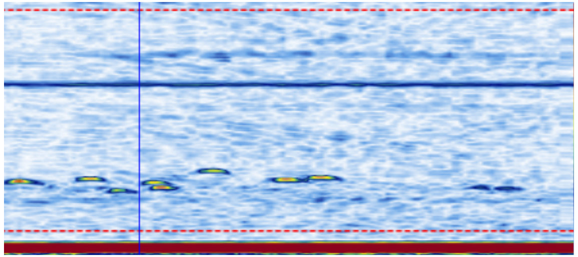


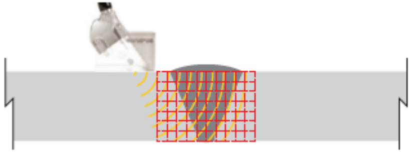
TFM , A-Scan

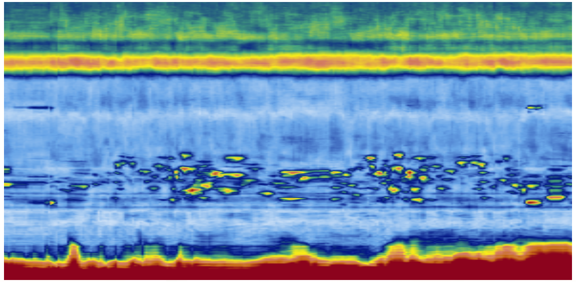
Study Case-1 (Plate)











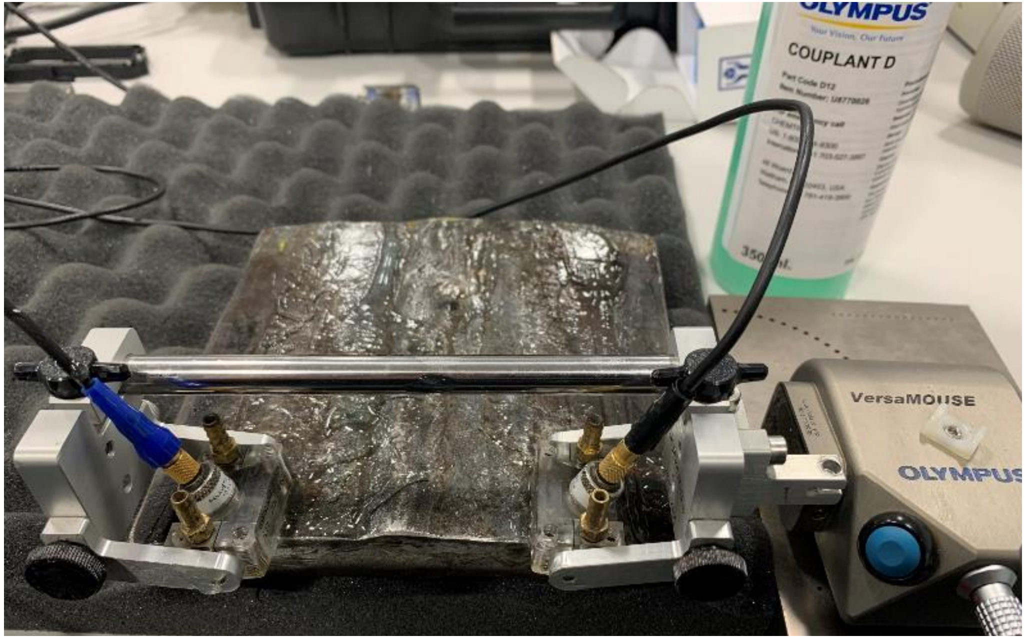
5

Study Case-2 (Weld)

Study Case-2 (Weld)

TOFD

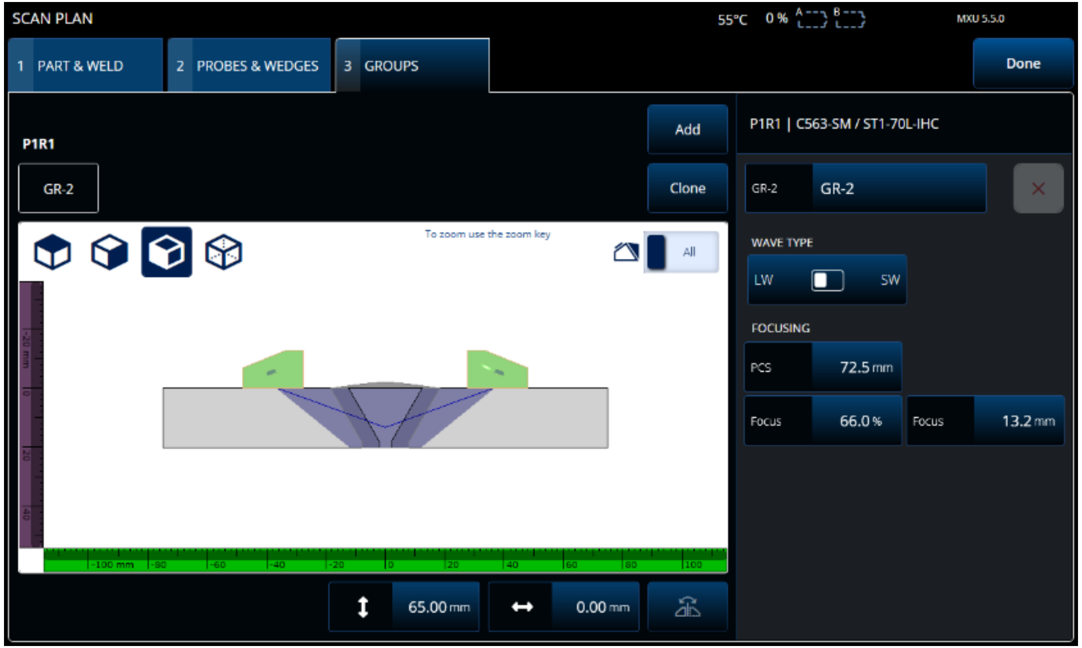
- **Probes :** C563-SM (10Mhz ,3mm)
- **Wedges :** ST1-70L-IHC
- **Scan Type :** Encoded
- **Scanner** : HST-X04
- **Part Thickness:** 20mm



Study Case-2 (Weld)

TOFD

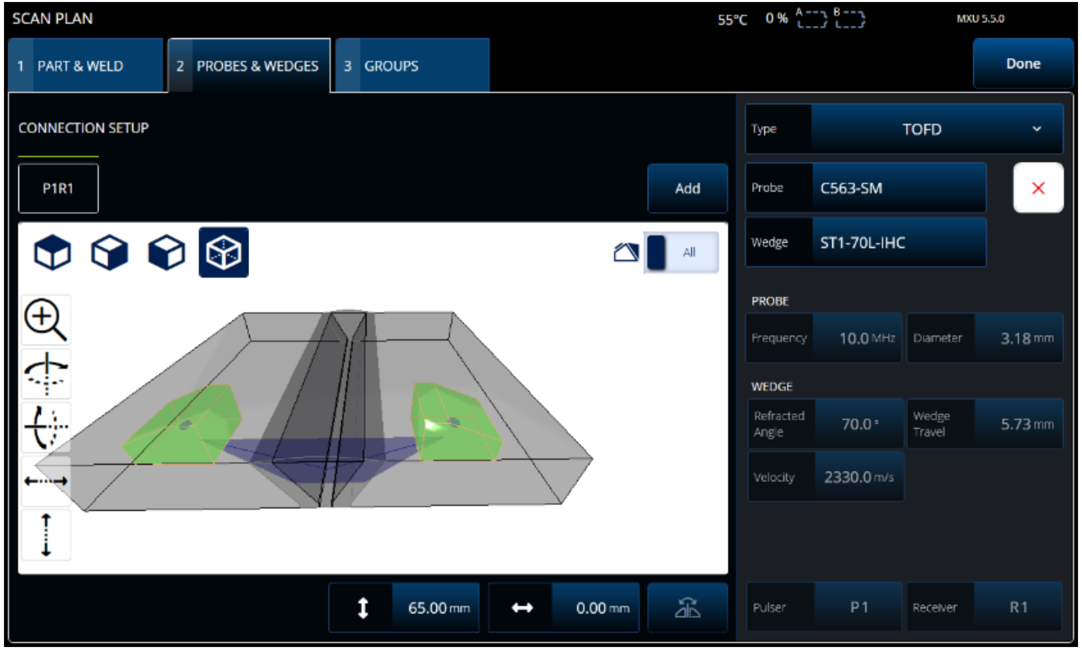
- **Probes :** C563-SM (10Mhz ,3mm)
- **Wedges :** ST1-70L-IHC
- **Scan Type :** Encoded
- **Scanner** : HST-X04
- **Part Thickness:** 20mm



Study Case-2 (Weld)

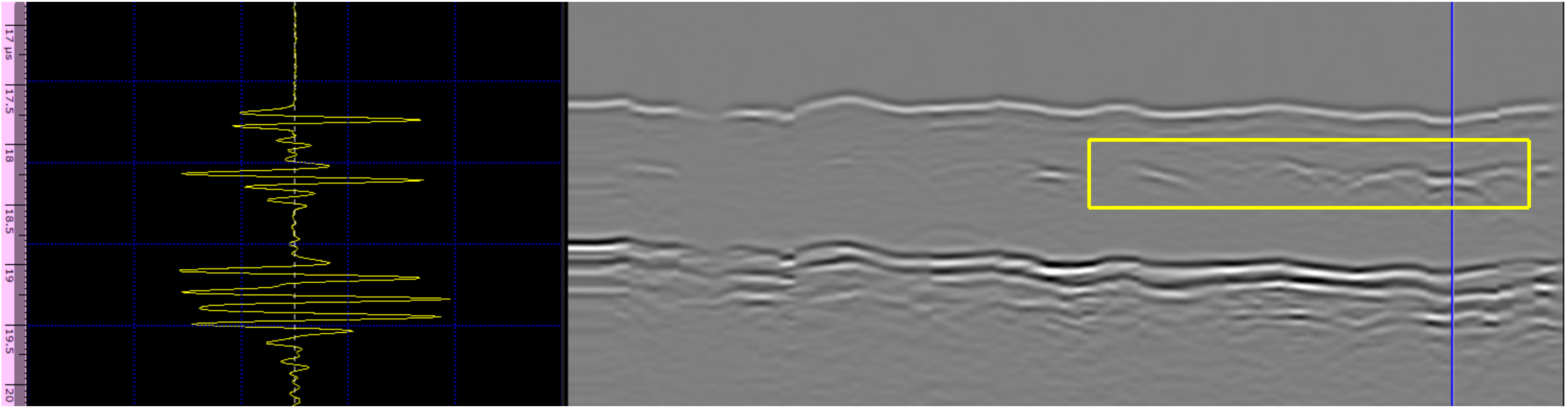
TOFD

- **Probes :** C563-SM (10Mhz ,3mm)
- **Wedges :** ST1-70L-IHC
- **Scan Type :** Encoded
- **Scanner** : HST-X04
- **Part Thickness:** 20mm



Study Case-2 (Weld)

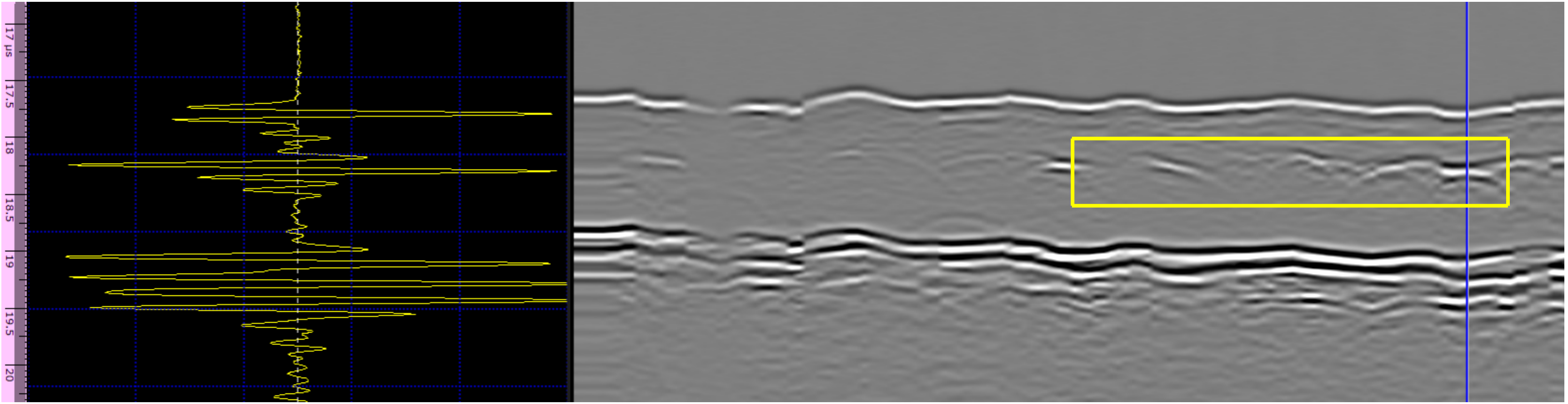
TOFD



%50 FSH Lateral Wave , No Filter , 63dB

Study Case-2 (Weld)

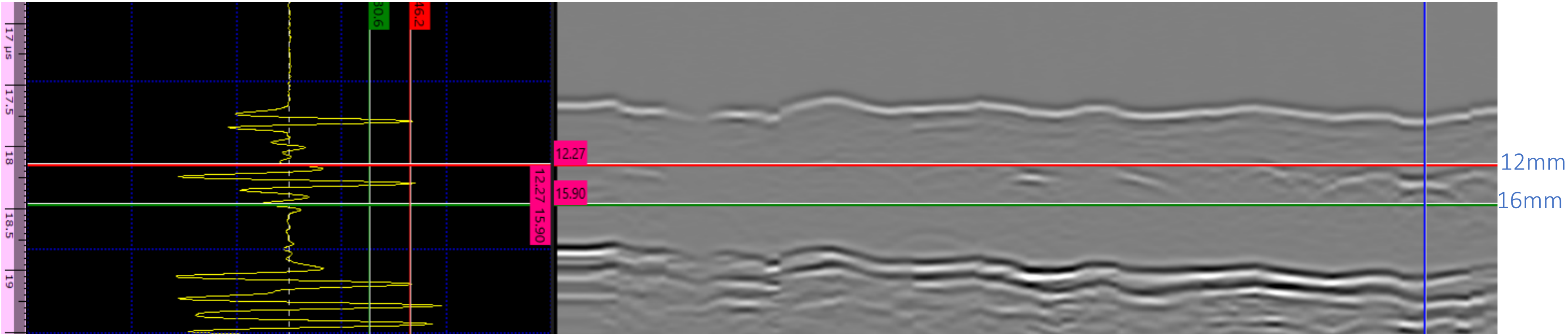
TOFD



%100 FSH Lateral Wave , No Filter, 69dB

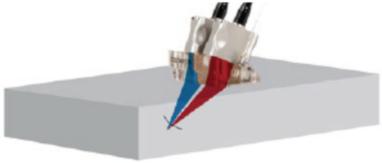
Study Case-2 (Weld)

TOFD



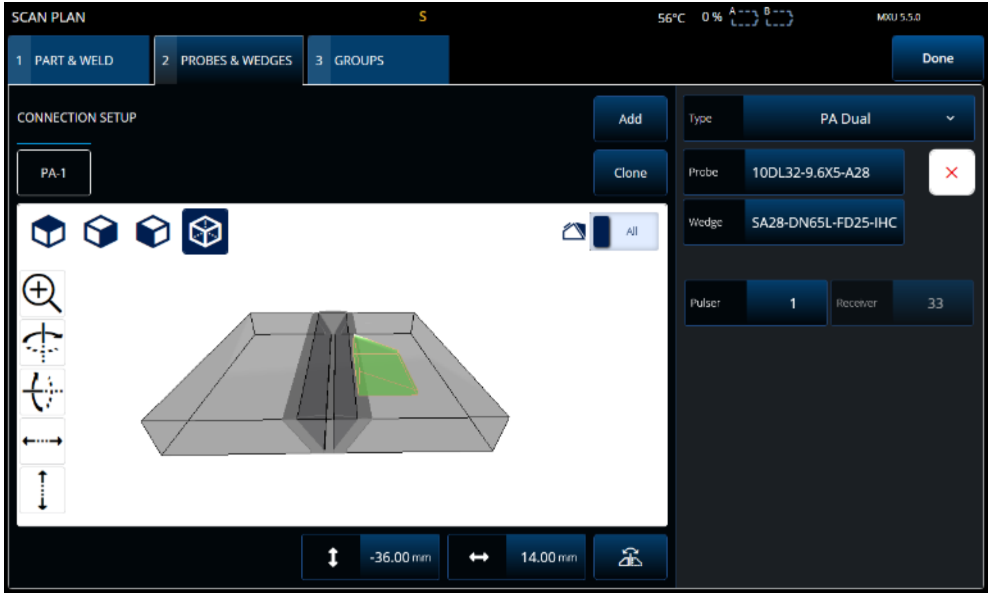
%50 FSH Lateral Wave , No Filter , 63dB

Study Case-2 (Weld)

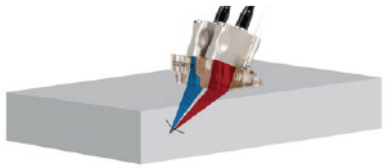


PAUT – DLA

- **Probes :** 10DL32-9.6X5-A28 (10Mhz, 0.31mm Pitch, Dual 32)
- **Wedges :** SA28-N65L-FD25
- **Scan Type :** Raster
- **Part Thickness:** 20mm

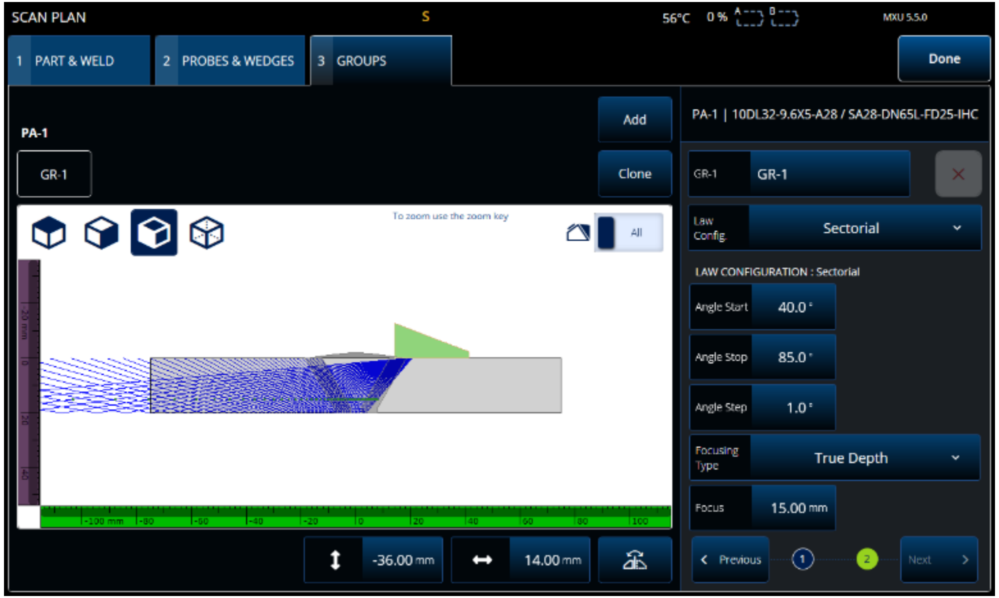


Study Case-2 (Weld)

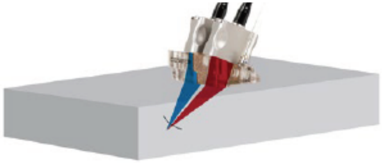


PAUT – DLA

- **Probes :** 10DL32-9.6X5-A28 (10Mhz, 0.31mm Pitch, Dual 32)
- **Wedges :** SA28-N65L-FD25
- **Scan Type :** Raster
- **Part Thickness:** 20mm

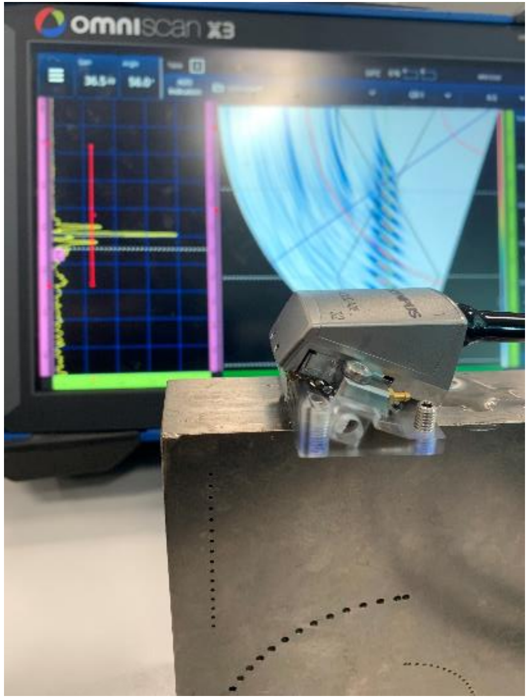


Study Case-2 (Weld)

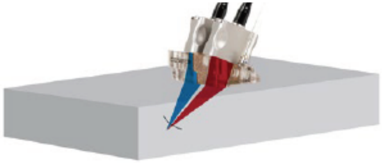


PAUT – DLA

- **Sizing Block :** ASTM E2491 Sensitivity Block
- **Reflector :** Vertical column of 16 holes at 0.040" diameter with 0.120" of separation between holes.
- **Sensitivity :** %80 FSH
- **Reference Gain :** 35.5dB
- **Scanning Sensitivity :** 35.5dB+ 16dB



Study Case-2 (Weld)



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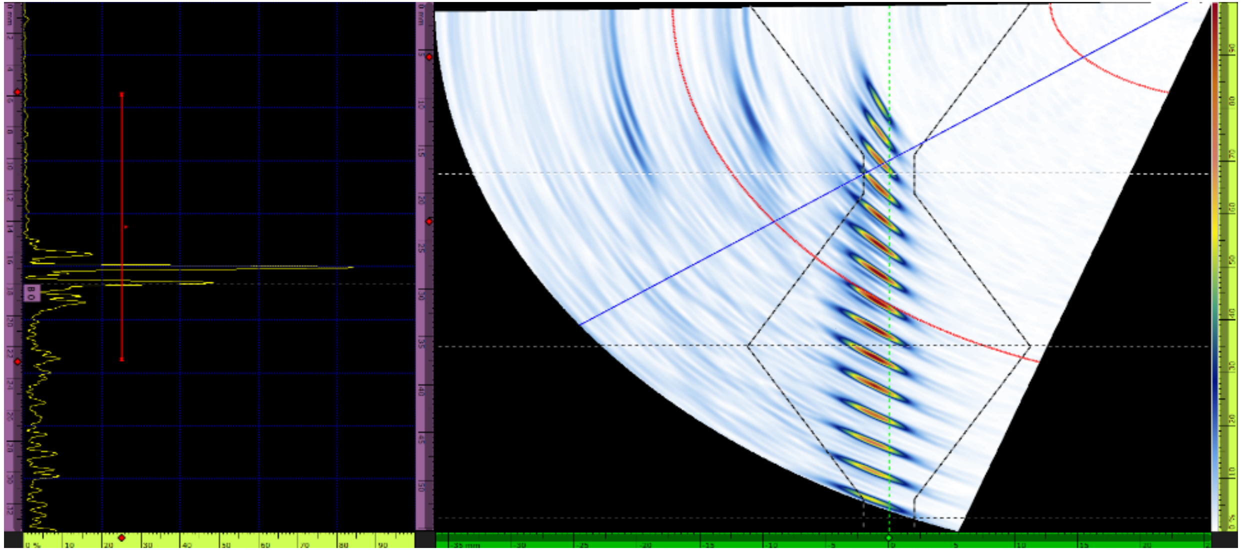
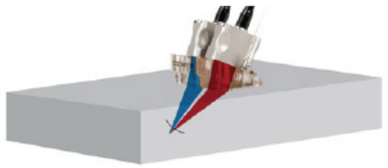
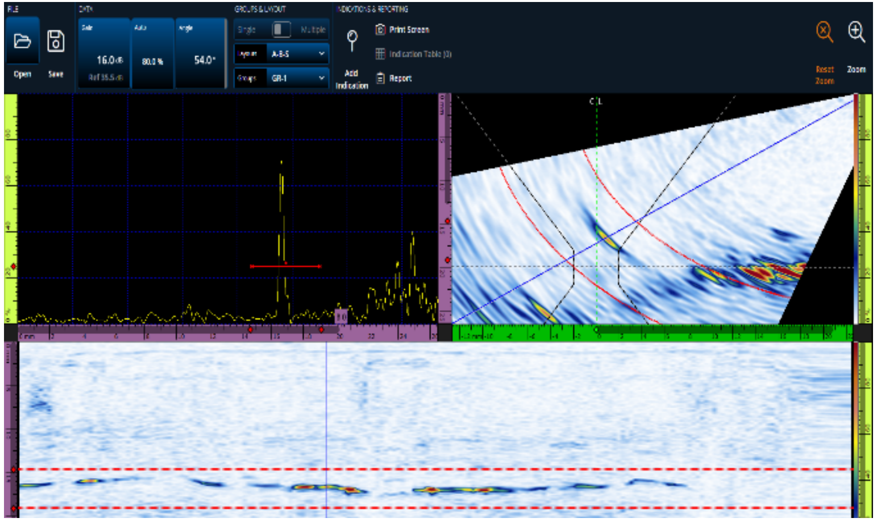


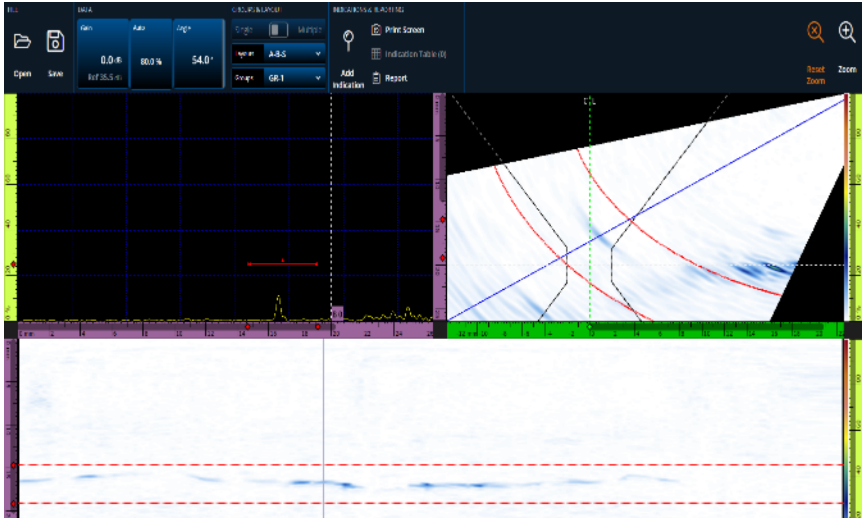
Study Case-2 (Weld)



PAUT – DLA



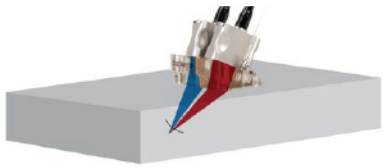
35.5dB+ 16dB

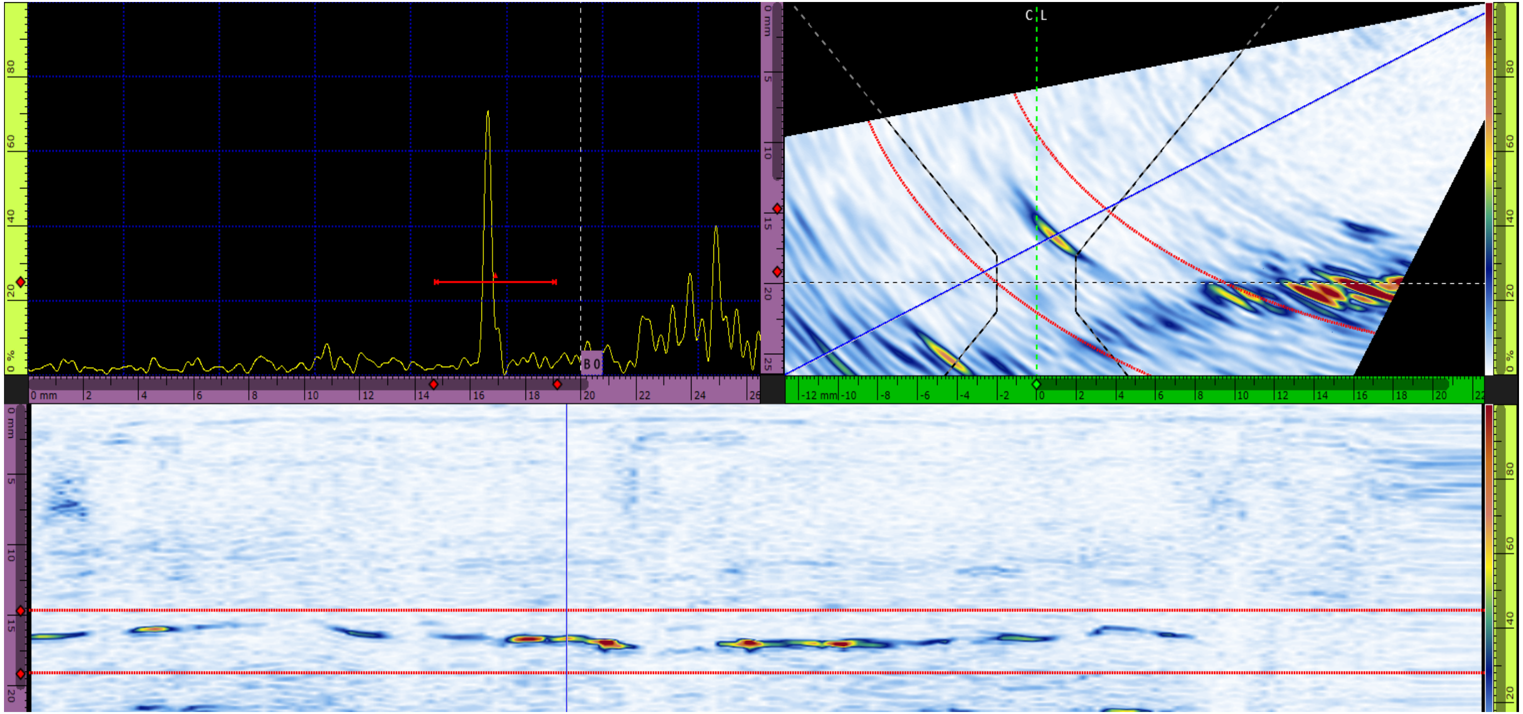


35.5dB

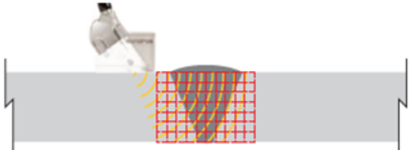
Study Case-2 (Weld)

PAUT – DLA



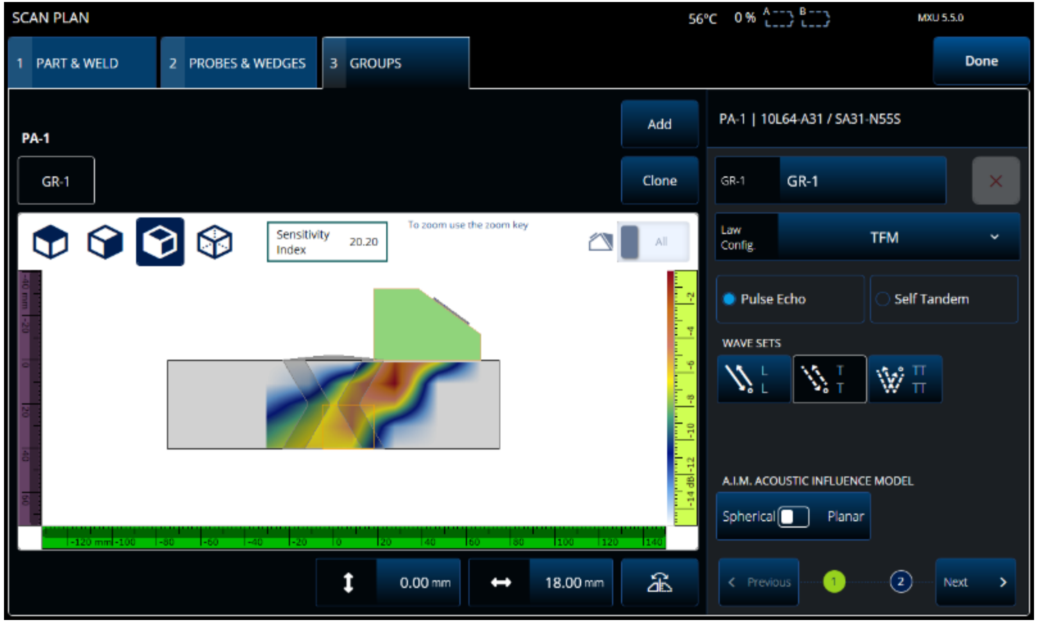


Study Case-2 (Weld)

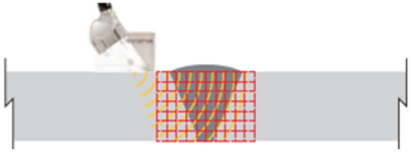


FMC/TFM

- **Probes :** 10L64-19.84X10-A31 (10Mhz, 0.31mm Pitch)
- **Wedges :** SA31-N55S
- **Scan Type :** Raster
- **Part Thickness:** 20mm
- **Wave Mode:** TT – Double Thickness



Study Case-2 (Weld)



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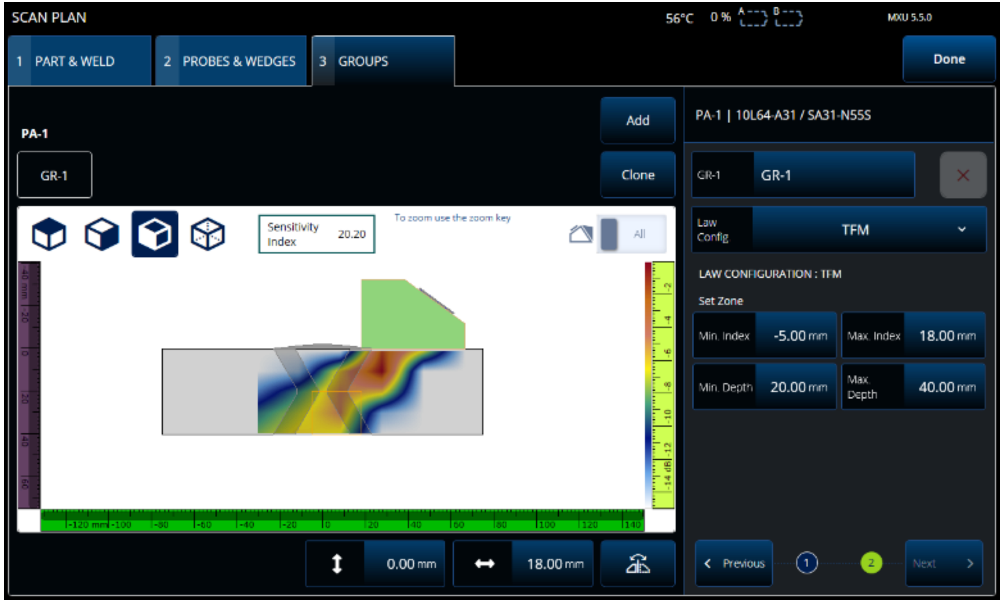
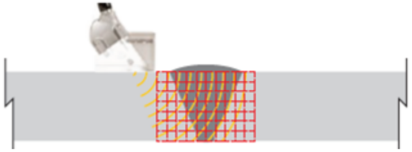
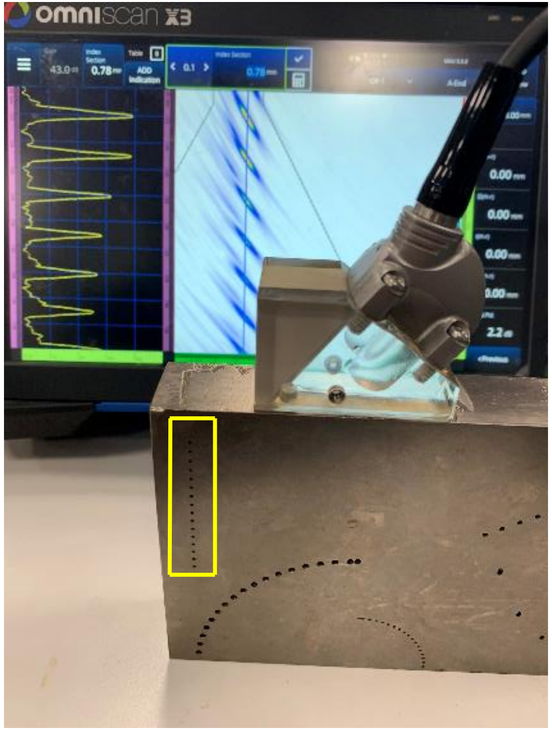


Study Case-2 (Weld)

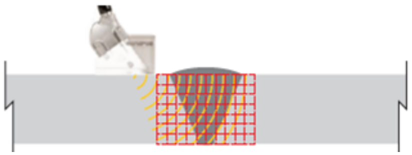


FMC/TFM

- **Sizing Block :** ASTM E2491 Sensitivity Block
- **Reflector :** Vertical column of 16 holes at 0.040" diameter with 0.120" of separation between holes.
- **Sensitivity :** %80 FSH
- **Reference Gain :** 43dB
- **Scanning Sensitivity :** 43dB+ 16dB



Study Case-2 (Weld)



FMC/TFM

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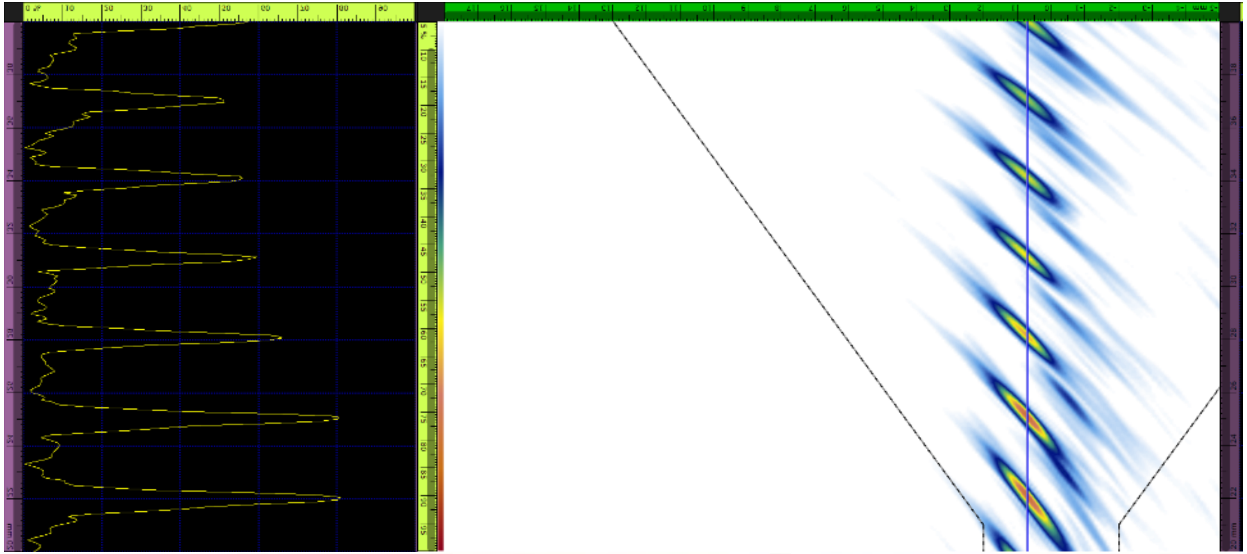
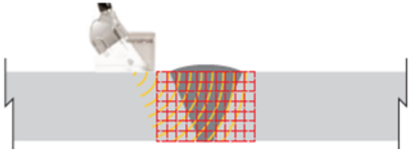
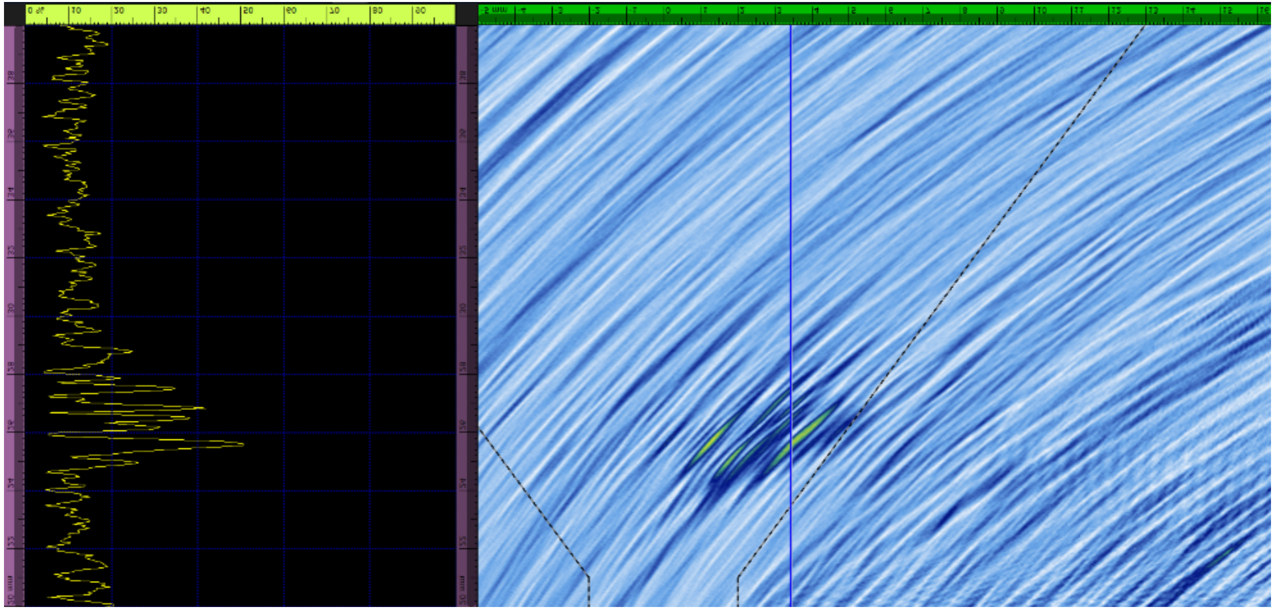


Study Case-2 (Weld)

FMC/TFM

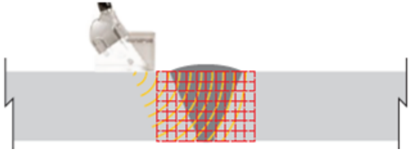


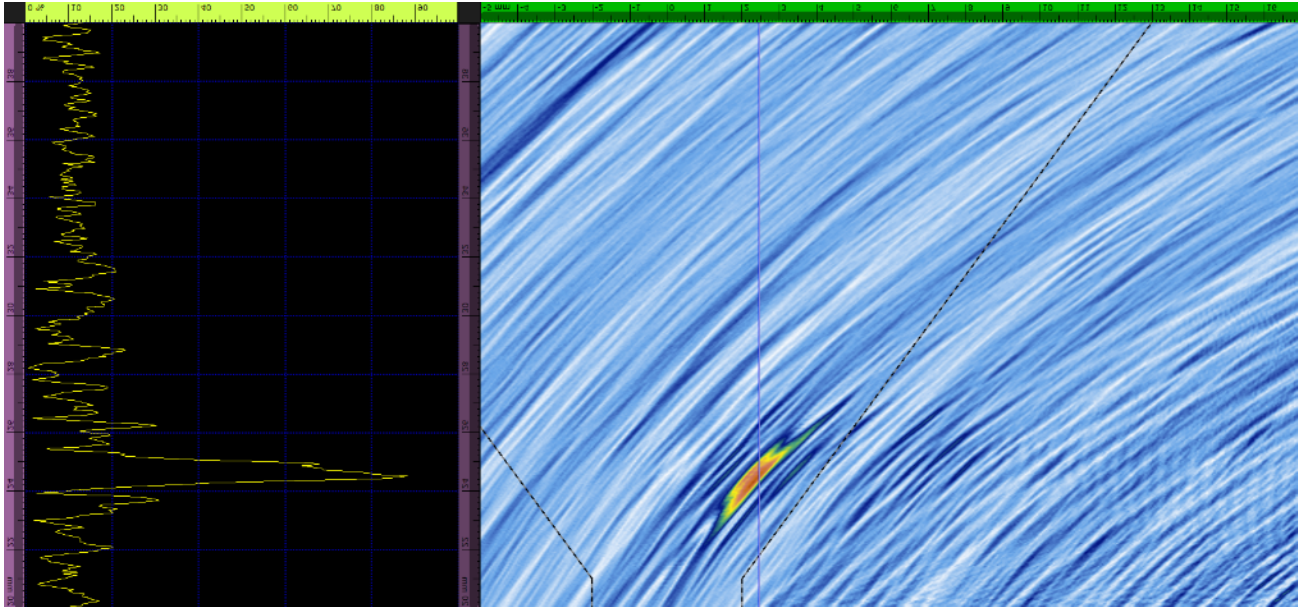


TFM T-T, A-End View

Study Case-2 (Weld)

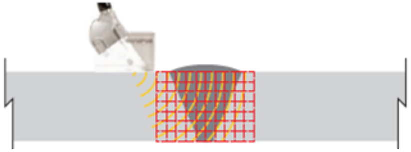
FMC/TFM



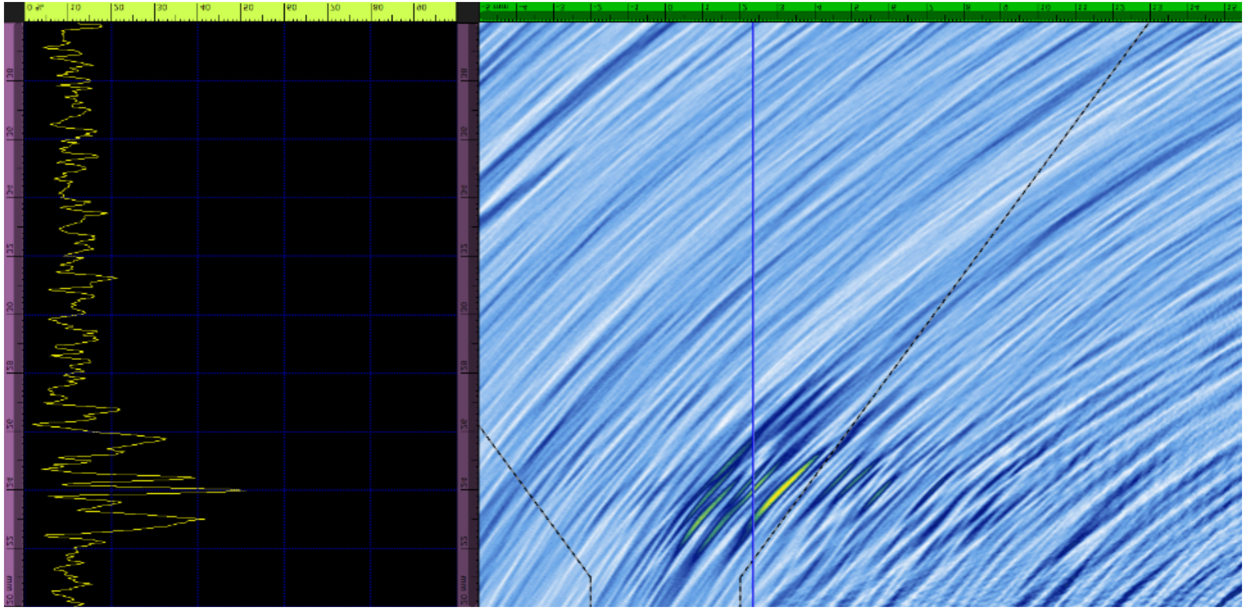


TFM T-T, A-End View

Study Case-2 (Weld)

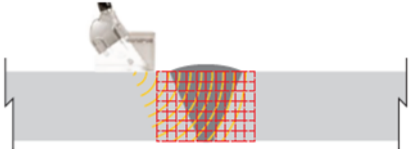


FMC/TFM

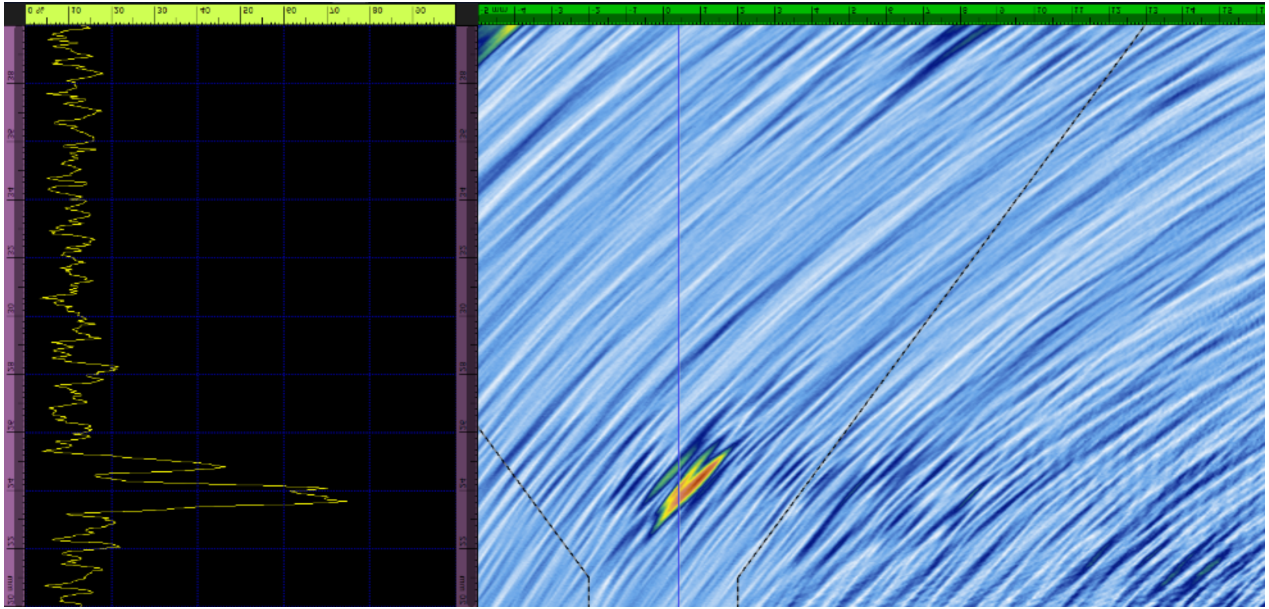


TFM T-T, A-End View

Study Case-2 (Weld)



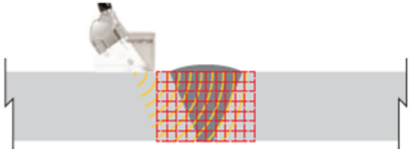
FMC/TFM

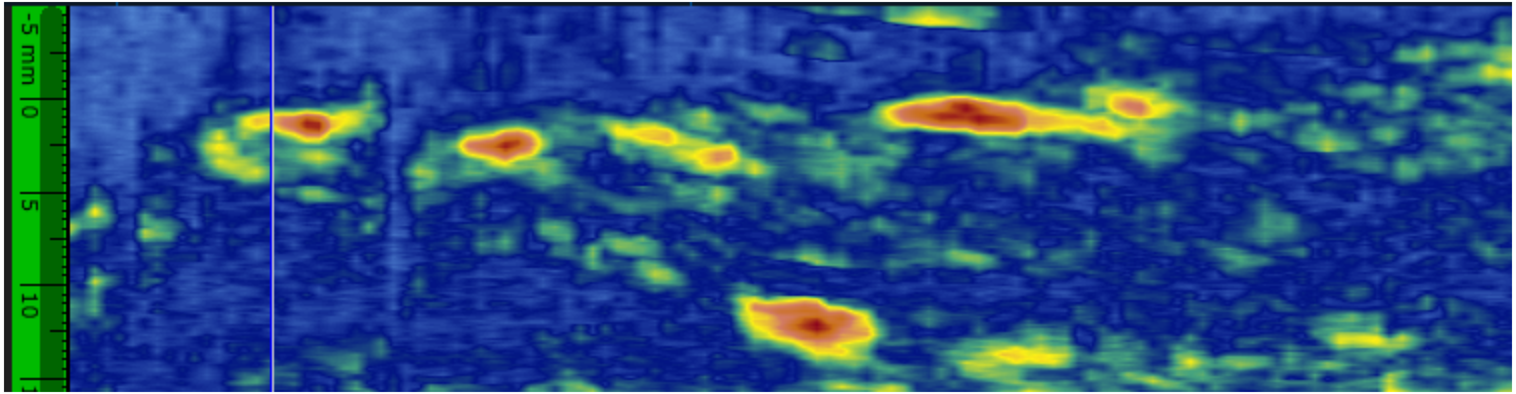


TFM T-T, A-End View

Study Case-2 (Weld)

FMC/TFM

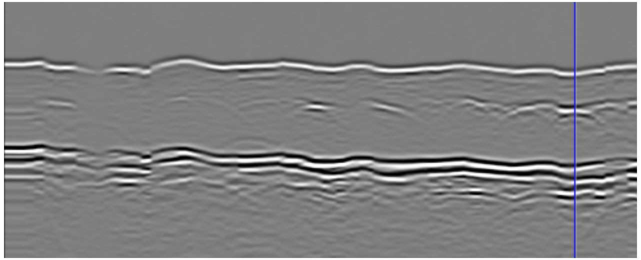


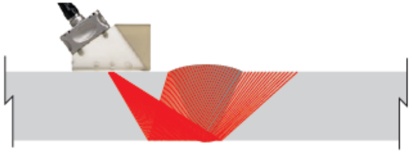


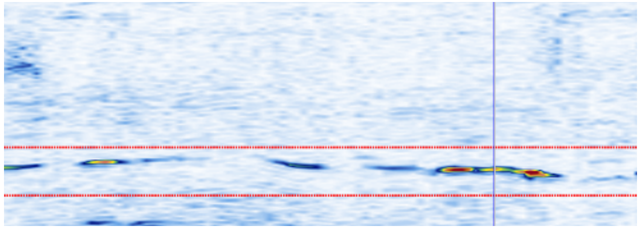
TFM T-T, Top View

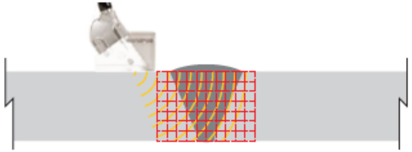
Study Case-2 (Weld)

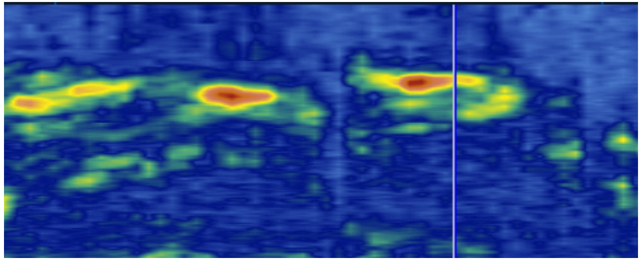
FMC/TFM











6

Conclusions

Conclusions

- TOFD detection capability usually effective
- TOFD is primary screening and exploring tool
- TOFD is limited for single side access
- PAUT focus needs to be adjusted carefully with information provided by TOFD (Depth)
- PAUT , DLA 10Mhz and A28 Probes are providing better SNR
- TFM is another confirming tool can provide better resolution
- TFM frame and wave mode needs to be selected carefully

- The fundamental principles of historical characterization techniques (backscatter signal pattern recognition, frequency spectrum analysis, and velocity ratio) are still applicable to further assist in indication characterization. These techniques can be applied on data collected from new techniques (TOFD, PAUT, and TFM) to improve capability and confidence for characterization between HTHA and other damage mechanisms.

7

Live Demonstration

8

Q&A

Additional Questions?

Contact:

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Thank you for participating!

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