Recent evolutions of the CIVA simulation platform & Applications

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- Introduction

- CIVA, version 10.1: Two additional techniques

    - CT: Computed Tomography

    - LRUT: Long Range UT using Guided Waves

- Applications

    - UT: Applications to stainless steel bars inspection

    - UT: PA and TOFD inspection of a heater

    - ET: Introduction of innovative process

CIVA

- Dedicated NDE modeling tool
- Multi-techniques :
  - UT : Ultrasounds
  - ET : Eddy Current
  - RT : Radiography
  - New: CT and Guided Waves
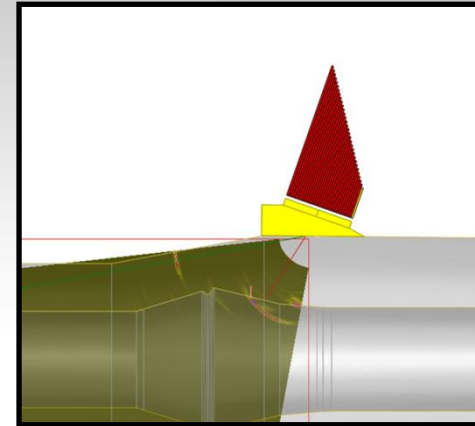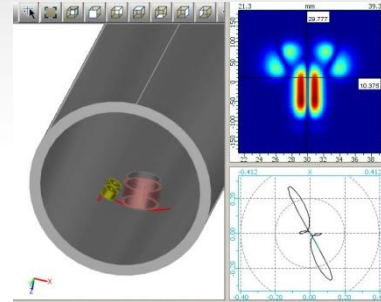
- Developped by CEA (French Atomic Energy commission: Research center)
  - NDT department: 100 people
  - Development & validation CIVA: 30 people
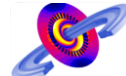- Semi-analytical models
- Distributed by EXTENDE since 2010

EXTENDE activities

CIVA Distribution

Technical support

Training courses

Consulting:

- Relying on CIVA (UT,ET,RT) and FLUX (ET,MT) software

Research & Development :

- Involved in French and European collaborative R&D programs

Benefits of NDT modeling

- **Help for methods and probes design:**
  - Time and cost savings: less prototypes
  - Improve performances and firm up choices
  - Help with introducing new innovations
  - Check controllability : Help in designing components
- **Expertise**:
  - Comparison between acquisitions and simulation
  - Better understanding of physical phenomena
  - Confirm or disprove a diagnosis
- **Support qualification documentation**
- **Technical support during bid proposal**:
  - Illustrate to convince
- **Training**

CIVA10.1:
Computed Tomography

- Additional CT module available in CIVA10.1
  - Relies on the same simulation kernel as CIVA RT module
    - Account for direct radiation (Beer Lambert straight line attenuation model)
    - Account for scattering (Monte Carlo model)
  - Successive RT simulations for all projections defined in the CT process
  - Implementation of 3D tomographic reconstruction algorithm. Currently available:
    - **FDK algorithm**
    - **PixTV algorithm**
- Example of 3D reconstruction obtained by simulation
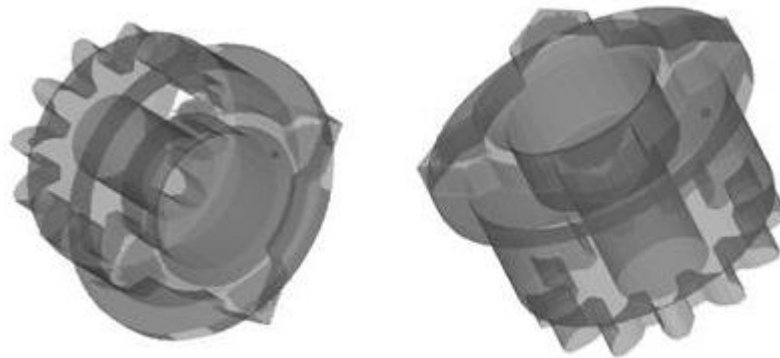
- More information : Roman Fernandez / "CIVA Computed Tomography Modeling »
/ Friday 20th morning / Session: Computed Tomography MR12-A

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CIVA10.1:
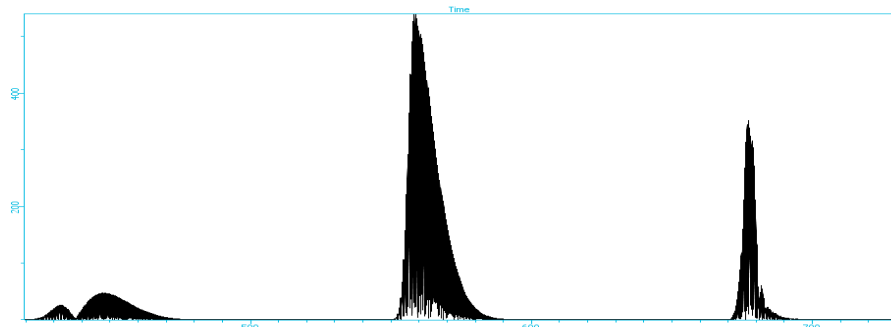# LRUT with Guided Waves

| Guided Wave module just released

| A Cost-effective "SAFE" approach: Semi-Analytical and Finite Elements model

- FEM in the guide section
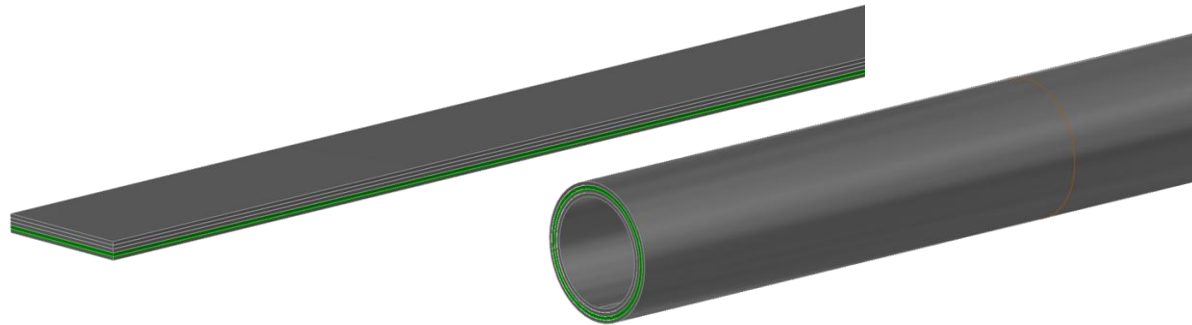- Analytical along the wave propagation axis

Pulse-echo
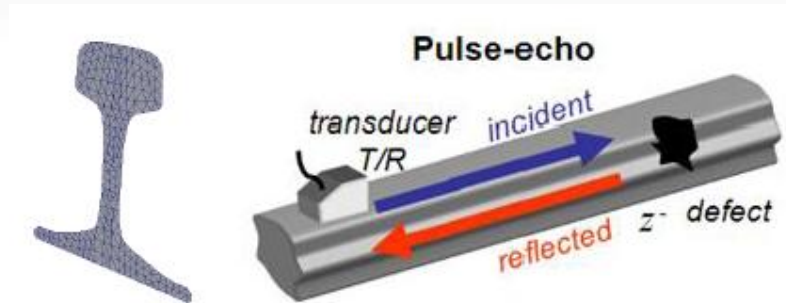
| 3 modules :

- Dispersion curves:
    - Predict potential modes in a given wave guide (Ax,Sx,SHx)
- Beam computation:
    - Display Stress/Displacement distribution generated by a transducer
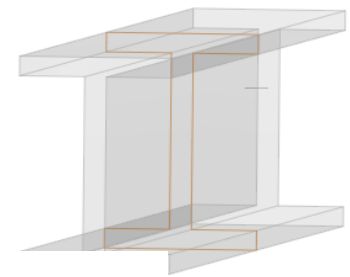- Defect response:
    - Predict Ascan at receiver

CIVA10.1:
LRUT with Guided Waves

- Capabilities of CIVA 10.1:
  - Planar or cylindrical structures
  - Accounts for coating, accounts for attenuation

- Main extended capabilities to be released in 2013:
  - 2D CAD shape of guide cross-section
  - Waveguide discontinuities
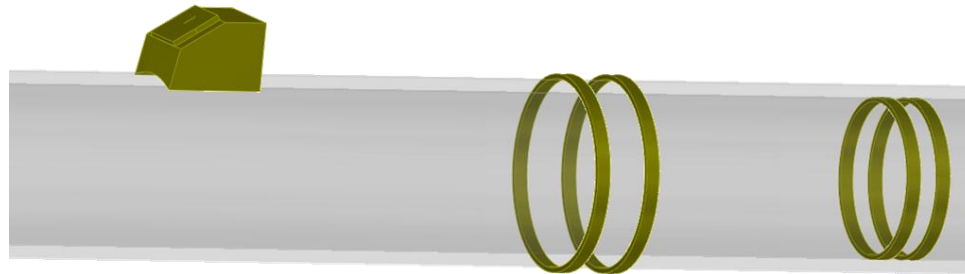 - Arbitrary number of defects
  - Anisotropy

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CIVA10.1:
LRUT with Guided Waves
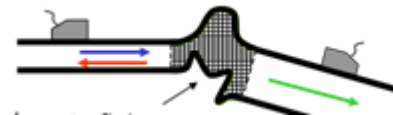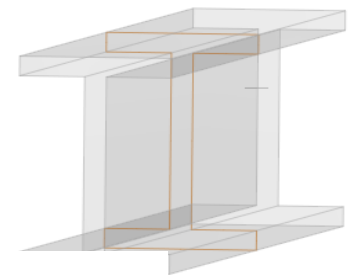
l Capabilities of CIVA 10.1:

- Planar or cylindrical structures
- Accounts for coating, accounts for attenuation
- Single element and phased-array transducers including encircling/ed arrays
- Different types of sollicitations: Torsional, Radial, longitudinal vibration
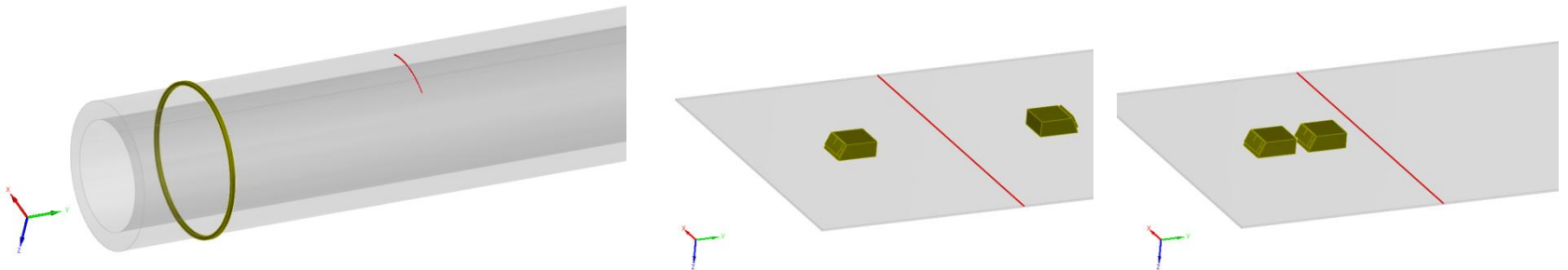
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- 2D CAD shape of guide cross-section
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CIVA10.1:
LRUT with Guided Waves

Capabilities of CIVA 10.1:

- Planar or cylindrical structures
- Accounts for coating, accounts for attenuation
- Single element and phased-array transducers including encircling/ed arrays
- Different types of sollicitations: Torsional, Radial, longitudinal vibration
- 1 flaw orthogonal to the guide axis
- Inspection modes: Pulse-Echo, Pitch-Catch Transmission, Pitch-Catch Reflection

Main extended capabilities to be released in 2013:

- 2D CAD shape of guide cross-section
- Waveguide discontinuities
- Arbitrary number of defects
- Anisotropy

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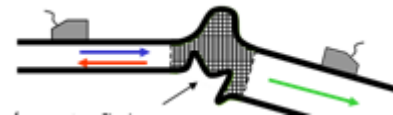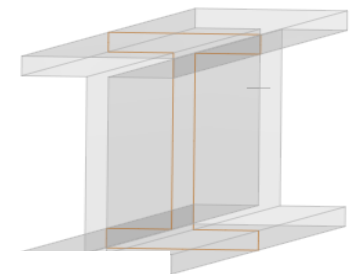
CIVA10.1:
LRUT with Guided Waves

| Application : Inspection of an aluminium plate

  - 1.5mm thickness
  - Contact probe at 2Mhz, Wedge angle 60°, phase velocity =3000m.s^{-1}
  - Pitch-Catch configuration with 200mm PCS
  - No shear sollicitation
  - Dispersion curves:
    - S0 mode predominant with also A0
  - Defect response :
    - A0 & S0 echoes received
    - Conversion modes due to a rectangular notch
    - Effect of the flaw height on the echoes amplitude (No flaw, 0.1mm notch, 0.5mm notch, 1mm notch)

Echo S0

Conversion mode due to defect scattering

Echo A0
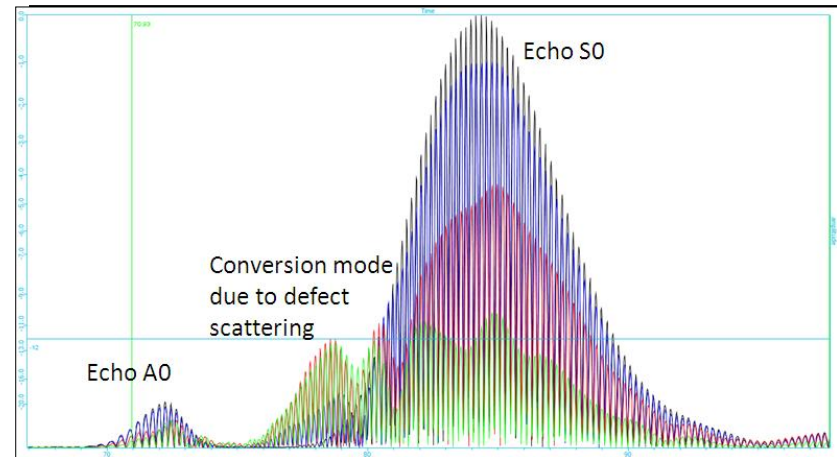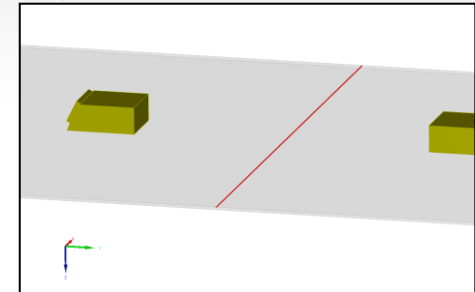
| More information : Bastien CHAPUIS: "Simulation of ultrasonic Guided Wave inspection in CIVA » / Wednesday 18th afternoon / Session: Guided Wave MR11-B

Application: PAUT inspection of stainless steel bars

- Industrial context:
  - Consulting study performed for UGITECH
  - Subsidiary of Schmolz & Bichenbach
  - One of the world leader for production of stainless steel long profiles

- PAUT inspection system under study:
  - Immersed 5MHz encircling array of 116 elements
  - Several arrays circumferentially spread around the bar while bar progresing longitudinally on production lines to inspect the full volume
  - Electronic scanning succesively enables shot sequences of 32 elements

PAUT configuration in CIVA
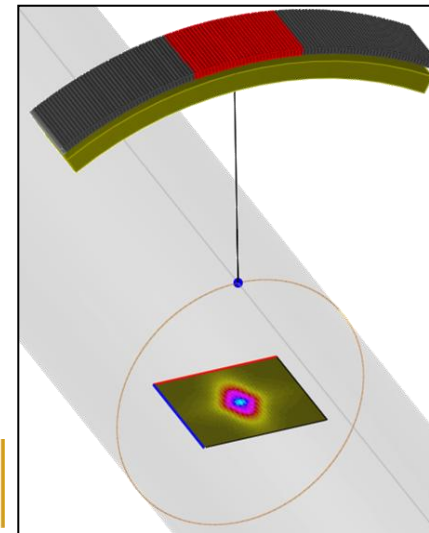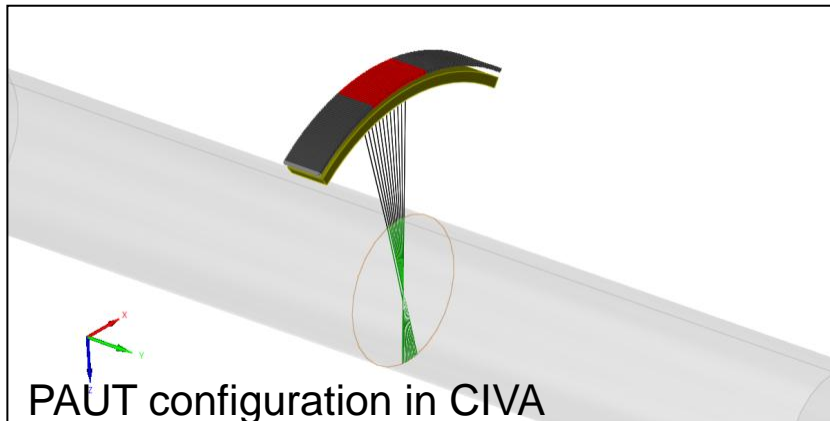
Beam spot at the center of the bar
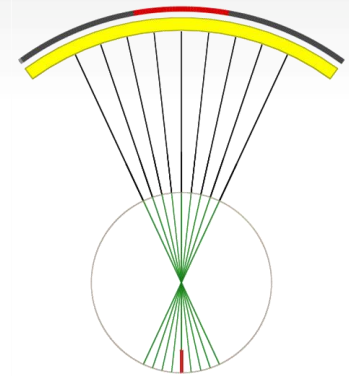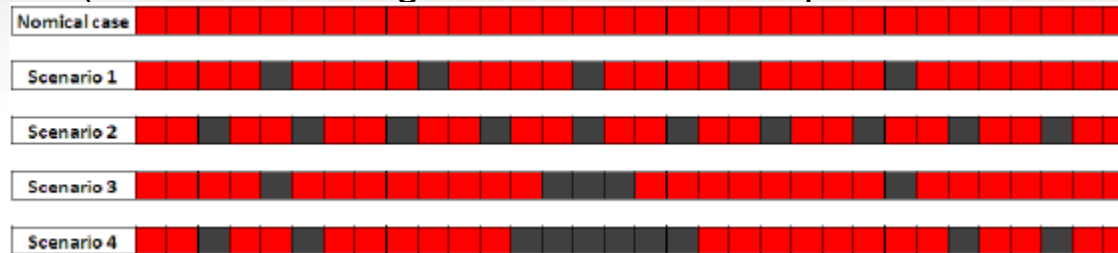
UGITECH
Providing special steel solutions

Application: PAUT inspection of stainless steel bars

| Impact of misfiring elements for L0 inspection:

- Several scenarri simulated
  (in black: misfiring elements in one sequence of 32 elements)

| Nomical case |
| Scenario 1 |
| Scenario 2 |
| Scenario 3 |
| Scenario 4 |

- Response a Flat Bottomed Hole centered versus the array :
- Main conclusions:
  - 3dB loss for 5 misfiring elements,
    6.5dB loss for 10 misfiring elements
  - For this flaw position, no real influence
    of the distribution of the broken elements

Scenario	Amplitude Loss
Nomical case	0 dB
Scenario 1	-3dB
Scenario 2	-6.5dB
Scenario 3	-3dB
Scenario 4 ---	-6.5dB

| Benefits of modelling: Estimate the limit of performance / Decide when it is relevant to repair/modify the system

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Application: PAUT inspection of stainless steel bars

| Inspection using S42 waves:
- To detect open crack with corner effect
- Defect response simulated for different notch depths (Bscan)

Creeping Waves

Corner echo

12.172

16.194
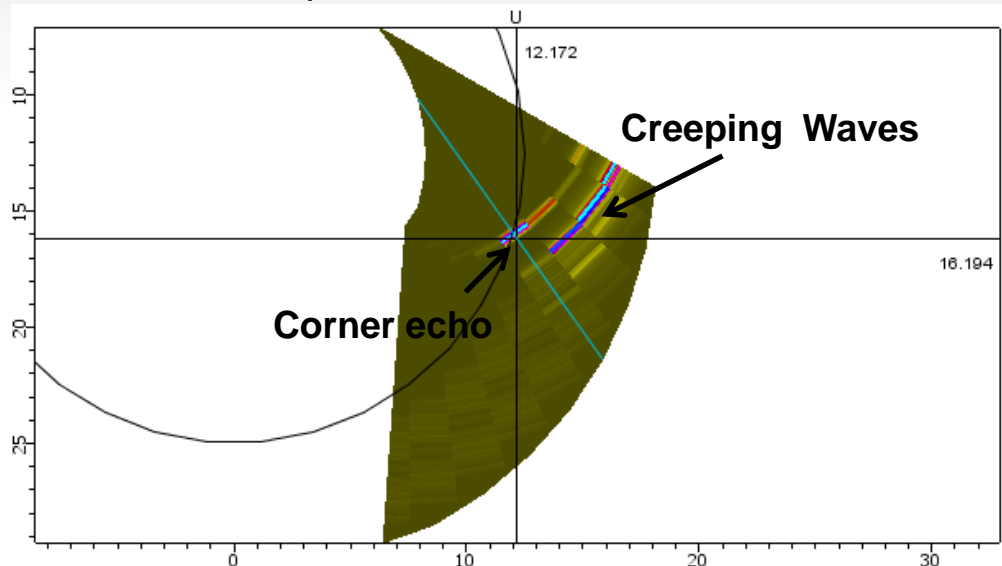
- Creeping wave mode in addition to corner echo
- Creeping wave not received in the expected angle of shot

- For some flaws, max amplitude is due to creeping wave
- Less easy to correlate flaw size and max amplitude

| Benefits of modelling: Understand better the different modes to avoid/reduce false alarms and improve characterisation

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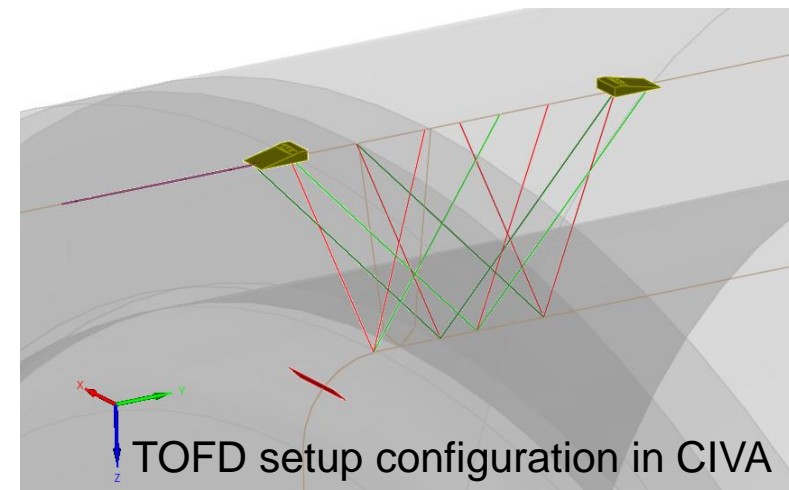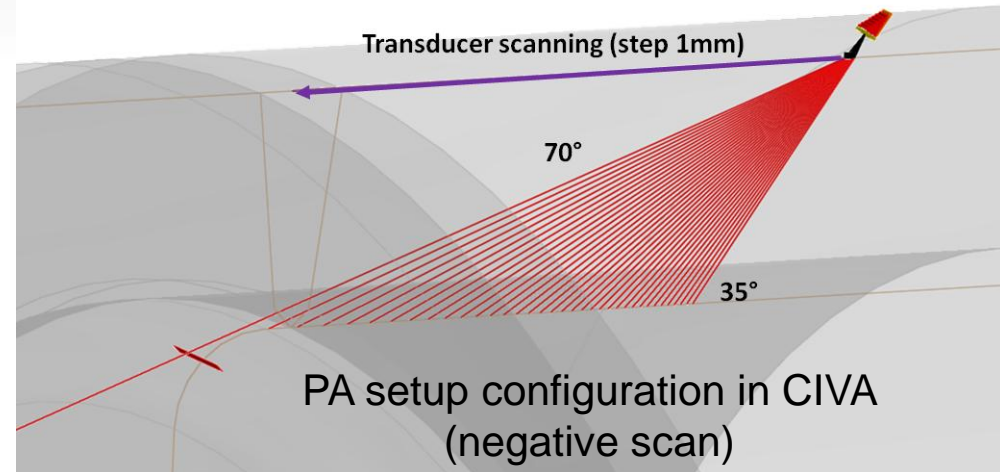
Application: PA and TOFD inspection of a heater

- Industrial context:
  - Consulting study performed for EDF DTG
  - Simulation of the inspection of a heater in a french oil-fired power plant
  - Region Of Interest: Fillet zone

- Inspection systems:
  - Phased-Array :
    - 2MHz linear array
    - 8 elements
    - Sectorial scanning 35-70°
    - Linear mechanical scanning in positive and negative directions

  - TOFD :
    - 4.2MHz contact probes
    - Lwaves 45°
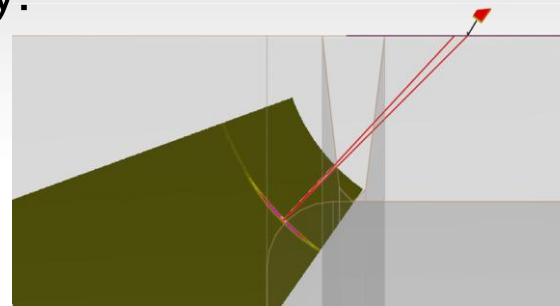   - PCS: 230mm
    - Linear mechanical scanning

Transducer scanning (step 1mm)

70°

35°

PA setup configuration in CIVA (negative scan)

TOFD setup configuration in CIVA

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Application: PA and TOFD inspection of a heater

- Study of defect response for different flaw sizes and profiles in the fillet
- Results with Phased-array:

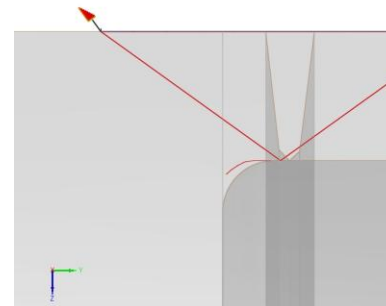 - Flaw radially orientated 5mm depth
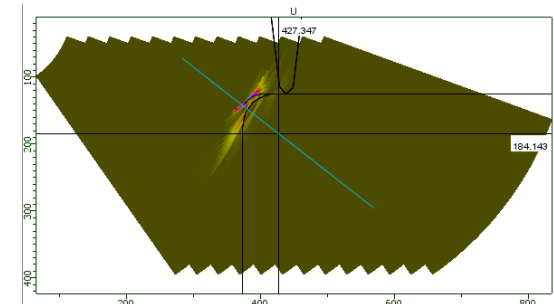

Single S-scan
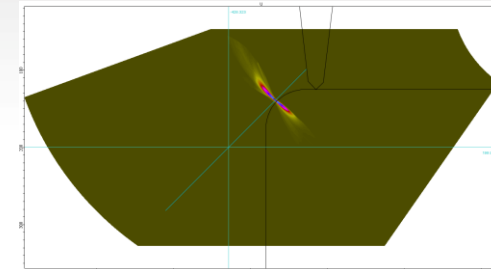
Cumulated S-Scan over the mech. scanning

  - Flaw curvature follows fillet curvature

Flaw visualisation
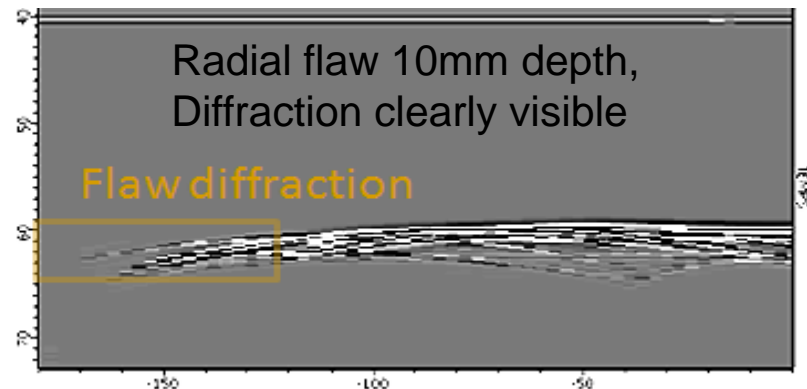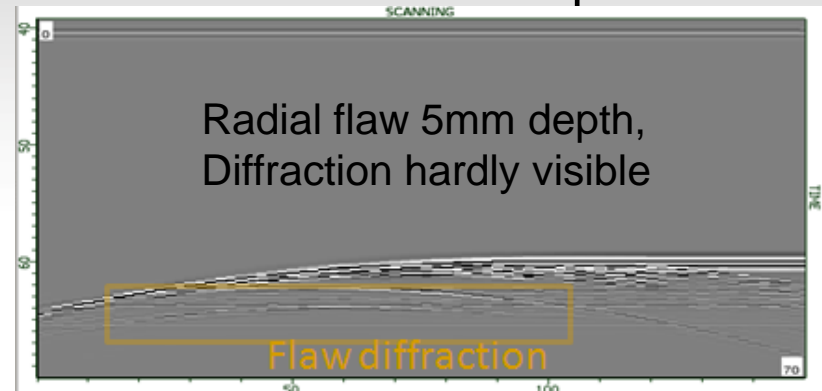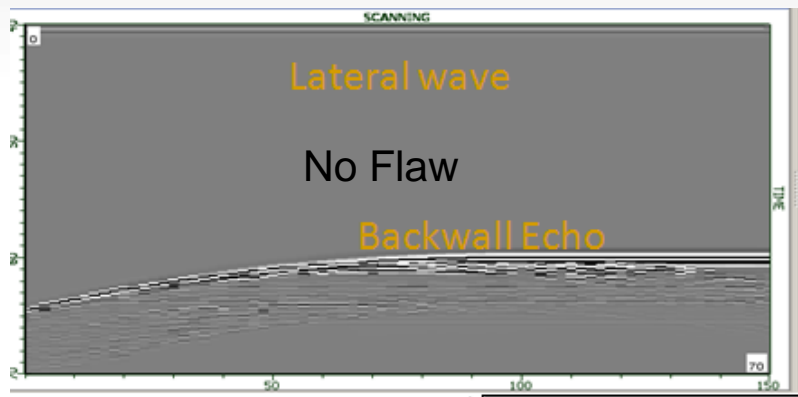

Cumulated S-Scan over the mech. scanning

- Advantage of PA: Sectorial scanning allow an easy detection (strong specular reflexion) for different orientations of the flaw

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Application: PA and TOFD inspection of a heater

| Study of defect response for radial law with different depths
| Results with TOFD:

Lateral wave

No Flaw

Backwall Echo

Radial flaw 5mm depth, Diffraction hardly visible

Flaw diffraction

Radial flaw 10mm depth, Diffraction clearly visible

Flaw diffraction

| Advantage of TOFD:
 More reliable characterisation

| Benefits of modelling: Virtual comparison of NDT techniques to demonstrate their complementarity and improve inspection procedures

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ET : Introduction of innovative process

| Example: ET array sensor
- Example of a sensor development made at CEA*:
  - 2 sets of 32 microcoils
  - Printed on a flexible kapton film
  - Silicone Roll to ensure good contact with the workpiece during scanning

- Advantages :
  - Good resolution for the detection of small cracks
  - Flexibility provided by the multi-elements monitoring
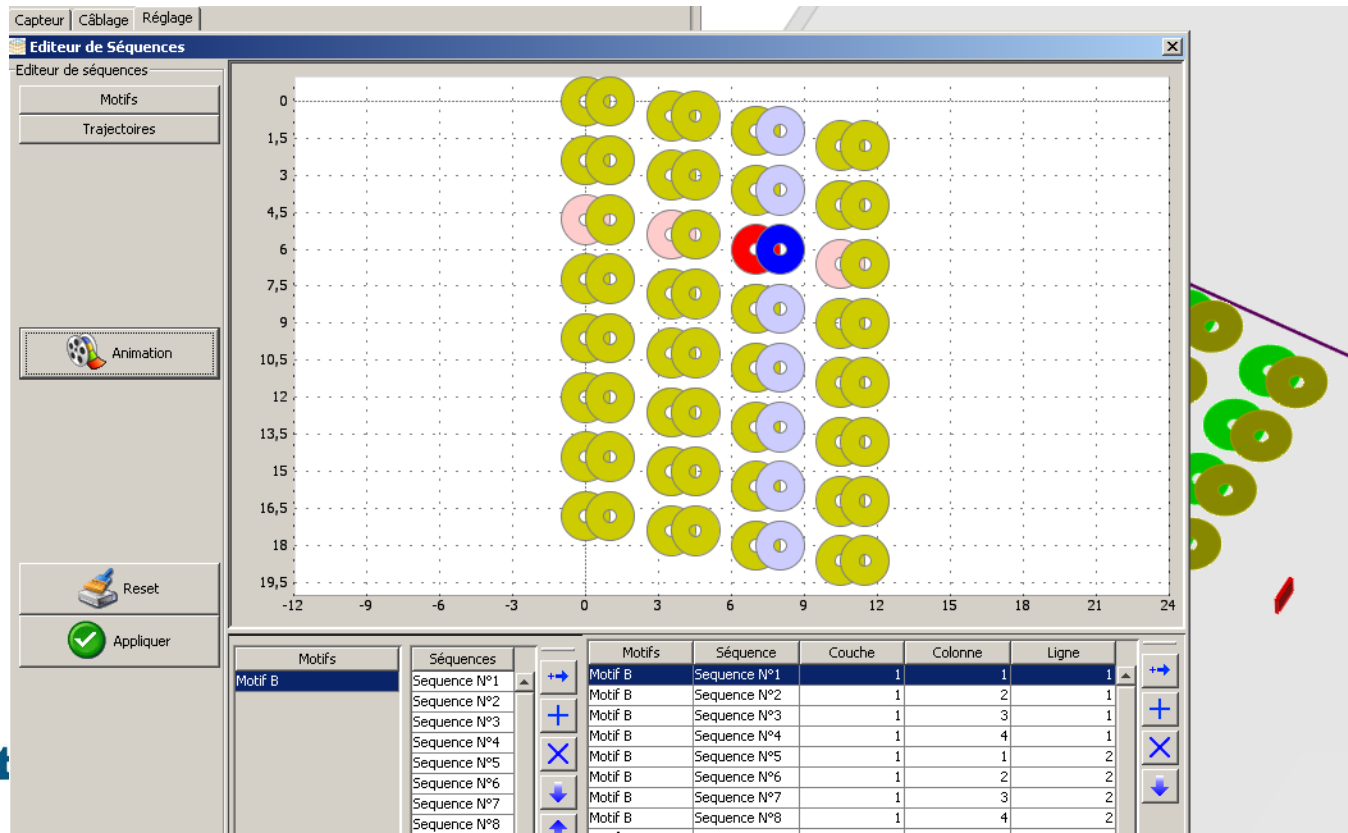 - Limitation of disturbing effects due to lift-off variation

| Simulation: Helps the design

*See : "Flexible and array eddy current probes for fast inspection of complex parts", B.Marchand, J. M. Decitre, and O. Casula, QNDE 2010

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ET : Introduction of innovative process

CIVA10: Built-in tools for ET arrays:
- Geometrical description of winding layers
- Definition of wiring
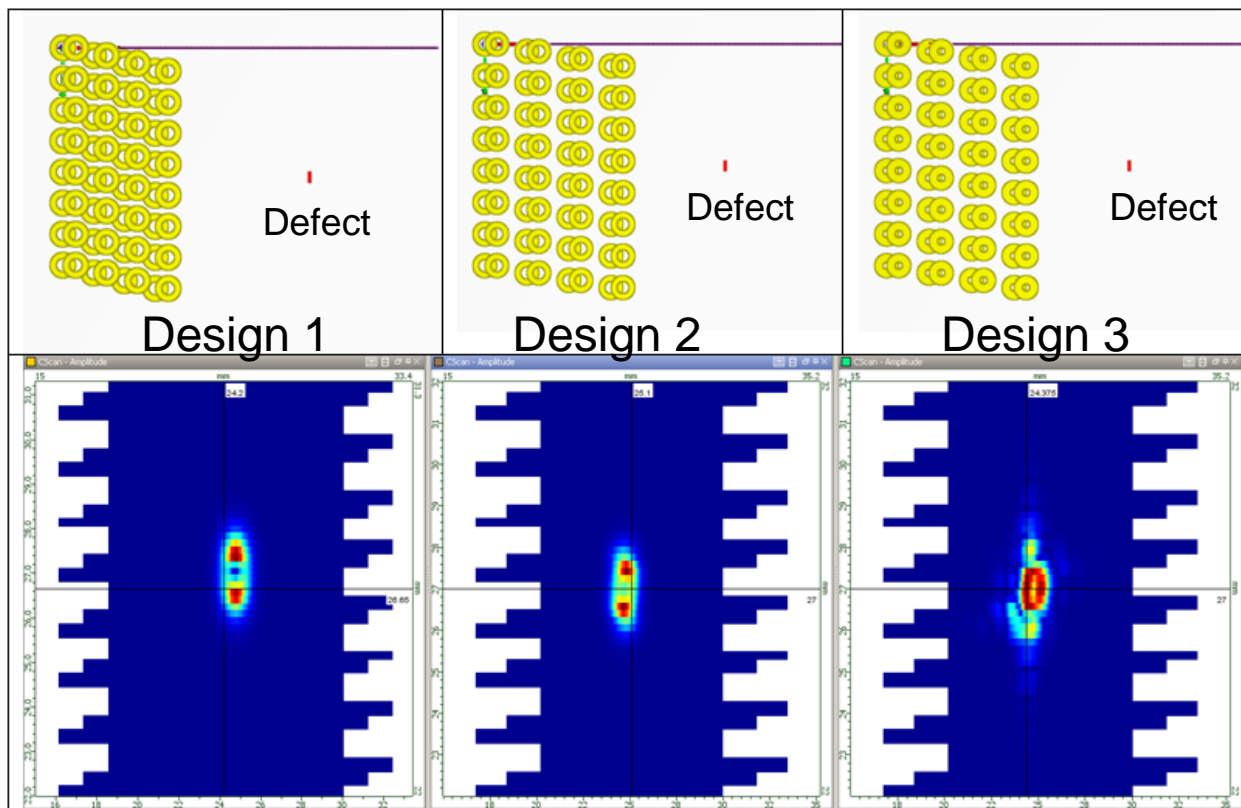- Definition of channels: "Patterns "and electronic "trajectories"

ET : Introduction of innovative process

Comparison of 3 designs (defect 0.4*0.2*0.1mm^3)

- 1 mechanical scanning axis / Acquisition 1Mhz
- Design 2 vs Design 1: Variation of inter-coils distances
- Design 3 vs Design 2: Variation of coils sizes

Defect   Defect   Defect

Design 1   Design 2   Design 3

ET : Introduction of innovative process

- Benefits of simulation:
  - **Virtual prototyping** allows to test numerous solutions before creating a physical prototype :
    - Time & cost saving: **Less prototypes**
    - Enhanced performances

  - **Evaluate before investing**: Virtually compare an existing conventional technique with an innovative one

  - New Technologies: It means by definition few feedback. Simulation allows to **better understand** and handle a new technique at low cost

Conclusion

I Benefits: Improve cost-efficiency of NDT at different stages of the process
- Design and qualification of inspection methods
- Preparation of inspection
- Expertise
- Training

I CIVA V10.1 : 2 additional techniques available in CIVA platform:
- Computed Tomography
- Long Range UT with Guided Waves

I Examples of industrial applications :
- PA UT inspection in stainless steel bars production lines
- PA UT and TOFD inspection of a heater in a power plant
- Designing innovative eddy current array sensors

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