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

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Outline

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- 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)
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  - Direct mode imaging
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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
$V_L = 5900 \text{ m/s}$
$V_T = 3230 \text{ m/s}$

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

$h = 70 \text{ mm}$
$L = 285 \text{ mm}$
Evaluation of a single element ultrasonic conventional control

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

-2 dB

- 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 N\times N 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

Echographic imaging

TFM imaging

Position 1

Position 2

TFM images ≈ Echographic images
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.

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

- 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!