SIMULATION STUDY TO IMPROVE THE DETECTION OF PLANAR DEFECTS LOCATED UNDER SHRINKAGE CAVITIES

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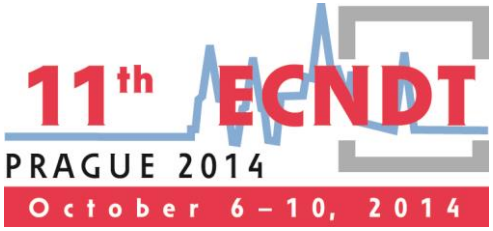
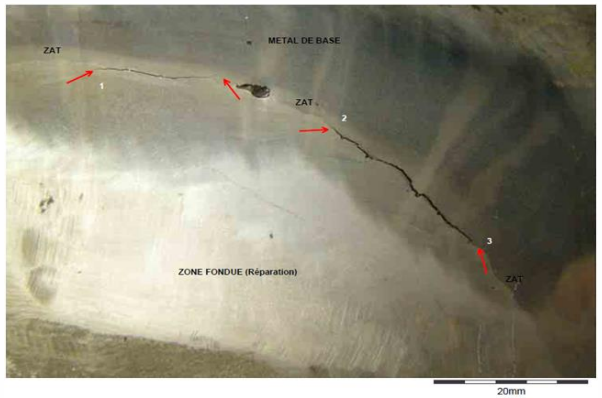


Outline

- Context and objectives
- Inspected component and flaws to detect
- Evaluation of a single element ultrasonic conventional control
- Evaluation of the phased array technology
- Contribution of the Total Focusing Method (TFM)
  - Principle
  - Direct mode imaging
  - « Corner mode » imaging
- Conclusion

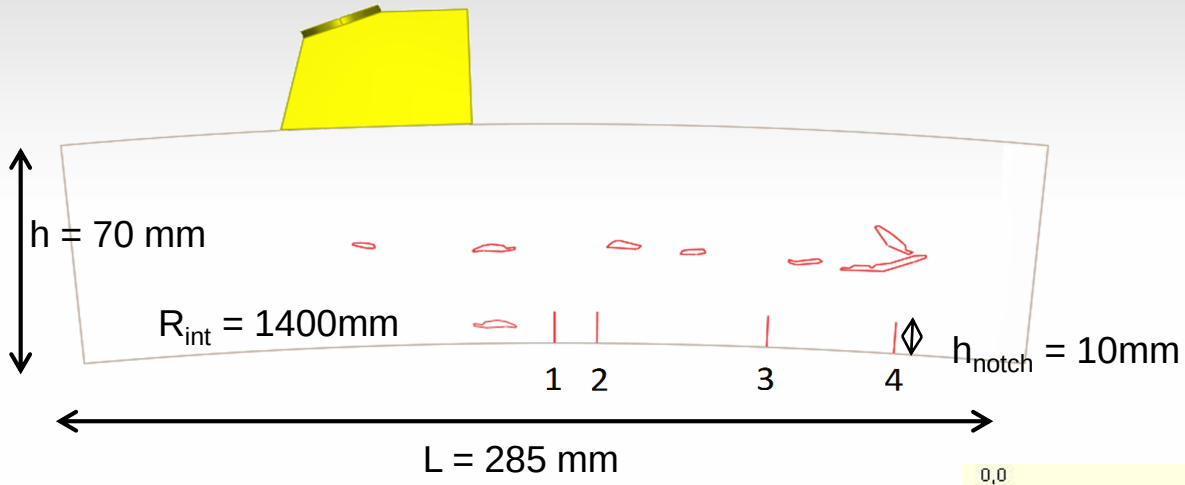
Context and objectives

- Conventional hydraulic and thermal production plants of EDF:
  - Many ferritic cast steel parts
  - Subject to high stresses and constraints : water pressure, corrosion damage, thermal fatigue,…
- Ultrasonic NDT:
  - Detection of flaws likely present since manufacturing: shrinkages
- Shrinkages:
  - Present as networks
  - Harmless
  - Located at mid-thickness
  - → shadowing of backwall breaking surface planar defects which may be critical



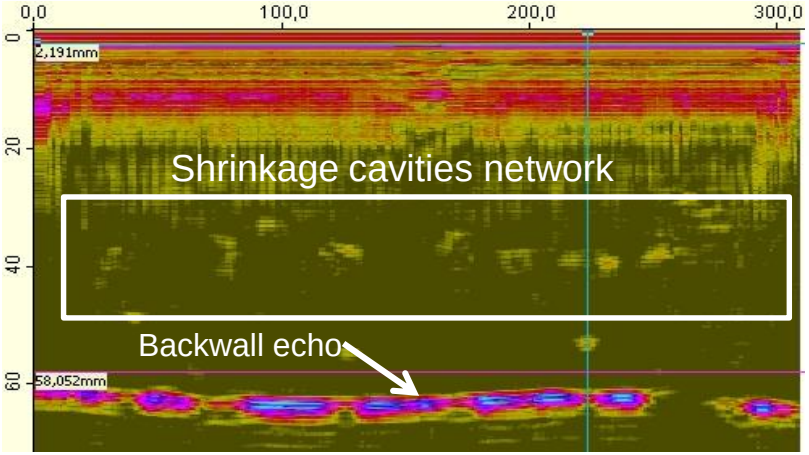
Objective : Feasibility of an ultrasonic control for notches detection despite the shrinkage cavities network.

Inspected component and flaws to detect



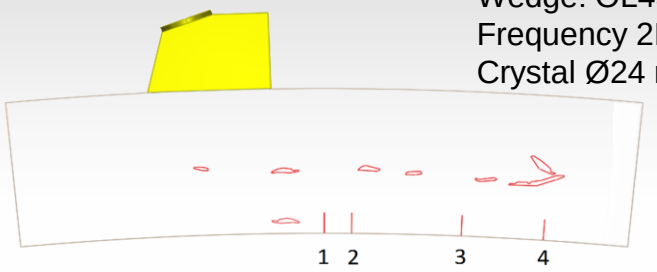
Isotropic ferritic steel
V_L = 5900 m/s
V_T = 3230 m/s

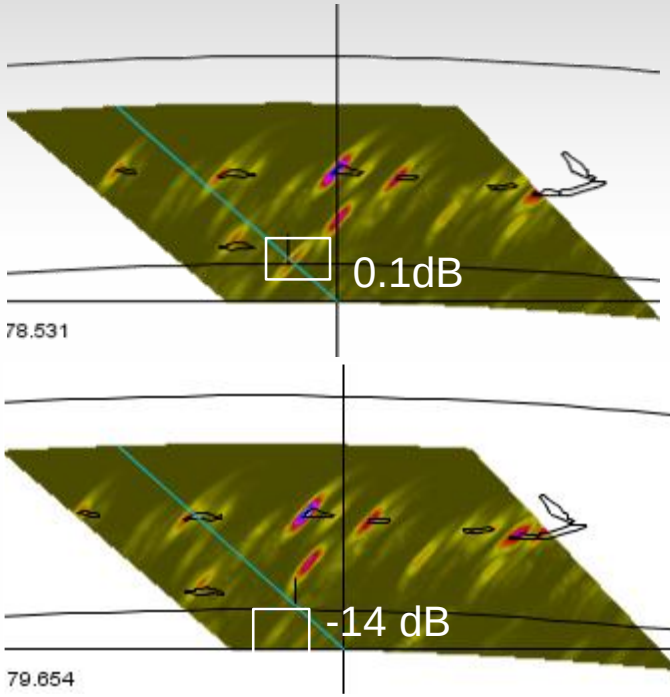
Porosities defined by -6dB contour tracing from echoes recorded on an acquisition performed at EDF-DTG with 1D smart flexible 2MHz phased array probe used in manual mode



Evaluation of a single element ultrasonic conventional control

Single element probe:
Wedge: OL45°
Frequency 2MHz
Crystal Ø24 mm





position 1

position 2

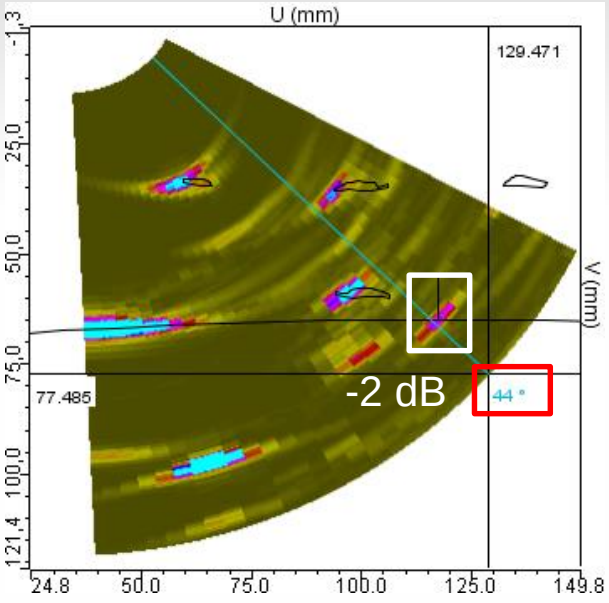
- Position 1 :
  - Well detected notch
  - Corner echo well positioned
- Position 2 :
  - Poor notch detection (-14 dB)
  - Bad positioning of the corner echo

The porosities mask the notch located at position 2 but not at position 1.

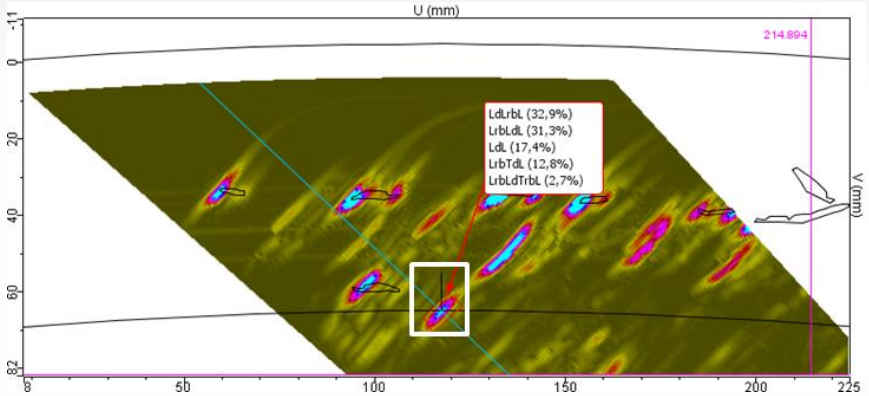
OL45° inspection with single element probe cannot ensure notch detection for all positions under the shrinkage cavities network.

Evaluation of the phased array technology

Position 1



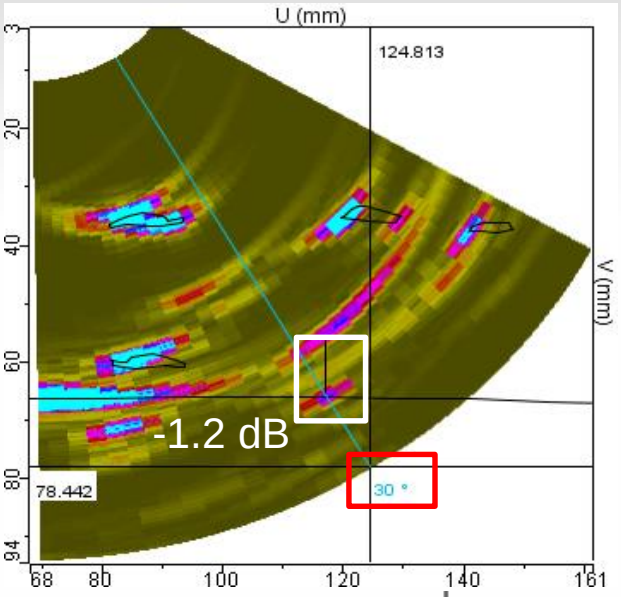
Phased array probe: OL45° wedge, 48 elements, Pitch 0.8mm, Frequency 2.25 MHz



- As for OL45° single element probe inspection, the phased-array transducer allows good detection of the notch.
- The detection is optimized for OL44° inspection.

Evaluation of the phased array technology

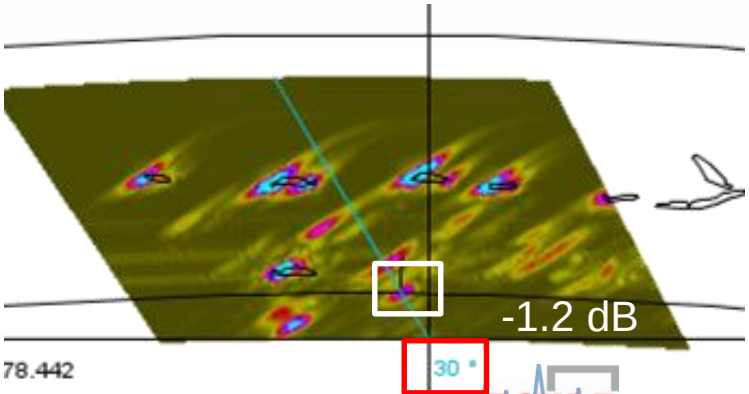
Position 2

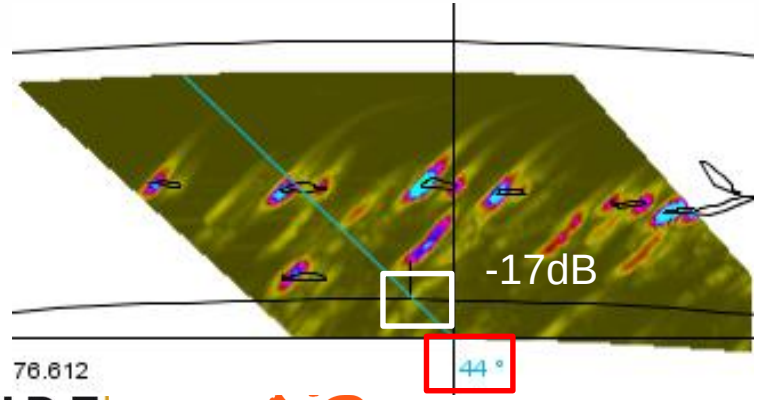


Phased array probe: OL45° wedge, 48 elements, Pitch 0.8mm, Frequency 2.25 MHz

- Contrary to single element inspection, the notch can be detected with phased array technology
- Suitable angle for the flaw unmasking = OL 30°
- **Phased-array :**
  - **Inspection along several angles with the same probe**
  - **Focusing: increase of resolution and positioning of the echoes**

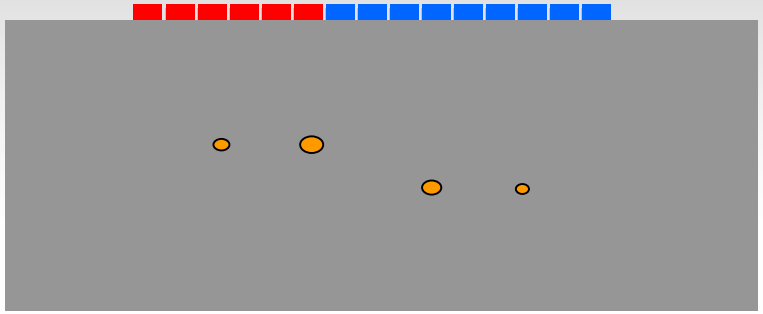
  →limitation of the impact of the shadowing effect





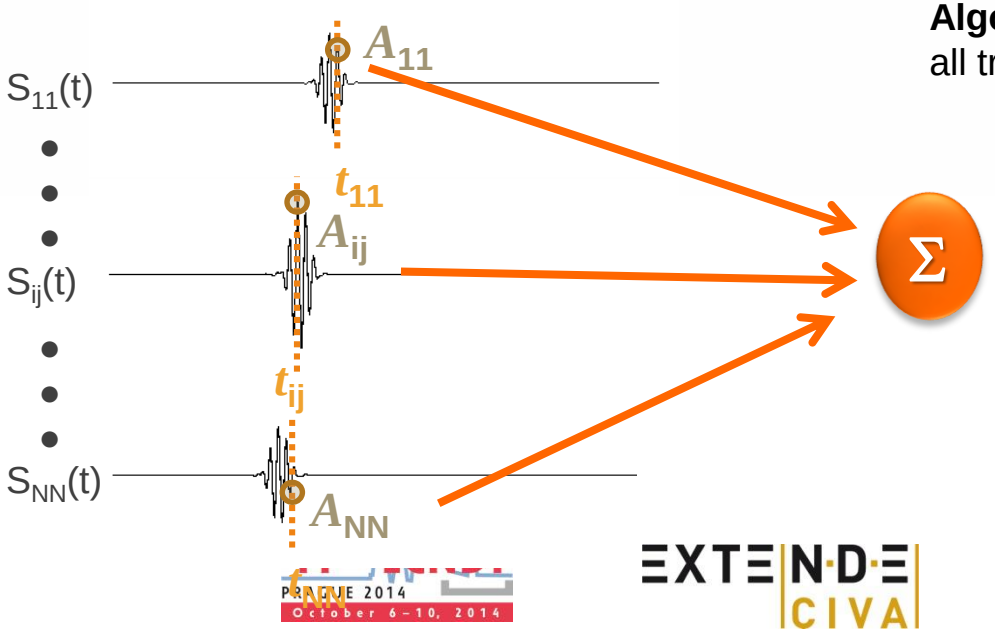
The Total Focusing Method: principe

- Step 1 : FMC acquisition (Full Matrix capture)
  - 1 element in transmission, N elements for reception
  - Acquisition of a NxN matrix

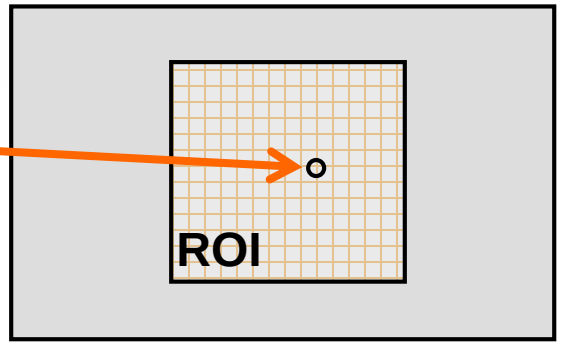


- Step 2 : Reconstruction of the TFM image

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 $(i;j)$



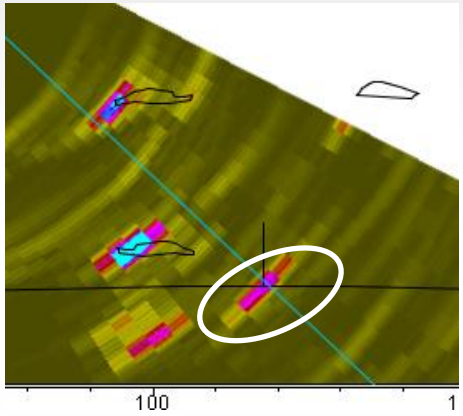
LL direct mode TFM imaging

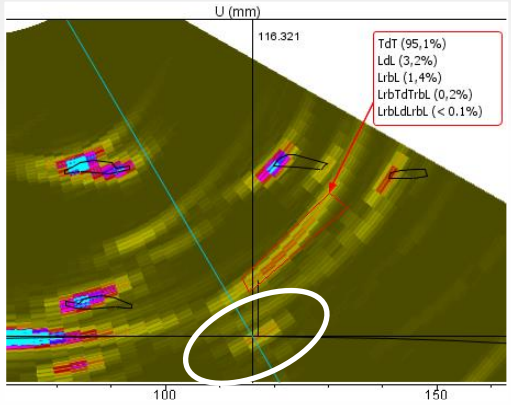
Direct mode: Direct ultrasonic sound paths: probe → point to be imaged

Position 1

Position 2

Echographic imaging





TFM images
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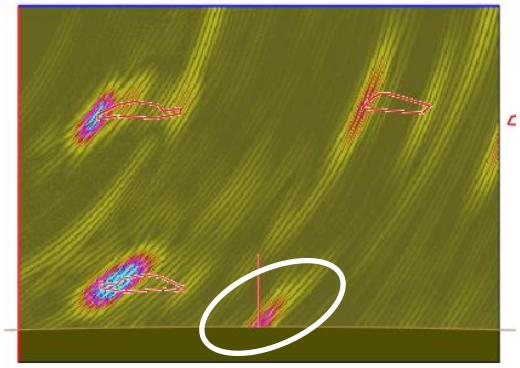
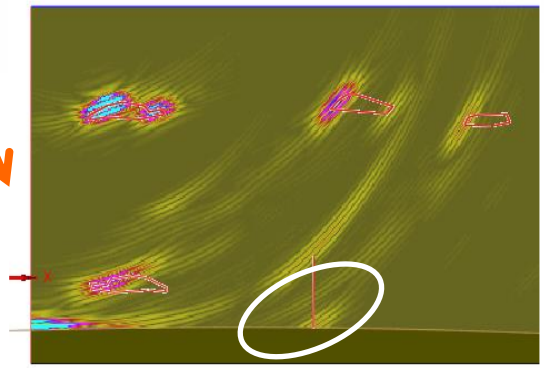
Echographic images

TFM imaging

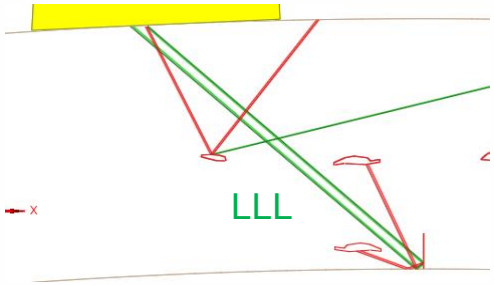




Corner echo mode TFM imaging

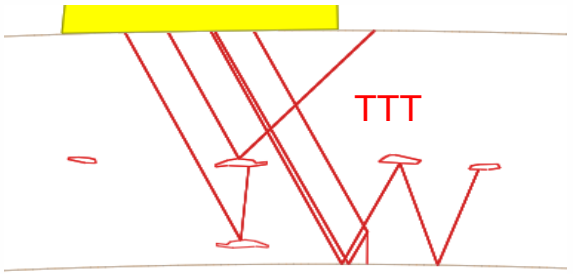
Corner echo mode: takes into account the interaction of the wave and its possible mode conversions on the backwall before reaching the defect

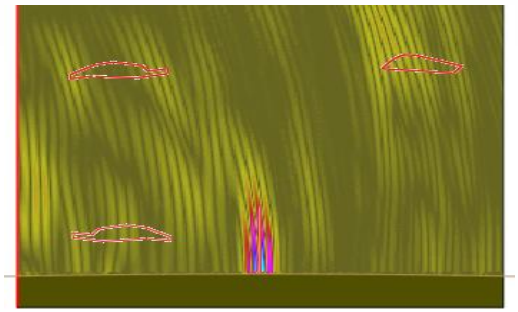
Position 1



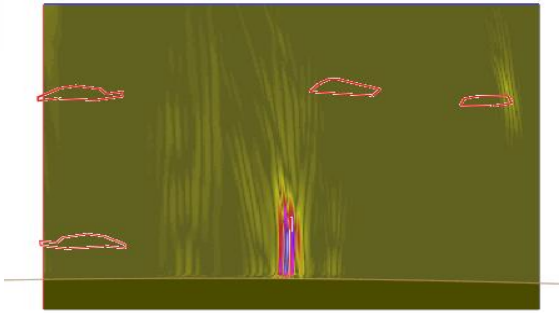
Use of the ray tracing tool to determine an appropriate mode for reconstruction

Position 2





- **Notch imaged on its entire length → confirmation of the origin of the echo**
- **No shrinkages echoes**



Conclusion

Feasibility evaluation of the detection of a backwall breaking notch located in a ferritic cast steel under a mid-thickness network

- Conventional OL45° single element probe inspection
  - Highlighting of the notch shadowing by the porosities
  - Inspection angle not optimal for all positions

- Contribution of phased-array technology
  - Angular scanning and focusing control the negative effect of shadowing
  - Detection possible for all positions
  - Diffraction echo too weak, corner echo detection only → problem of flaw identification

- TFM imaging:
  - Direct mode ≈ focused angular scanning
  - Corner echo mode: notch imaged on its entire length → unambiguous identification of the flaw

- Results are valid provided there is sufficient SNR (attenuation and structural noise have not been simulated)

- Experimental study necessary to validate the results

Thank you for your attention !