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# Feasibility study of the characterization of planar defects in a circular weld with Total Focusing Method

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7. Conclusion

# Context

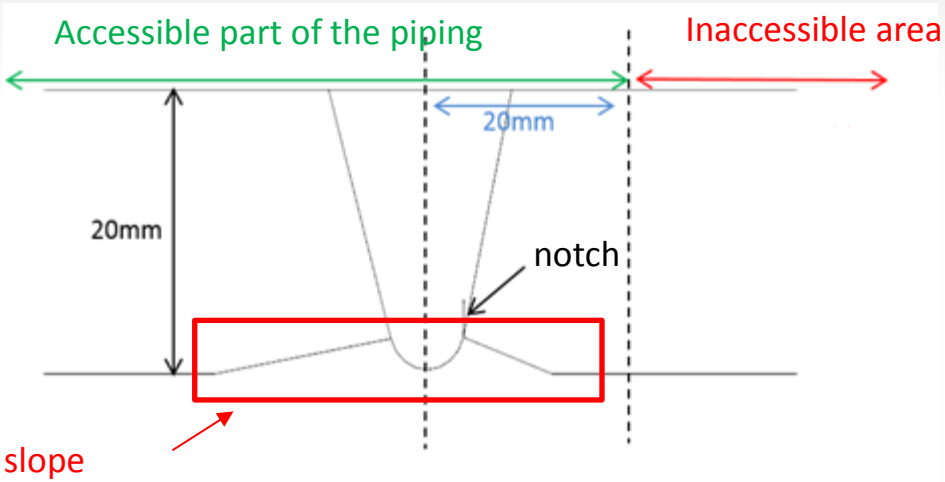
- Welded assemblies of the circuits of the Nuclear Power Generation Centers present various geometries.

- Some geometries have limited access for probes on one side of the weld
  → Area coverage or characterization limitations

- Objectives :
  - Investigate in a technological watch context the interest of the Total Focusing Method in these configurations
    - Detection
    - Characterization (volumic or planar defect)
    - Artifact/defect discrimination
    - Height sizing

# Problematic

- Knowledge of the profile necessary for:
  - Reconstruction and interpretation of the results




Optimization of control parameters and post-processing options by CIVA simulation

Artifacts

Characterization problems
+
artifact / default discrimination

Interest of the TFM?

# Experimental set-up

## Specimens

- Machined mock-up :
  - Ferritic steel
  - EDM notches ( from 1.5mm to 8mm height)
- Piping sample:
  - Ferritic steel
  - Complex 3D geometry
  - Thermal fatigue crack close the weld bead


## Probe/Acquisition system

- Probe : 64 elements with 0,6mm pitch
- Frequency: 5MHz
- Acquisition System: MultiX from M2M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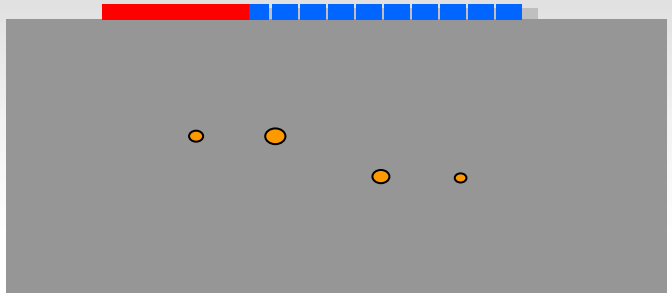
# TFM imaging: principle

❑ Step 1: FMC (Full Matrix capture) acquisition

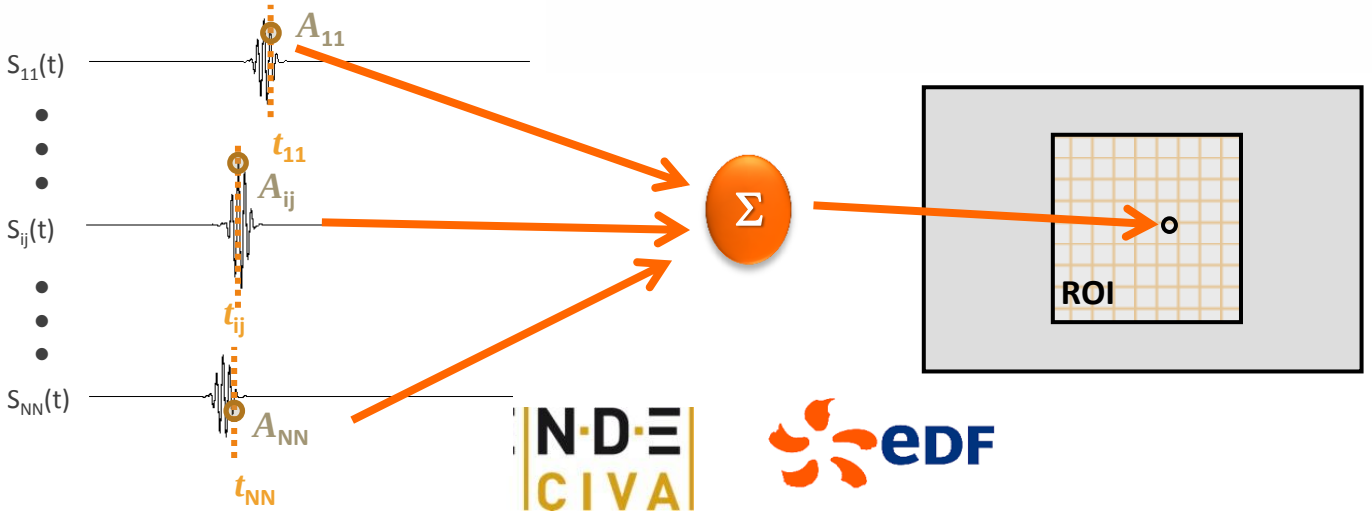
- 1 element for transmission, N elements for reception
- Acquisition of a NxN matrix



❑ Step 2 : TFM imaging reconstruction

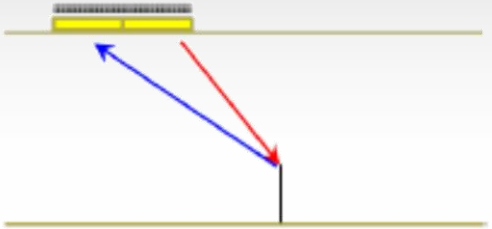
- A posteriori **focusing** by coherent **summation** of all received signals $S_{ij}(t)$ for all points $P$ of the zone to be imaged.

**Algorithm :** $T_{ij}(P)$ time of flight calculation for all transmit/receive couples $(i;j)$

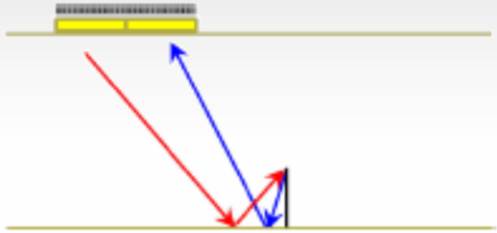


# Reconstruction modes

*Direct path*



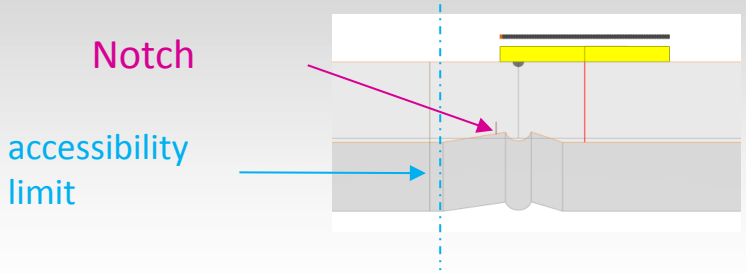
*Indirect* path



*Corner echo* path

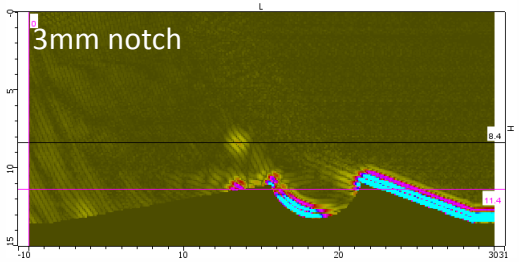
- Suited for planar defects
- Reconstruction along the entire length

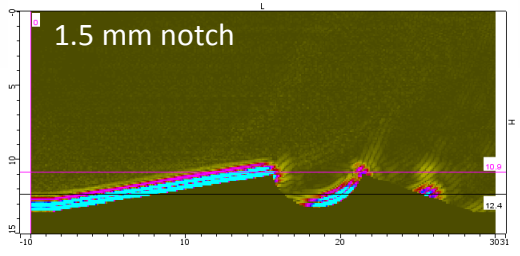
# Machined mock-up: Results in *direct* mode



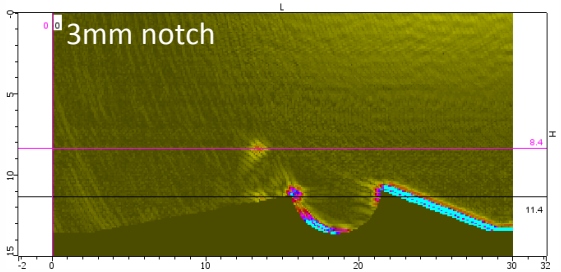

Probe's aperture does not fully cover the area to be controlled

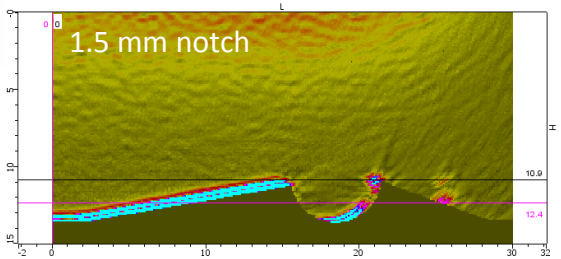
**Simulation**




**Experiment**



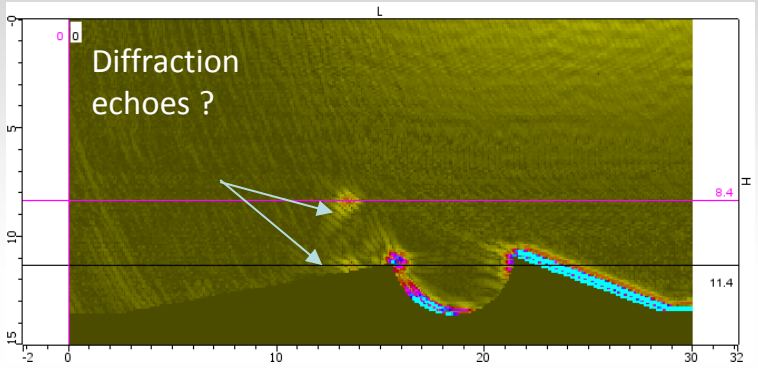

| Notch # | Theoretical height | LL simulated height (mm) | LL expermental height (mm) |
|---|---|---|---|
| 1 | 3 | 3 | 3 |
| 2 | 1.5 | 1.5 | 1.4 |

Detection and height dimensioning are possible.

Good estimation of the height of the defect

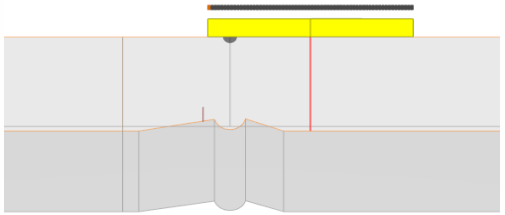
Good agreement between simulation and experimental results

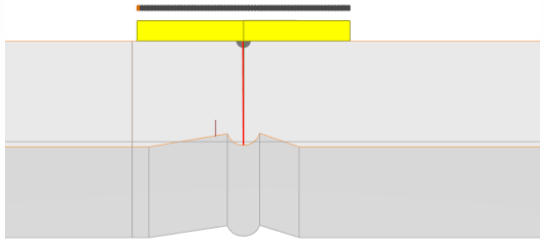
# Machined mock-up: characterization in *direct* mode

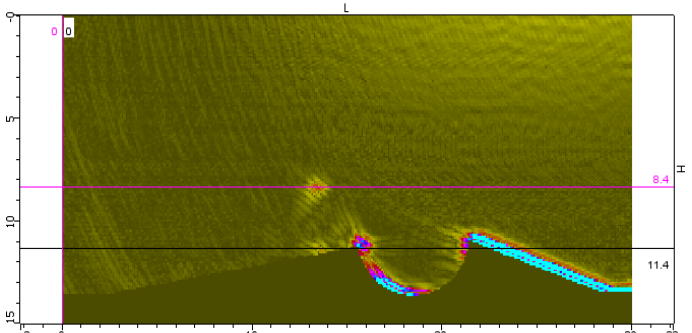


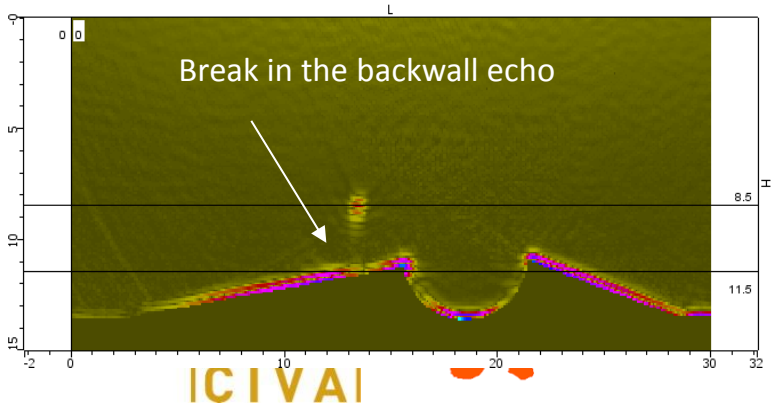

Do the echoes observed belong to a planar defect or an inclusion-type volume defect?

➡ Verification in *direct* mode by displacement the probe aperture







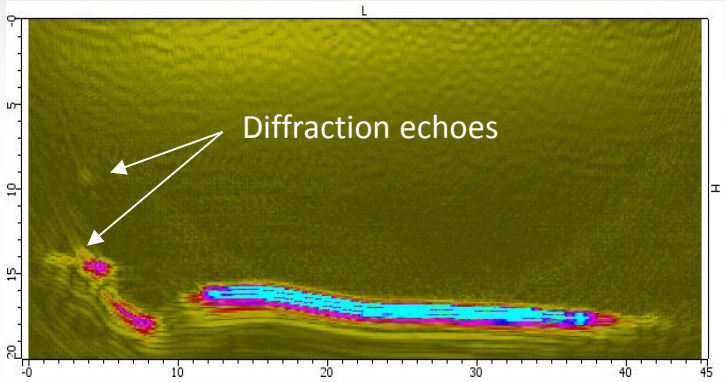

The break in the backwall echo associated with the diffraction echo indicates the presence of a breaking planar defect

# Piping sample: characterization in *direct* mode

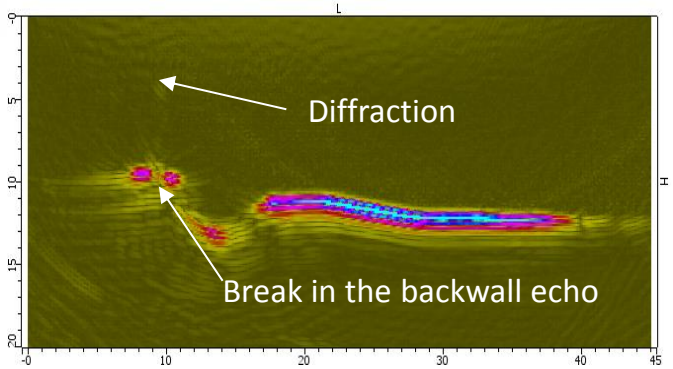
Experimental measurement on the cracked coupon show that TFM allows detection and characterization of a fatigue crack in *direct* mode

The measured height is equal to the actual height of the crack ± 0.2 mm (height = 5mm)

Experiment – crack outside the probe aperture




Experiment – crack below the probe aperture

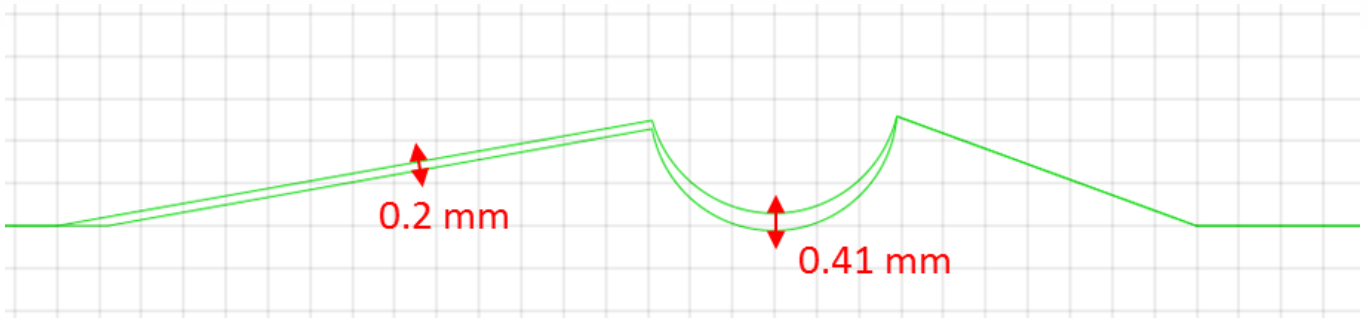


# Results in *corner echo* mode - profile reconstruction

- The knowledge of the backwall profile is necessary for accurate reconstruction of the TFM image in *corner echo* mode

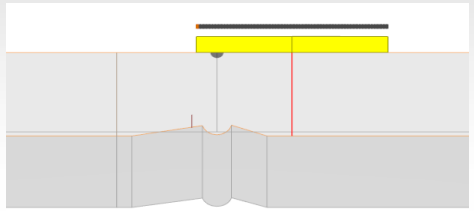
- CIVA allows recontruction of specimen profile with TFM imaging
  - Provides good results when the probe/specimen coupling is good and when the geometry to be reconstructed is 2D

*Comparison of theoretical and reconstructed mock-up backwall profile*

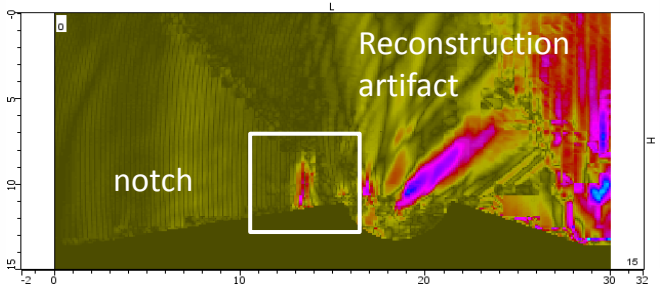


# Machined mock-up: results with *corner echo* mode

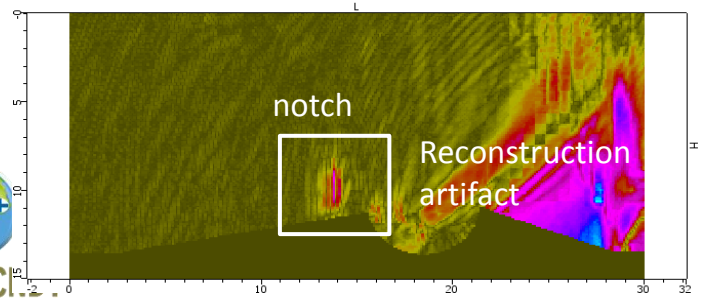
3mm notch



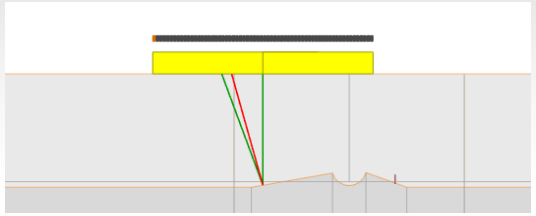
**Simulation**



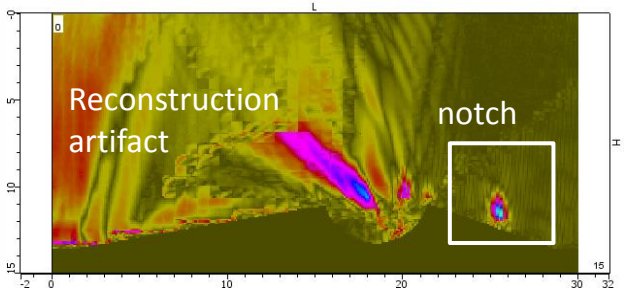

**Experiment**



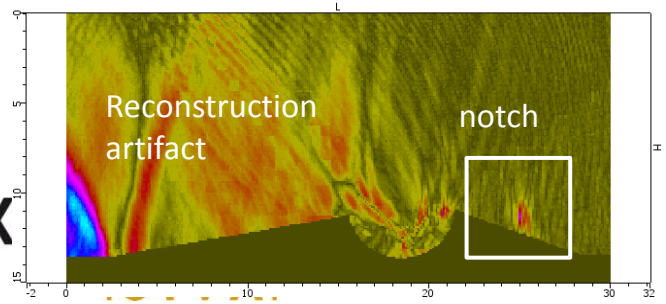

1.5 mm notch



**Simulation**




**Experiment**




Determination of the most relevant reconstruction mode by simulation → LTdT

Good estimation of the notch height

Good agreement between simulation and experiment

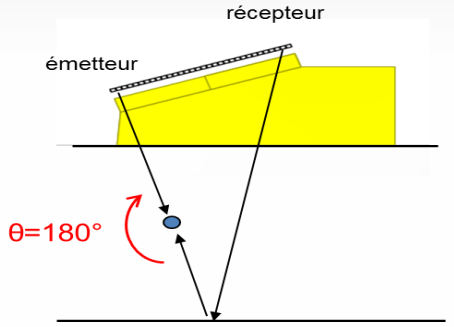
-6 dB drop amplitude sizing: OK

# Artifact filtering

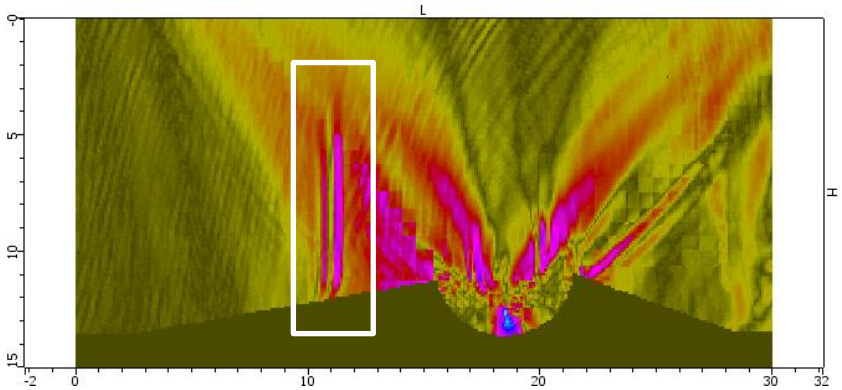
**Artifact filtering:**

- Option available since CIVA 2016
- Filters artifacts due to bad reconstruction of the backwall echo in corner echo mode reconstruction
- Elimination of the paths without physical sense

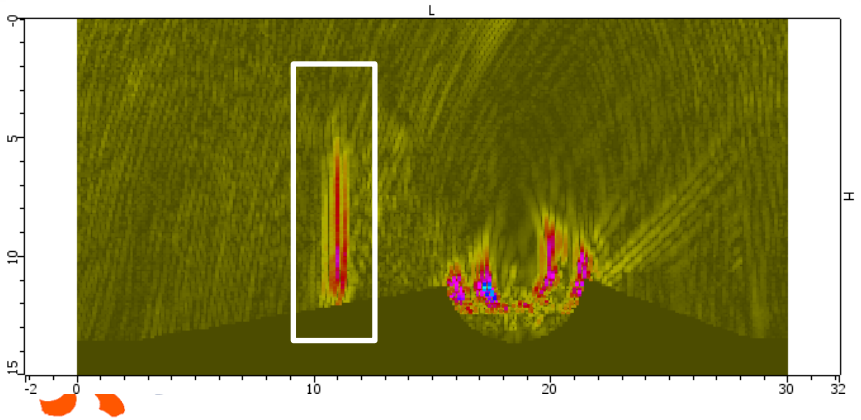
$$f(\theta) = \cos^2(\theta/2) = \frac{1+\cos(\theta)}{2}$$



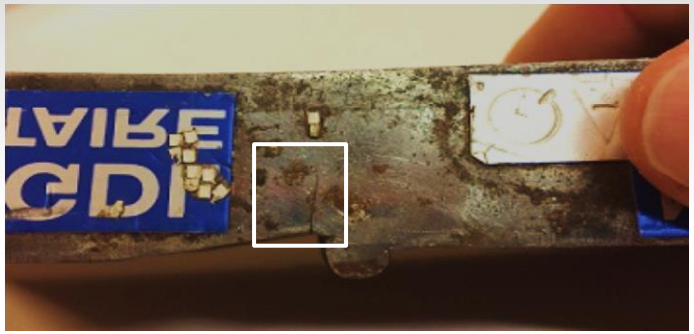

**Without articfact filtering**



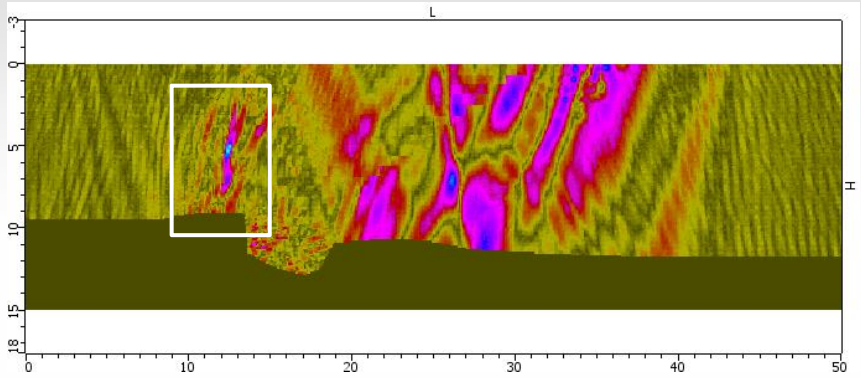

**With artifact filtering**



# Piping sample: results in *corner echo* mode



**Without artifact filtering**




Presence of an acoustic signature at the crack position

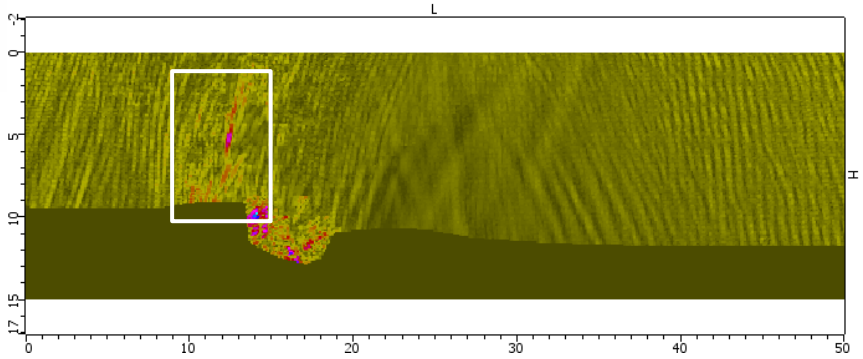
Reconstruction less « clear » than the one from the EDM notch

→ Complex geometry (twisted component)

→ Coupling probe/specimen non-optimal

Characterization is possible but trickier

**With artifact filtering**



# Conclusion

- Implementation by simulation and experimental validation of an advanced methodology to detect and characterize thermal fatigue cracks with CIVA

- Good agreement between simulation and experiment
  - Detection :
    - In LL mode
    - Observation of the diffraction echo or rupture of the backwall echo

  - Characterization :
    - In LL mode : observation of the top diffraction echo + rupture of the backwall echo
    - In LTdT corner echo mode : reconstruction of the flaw on its entire height

# Thank you for your attention